This thesis has been submitted in fulfilment of the requirements for a postgraduate degree (e.g. PhD, MPhil, DClinPsychol) at the University of Edinburgh. Please note the following terms and conditions of use:

- This work is protected by copyright and other intellectual property rights, which are retained by the thesis author, unless otherwise stated.
- A copy can be downloaded for personal non-commercial research or study, without prior permission or charge.
- This thesis cannot be reproduced or quoted extensively from without first obtaining permission in writing from the author.
- The content must not be changed in any way or sold commercially in any format or medium without the formal permission of the author.
- When referring to this work, full bibliographic details including the author, title, awarding institution and date of the thesis must be given.
Injuries and illnesses in golfers and returning to play following orthopaedic surgery

Patrick Gordon Robinson
MBChB, MRCSEd, MScR, MBA

Doctor of Philosophy by Publication
University of Edinburgh
2023
Declaration

This thesis is my own work. Any collaboration is specifically indicated throughout the thesis. Appropriate acknowledgement has been given where reference has been made to the contribution of others. Where other sources of information are cited, full references are provided. I have carried out the work presented in this thesis with advisory support from Dr. John Kelly, Dr. Debbie Palmer, Prof. Andrew Murray and Mr. Nick Clement.

I have not submitted this work for any other degree, diploma or professional qualification. It does not exceed the word limit of 100,000 words set by the University of Edinburgh Degree Programme Regulations.

Patrick G. Robinson

July 2023
Acknowledgements

I would like to express my thanks to my advisors Dr. Debbie Palmer, Dr. John Kelly, Prof. Andrew Murray and Mr. Nick Clement for their guidance and support. I would also like to thank my co-authors who I have worked closely with to bring these research projects to peer-reviewed publication.

I would like to thank my parents for their ongoing encouragement to strive for the highest of accomplishments. Finally, to my wife Victoria, thank you for your continued support in both my professional and personal life. None of this would be possible or worth it without you.
Abstract

This thesis represents a discussion and critical appraisal of a selected number of research articles published in international peer-reviewed journals in the field of sports medicine and orthopaedic surgery. This work reflects over 5 years of dedication and passion in the field of golf medicine. The research is novel in a number of domains including assessing rates of COVID-19 in elite golfers, rates of returning to golf following orthopaedic surgery, and introducing new methods to this field.

This body of work was initially planned to be focussed on the injuries of elite golfers however, two unique scenarios arose early in the process. The first was the COVID-19 pandemic and the need for evidence-based protocols for conducting professional golf events. The second was the opportunity for international collaboration around returning to golf following orthopaedic surgery which developed during the 2nd International Congress for Golf and Health. Therefore, this thesis is divided into two themes; the first on injuries and illnesses in golfers and the second on returning to golf following orthopaedic surgery. The thesis contains; two retrospective studies, four prospective studies, one prospective study protocol, one systematic review, one systematic review/meta-analysis, one narrative review, one consensus statement, one letter to the editor and one infographic. It flows in chronological order from theme one into theme two which represents the strategy in place moving from one project to another and the interconnected nature of each study. There was a small amount of overlap as theme two began and theme 1
concluded and this represents the opportunity to begin collaborative work following the golf and health congress.

Each study is critically appraised in turn covering the aims and objectives, methodology, results and conclusions as well the contribution of the study to the literature and my own contribution. This thesis builds on existing research, identifies knowledge gaps, and presents reviews and original research that contribute to and enhance knowledge in the area of golf injury and illness.
Lay Summary

This thesis presents a body of published work with a central, theme of golf and its relationship with illness and injury. Golf is played by >66 million people worldwide with ages ranging from 4 to 104 years old. However, despite this and compared to other sports of similar popularity there is a lack of research on the health benefits but also the risks associated with playing the game. The first theme of the thesis explores the rate of injuries and illness in golfers. In particular, we review the current studies reporting on injuries in professional golfers and found the research to be of an overall poor standard. A consensus on how to report injuries and illnesses was then performed which we hope will standardise the methods of future research. The thesis then moves on to explore the COVID-19 pandemic impact on professional golf and the safety of using protocols to reduce risks in professional players and support staff. The data from these studies was applied when discussing future professional golf events with public health officials and policy makers in governments internationally. The data from these studies avoided the cancellation of a number of international tournaments due to unnecessary isolation of players and support staff. Finally, we ran a further pilot study to assess the tournament transmission rates when asymptomatic, positive players participated in two events in South Africa and found this approach to be safe.

The second theme of the thesis explores the rate of returning to golf following orthopaedic surgery. Golf is popular hobby for patients undergoing joint replacement in the United Kingdom. We first conducted a review of the
available data, and showed varying rates of returning to golf depending on whether patients underwent a hip, knee or shoulder replacement. We then studied two groups of hip and knee replacement patients and compared their pre- and postoperative functional outcomes and health-related quality of life to non-golfers. We found golfers undergoing hip and knee arthroplasty to have superior function preoperatively however, hip arthroplasty patients also had greater function compared to non-golfers postoperatively. Finally, we developed a protocol for the first multicentre study evaluating the rates of returning to golf following hip, knee, ankle or shoulder surgery. We hope this study will be the most informative to date for golfers and clinicians regarding the recovery process after joint replacement and their journey to returning to play the game.
# Table of Contents

*Declaration* ...............................................................................................................................2

*Acknowledgements* ....................................................................................................................3

*Abstract* .........................................................................................................................................4

*Lay Summary* ................................................................................................................................6

*Table of Contents* ..........................................................................................................................8

*Publication list* .............................................................................................................................13

1. *Chapter 1 Introduction and Preface* ........................................................................................17
   1.1 Introduction .............................................................................................................................17
   Theme 1 .........................................................................................................................................18
   Theme 2 .........................................................................................................................................20
   1.2 Professional and personal background .................................................................................22
   1.3 Concept and rationale for the programme of research .......................................................25
   1.4 Aims ..........................................................................................................................................29

2. *Chapter 2 Critical review of theme 1: Injuries and illnesses in golf* ......................................30
   2.1 Study 1: Systematic review of musculoskeletal injuries in professional golfers ..................30
      2.1.1 Aims and objectives ........................................................................................................30
      2.1.2 Methodology ................................................................................................................31
      2.1.3 Results ..........................................................................................................................32
      2.1.4 Conclusion ....................................................................................................................33
      2.1.5 Contribution to knowledge ...........................................................................................33
      2.1.6 Student contribution .......................................................................................................34
      2.1.7 Publication ....................................................................................................................35
   2.2 Study 2: International consensus statement: methods for recording and reporting of epidemiological data on injuries and illnesses in golf ........................................42
      2.2.1 Aims and objectives ........................................................................................................42
      2.2.2 Methodology ................................................................................................................42
      2.2.3 Results ..........................................................................................................................43
      2.2.4 Conclusion ....................................................................................................................45
2.6.4 Conclusion .................................................................................................................. 106
2.6.5 Contribution to knowledge base..................................................................................... 107
2.6.6 Student contribution....................................................................................................... 107
2.6.7 Publication .................................................................................................................... 108

2.7 Study 7: Returning persons with SARS-CoV-2 to the field of play in professional golf: A risk assessment and risk reduction approach .......... 115
   2.7.1 Aims and objectives .................................................................................................... 115
   2.7.2 Methodology .............................................................................................................. 116
   2.7.3 Results ....................................................................................................................... 117
   2.7.4 Conclusion ................................................................................................................. 118
   2.7.5 Contribution to knowledge base.................................................................................. 118
   2.7.6 Student contribution................................................................................................... 119
   2.7.7 Publication ................................................................................................................ 120

2.8 Summary of theme 1 .................................................................................................... 130

Chapter 3 Critical review of theme 2: Returning to golf following orthopaedic surgery ............................................................................. 134

3.1 Introduction to theme 2................................................................................................. 134
   3.1.1 Introduction ............................................................................................................... 134

3.2 Study 8: Rate and timing of return to golf after hip, knee or shoulder arthroplasty: A systematic review and meta-analysis .................. 136
   3.2.1 Aims and objectives ................................................................................................. 136
   3.2.2 Methodology .......................................................................................................... 137
   3.2.3 Results ..................................................................................................................... 138
   3.2.4 Conclusion .............................................................................................................. 140
   3.2.5 Contribution to knowledge ...................................................................................... 140
   3.2.6 Student contribution ............................................................................................... 141
   3.2.7 Publication .............................................................................................................. 142

3.3 Study 9: Letters to the Editor: Total Joint Arthroplasty and Golf Play: Analysis of Regional Golf Handicap Database ....................... 150
   3.3.1 Aims and objectives ............................................................................................... 150
   3.3.2 Methodology ......................................................................................................... 150
   3.3.3 Results ................................................................................................................... 151
   3.3.4 Conclusion .............................................................................................................. 151
   3.3.5 Contribution to knowledge base ............................................................................. 152
3.3.6 Student contribution ................................................................. 152
3.3.7 Publication .............................................................................. 153

3.4 Study 10: Golfers have greater preoperative and equal postoperative function when undergoing total knee arthroplasty compared to non-golfers ............................................................................................................. 155

3.4.1 Aims and objectives ............................................................... 155
3.4.2 Methodology .......................................................................... 155
3.4.3 Results .................................................................................... 158
3.4.4 Conclusion .............................................................................. 158
3.4.5 Contribution to knowledge base ........................................... 158
3.4.6 Student contribution ............................................................... 159
3.4.7 Publication .............................................................................. 160

3.5 Study 11: Golfers have a greater improvement in their hip specific function compared to non-golfers after total hip arthroplasty but less than three-quarters returned to golf ........................................................................................................... 167

3.5.1 Aims and objectives ............................................................... 167
3.5.2 Methodology .......................................................................... 167
3.5.3 Results .................................................................................... 169
3.5.4 Conclusion .............................................................................. 170
3.5.5 Contribution to knowledge ................................................... 170
3.5.6 Student contribution ............................................................... 171
3.5.7 Publication .............................................................................. 172

3.6 Study 12: Infographic: Total hip arthroplasty in golfers .......... 179

3.6.1 Aims and objectives ............................................................... 179
3.6.2 Methodology .......................................................................... 179
3.6.3 Results .................................................................................... 180
3.6.4 Conclusion .............................................................................. 180
3.6.5 Contribution to knowledge ................................................... 180
3.6.6 Student contribution ............................................................... 181
3.6.7 Publication .............................................................................. 182

3.7 Study 13: Golfing after Orthopaedic surgery: a Longitudinal Follow up project (GOLF): A prospective study protocol ......................................................... 185

3.7.1 Aims and objectives ............................................................... 185
3.7.2 Methodology .......................................................................... 186
3.7.3 Results .................................................................................... 188
3.7.4 Conclusion .............................................................................. 189
3.7.5 Contribution to knowledge base ................................................................. 189
3.7.6 Student contribution .............................................................................. 189
3.7.7 Publication .............................................................................................. 191

3.8 Summary of theme 2 .................................................................................. 205

Chapter 4 Impact of the research and future perspectives ...................... 209

4.1 Introduction .................................................................................................. 209
4.2 Impact of this work on policy and practice ............................................. 210
4.3 Directions for future research ................................................................. 213

References ....................................................................................................... 217
Publication list

Theme 1: Golf injuries & illnesses


6 Robinson PG, Murray A, Watson M, Close G, Kinane DF. Risk assessment and implementation of risk reduction measures is not associated with increased transmission of SARS-CoV-2 compared to standard isolation at professional golf events. BMJ Open Sport Exerc Med. 2022;8:e001324. PMID: 35601139


Theme 2: Returning to golf after arthroplasty

8 Robinson PG, TR Williamson, AD Creighton et al. Rate and timing of returning to golf after hip, knee or shoulder arthroplasty: A systematic review and meta-analysis. AJSM. 2022. Jan 12. PMID: 35019735


11 Robinson PG, Khan ST, MacDonald D, Murray AD, Clement ND. Golfers have a greater improvement in their hip specific function compared to non-golfers after total hip arthroplasty but less than three-quarters returned to golf. Bone Jt Open. 2022 Feb;3(2):145-151. PMID: 35172585


<table>
<thead>
<tr>
<th>No.</th>
<th>Study</th>
<th>Study Type</th>
<th>Journal</th>
<th>Impact Factor</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A systematic review of musculoskeletal injuries in professional golfers</td>
<td>Systematic review</td>
<td>Br J Sports Med</td>
<td>18.48</td>
<td>2019</td>
</tr>
<tr>
<td>3</td>
<td>Public health considerations regarding golf during the COVID-19 pandemic: a narrative review</td>
<td>Narrative review</td>
<td>BMJ Open SEM</td>
<td>4.80</td>
<td>2021</td>
</tr>
<tr>
<td>4</td>
<td>Assessing the risk of SARS-CoV-2 transmission in international professional golf</td>
<td>Prospective</td>
<td>BMJ Open SEM</td>
<td>4.80</td>
<td>2021</td>
</tr>
<tr>
<td>5</td>
<td>Pilot evaluation of risk assessment and enhanced protocols regarding contacts at a professional golf event</td>
<td>Prospective</td>
<td>BMJ Open SEM</td>
<td>4.80</td>
<td>2021</td>
</tr>
<tr>
<td>6</td>
<td>Risk assessment and implementation of risk reduction measures is not associated with increased transmission of SARS-CoV-2 compared to standard isolation at professional golf events</td>
<td>Prospective</td>
<td>BMJ Open SEM</td>
<td>4.80</td>
<td>2022</td>
</tr>
<tr>
<td>7</td>
<td>Returning persons with SARS-CoV-2 to the field of play in professional golf: A risk assessment and risk reduction approach</td>
<td>Prospective</td>
<td>BMJ Open SEM</td>
<td>4.80</td>
<td>2022</td>
</tr>
<tr>
<td>8</td>
<td>Rate and timing of returning to golf after hip, knee or shoulder arthroplasty: A systematic review and meta-analysis</td>
<td>Systematic review / Meta-analysis</td>
<td>AJSM</td>
<td>7.01</td>
<td>2021</td>
</tr>
<tr>
<td>9</td>
<td>A letter to the editor: Total Joint Arthroplasty and Golf Play: Analysis of Regional Golf Handicap Database</td>
<td>Letter to editor</td>
<td>J AAOS</td>
<td>4.0</td>
<td>2021</td>
</tr>
<tr>
<td>10</td>
<td>Golfers have greater preoperative and equal postoperative function when undergoing total knee arthroplasty compared to non-golfers</td>
<td>Retrospective</td>
<td>Eur J Orthop Surg Traumatol</td>
<td>0.61</td>
<td>2022</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Study Type</td>
<td>Journal</td>
<td>Issue</td>
<td>Year</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------</td>
<td>--------------------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>11</td>
<td>Golfers have a greater improvement in their hip specific function compared to non-golfers after total hip arthroplasty but less than three-quarters returned to golf</td>
<td>Retrospective</td>
<td>Bone Jt Open</td>
<td>3.1</td>
<td>2022</td>
</tr>
<tr>
<td>12</td>
<td>Infographic: Total hip arthroplasty in golfers</td>
<td>Infographic</td>
<td>Bone Jt Open</td>
<td>3.1</td>
<td>2022</td>
</tr>
<tr>
<td>13</td>
<td>Return to golf following hip, knee or shoulder arthroplasty: Protocol for a prospective, multi-centre longitudinal follow up study</td>
<td>Study Protocol</td>
<td>Bone Jt Open</td>
<td>3.1</td>
<td>2023</td>
</tr>
</tbody>
</table>
Chapter 1 Introduction and Preface

1.1 Introduction

Golf is played by >66 million people worldwide in 206 countries and territories with ages ranging from 4 to 104 years old. It is a unifying sport allowing those with varying levels of fitness and mobility to participate. Its global reach was also evidenced by its re-inclusion into the 2016 Olympic Games. The sport has substantial benefits to the economy and in 2016 the game of golf drove $84.1 billion of economic activity in the United States while in 2019, United Kingdom (UK) golfers spent £5.1 billion on the sport, which reflects a 20% increase in consumer spending since 2014.

Playing golf can provide moderate intensity aerobic physical activity (with a reported general metabolic equivalent [MET] of 4.8), while one 'round' of 18 holes can, on average, burn 1200kcals and take approximately 11,000 to 16,000 steps over 4-8 miles. The sport helps persons meet the World Health Organisation (WHO) recommendations for health enhancing physical activity and the health benefits of golf have been well described in a scoping review by Murray et al. The authors studied 301 articles related to golf and health and concluded that practitioners and policymakers should be encouraged to support more people to play golf due to its associations with improved physical and mental well-being.

The golf swing is a complex, asymmetric movement which includes movement from most joints in the upper and lower limb as well as the spine. There are typically four agreed phases to the swing which are the address, backswing, downswing and follow-through. The typical modern golf swing is ideally performed with proximal-to-distal limb sequencing which increases the velocity of the distal segment by initiating maximal velocity at the proximal segment first. This creates a
summation of velocity greater than what could be achieved by isolated distal muscle actions. Recent golf instruction has populated the concept of the ‘X-factor’ which is described as a dissociation between the upper and lower body in the downswing. More specifically, it is the difference in angle between the torso and the pelvis which can be measured at the top of backswing and again at the beginning of the downswing.\textsuperscript{11} It is thought that this movement increases downswing rotational force and hence clubhead speed and is seen more frequently in elite players. In addition, lower body kinematics and ground reaction force predicts clubhead speed by 40%.\textsuperscript{12} With regards to the upper limb, electromyography studies have shown subscapularis, latissimus dorsi and pectoralis major to be major drivers of movement in both the backswing and the downswing with supraspinatus, infraspinatus and the deltoid having a much smaller role.\textsuperscript{13}

**Theme 1**

Injury rates within golf are low compared to other sports and have been reported as 0.28-0.60 injuries per 1000 hours played.\textsuperscript{14-16} The largest series of 708 amateur golfers reported the most frequent injuries to be located in the lower back (35%), elbow (33%) and hand/wrist (20%).\textsuperscript{17} Mechanisms reported to be the most prevalent contributors to injury included ‘excessive play or practice’, ‘poor swing biomechanics’ and ‘hitting the ground’. Gosheger \textit{et al.} analysed the nature of amateur golf injuries in cross-sectional fashion and found 83% of injuries to be overuse and 17% to be acute.\textsuperscript{18} McCarroll & Gioe reported 85% of upper limb injuries were lead sided (i.e. the left side in a right handed golfer).\textsuperscript{19}

Professional injuries have been reported to differ from amateur injuries. In the same study performed by Gosheger \textit{et al.} the authors examined professional injuries and
found back, hand/wrist and shoulder injuries to be most common. There were a significantly higher proportion of hand/wrist injuries compared to amateurs and a significantly lower proportion of elbow injuries. Sugaya et al. studied the side of lumbar back injuries, and found 51% were right-sided pain, 28% reported left-sided pain and 21% reported central or generalised pain. Injury rates in professional players are higher than in amateurs, but relatively lower in comparison to other Olympic sports.

Sorbie et al. studied the impact of golf course closure and opening during the COVID-19 pandemic on wellbeing and life satisfaction. The authors reported that belonging, enjoyment and wellbeing were significantly associated with outdoor course activity and a sense of belonging and satisfaction increased following golf course reopening. The COVID-19 pandemic has had a significant impact on both recreational, amateur and professional sport. With the introduction of social distancing globally, sporting activities were significantly inhibited, even if performed outdoors. There has been a reduction in physical activity during COVID-19 secondary to government enforced lockdown periods and suggestions have been made on how best introduce people back to an active lifestyle. Golf is likely to be a suitable sport for patients looking to achieve health enhancing physical activity in an outdoor environment and this became evident during the COVID-19 pandemic.

The professional game of golf was one of the first sports to re-commence during the COVID-19 pandemic. The outdoor and socially distanced nature of the game made it an ideal sport to comply with many of the public health regulations and allow for plentiful mitigating factors to be applied to reduce the contraction and spread of the SARS-CoV-2 virus. Due to the global nature of the DP World Tour and the need for various public health and government officials to align with the planning of events,
it was vital that the medical and scientific team within the tour had data to demonstrate their approach to both event management and contact tracing was safe and effective and evolved as new information became available.

**Theme 2**

Total joint arthroplasty is one of the most common and cost-effective operative procedures worldwide and is an excellent intervention for patients suffering from arthritis.\(^{25}\)\(^{26}\) It leads to reduced levels of pain and improved levels of function.\(^{27}\)\(^{28}\) There are approximately 175,000 hip and knee arthroplasties performed in England, Wales and Scotland each year,\(^{29}\)\(^{30}\) while there are approximately 1.9 million hip and knee arthroplasties performed in the United states per annum.\(^{31}\) Prediction models has estimated arthroplasty in the United States will grow to between 2 to 4 million cases per annum by 2030.\(^{31}\)\(^{32}\)

A number of studies have previously aimed to report the golf-related outcomes following joint arthroplasty. Joint arthroplasty of the hip, knee, and shoulder have been reported thus far. To date, all studies have been retrospective in their methodology, with heterogenous reporting of outcomes and a range in return to play from 87-95% following hip arthroplasty\(^{33}\)\(^{34}\), 30-99% following knee arthroplasty\(^{35}\)\(^{36}\) and 50-96% following shoulder arthroplasty.\(^{37-39}\) The time to return to golf appears to differ depending on what arthroplasty is performed and there has been a large variation in the change in golfing performance following surgery with studies quoting a change in handicap ranging from -5 (golf performance improving) to +2 (golf performance declining).\(^{37}\)\(^{40}\)

Pioger *et al.*\(^{35}\) and Gorbaty *et al.*\(^{41}\) used golf participant databases to extract the players who had previously undergone arthroplasty. Pioger *et al.* collected data from
a database of 54,625 golfers over the age of 50 years achieving a response rate of 0.5%. Undoubtedly, the majority of the people within this database will not have had total knee arthroplasty (TKA) and therefore the response rate will be expectantly low. However, the prevalence of knee arthroplasty in an age-matched group of the general population has been reported to be 4.6%. This would suggest that the present study suffers from a low response rate and consequentially potential for response bias. The population sampled may include those who have returned to golf, in view of their continued membership of the French Golf Federation, after a minimum of 2-years following TKA. In contrast, patients not returning to golf following TKA may no longer be a member of the French Golf Federation. Furthermore, it is possible that those who have had satisfactory outcomes following the surgery may be more likely to respond and this has been shown in previous arthroplasty studies. The authors reported that 99% of respondents returned to golf which is 5% higher than the previous best in the available literature. This number may be subject to overestimation of the true rate within the total cohort, given the mechanism for recruitment was driven by current membership of a golf organisation. In addition, preoperative function was assessed retrospectively. The return-to-golf rate is critically important for managing patients’ expectations before and after TKA and there are clearly a multitude of factors which will influence a golfer’s ability to return to golf beyond the joint arthroplasty itself.

The lead limbs and the trail limbs undergo different forces during the golf swing. A previous study has reported increased pain in the lead knee during the golf swing following TKA and this correlates with higher tibial forces. However, golf-related outcomes for the lead and trail knee were not specified. In addition, the authors did not report the method by which participants mobilised around the golf course pre or postoperatively. A previous study has shown that the number of golfers using carts
to mobilise over 18 holes of golf following TKA doubles.\textsuperscript{45} The energy expenditure of walking the golf course is almost double that of riding in a golf cart.\textsuperscript{48} These mobility variables are important to consider when assessing the nature of how patients return to golf and also when considering the health benefits of golf in future studies.\textsuperscript{49}

Gorbaty \textit{et al.} employed similar methodology, contacting players within a golf membership regarding previous joint arthroplasty surgery. They had 120 responses (n=50 hip and n=70 knees) and, based on their responses, all patients had returned to golf. Patients undergoing their second joint arthroplasty on the contralateral side increased their average monthly golf participation more than unilateral arthroplasties and had higher handicaps.\textsuperscript{41}

Having identified and discussed a trend in the shortcomings of a number of the studies evaluating returning to golf following arthroplasty with orthopaedic colleagues, and scientists working with a golf global governing body, it was felt that what was required was a deeper evaluation of the existing literature, and prospective work enhancing the methodology employed in this area of research.

\textbf{1.2 Professional and personal background}

My professional background is as a trauma and orthopaedic surgery registrar in Scotland / University of Edinburgh rotation. My clinical and academical interest is in sports medicine. My interest in academic orthopaedics was facilitated early in my career by being accepted onto the academic foundation programme in South-East Scotland for two years prior to joining the orthopaedic surgery programme. During my orthopaedic surgery training I completed a Masters of Science by Research in the field of orthopaedic sports medicine in 2020. My thesis title was ‘Is there a role
for biologics within hip arthroscopy and how do we measure their effect?’. The focus of this research included performing a systematic review of the efficacy of biologics in the management of hip pathologies. I then assessed the clinimetric properties of commonly used patient reported outcomes measures such as the Forgotten Joint Score and the International Hip Outcome Tool to evaluate if they demonstrated the validity and reliability to measure changes in young, active patients with femoroacetabular impingement. This work was awarded a Merit by the University of Edinburgh.

I have also developed an interest in population health, and health policy. During 2021/22 I was awarded a position as a Scottish Clinical Leadership Fellow based at the Scottish Government and the Royal College of Surgeons of Edinburgh (RCSEd). The mentorship and support through this program allowed me to develop a greater understanding of the interaction between research, clinical care, and health policy. Two key aspects of this role are relevant to this thesis. The first was my involvement in the COVID-19 Working Group for Elite Sport in the Scottish Government as well as the DP World Tour COVID-19 events team. These roles gave me an understanding of the wider COVID-19 public health approaches to virus transmission and prevention as well as the government’s methods of risk assessment and minimisation. This was during a period where processes and control measures were put in place for event organisation. Therefore, the papers in this thesis related to SARS-CoV-2 transmission and the risk mitigating approaches were formulated based on an immediate requirement for research in this area to guide government and sporting organisations in their policy. Furthermore, there was a clear route to generating uptake, use and impact in this field via presenting such work to forums including the global Chief Medical Officer in Sports Group, the UK COVID-19 Work Group for Elite Sport, the All-Parliamentary Group for Golf amongst
others. The DP World/ European Tour Group conducts events in 34 different countries, and this work was relevant to discussions with each public health authority, and host national government during the pandemic. These conversations also informed decisions as to what research should be prioritised next.

The second relevant aspect to this fellowship was organising the 2nd International Congress for Golf and Health at the RCSEd alongside Prof. Murray. This conference brought together over 100 delegates in the field of golf medicine to share research and acted as a think tank for further research ideas. Guests included Prof. Fiona Bull the head of physical activity at the World Health Organisation (WHO). I presented a workshop on the research regarding COVID-19 on the DP World Tour. My colleague Mr Nick Clement presented our work on returning to golf following arthroplasty and it was from this conference that plans solidified regarding prospective research in this area. The conference was instrumental in bringing the world of golf research together and driving collaboration.

I have always had an interest in the field of golf medicine given my personal interest as a golfer. Early exposure to golf medicine in the form of shadowing medical, physiotherapy, physical preparation and orthopaedic teams at DP World Tour events gave me an appetite to be involved in a more official capacity. It was clear there was vast potential for golf to be researched in a number of domains both at the elite and recreational levels. I took great interest in Prof. Murray’s seminal PhD work in golf and health. When the opportunity arose to perform the first systematic review of injuries in professional golf, I was delighted to take it and start my journey on this body of work which I present in this thesis. I later became a DP World Tour Medical Research Fellow for two years beginning in 2020, a role that has been extended to 2024.
1.3 Concept and rationale for the programme of research

This thesis presents a body of published work with a central, theme of golf and its relationship with illness, injury and physical activity. This thesis reflects a determination from myself and my co-authors (particularly Prof. Andrew Murray and Mr Nick Clement) to understand more about the sport of golf, its injury profile, relationship to illness (primarily during the COVID-19 pandemic) and playability following orthopaedic surgery.

The first theme explores the epidemiology of injuries and illness in golfers. The initial study was an attempt to summarise the current literature on musculoskeletal injuries in professional golfers. This was a foundational piece of work which was firstly a key moment in establishing my interest in golf medicine research but secondly in evaluating the golf injury research which had previously been performed and considering future research priorities. This research was done immediately prior to the International Olympic Committee publishing their consensus statement on the reporting and recording of injuries and illnesses in sport. They encouraged sports to design sports-specific statements which may be able to highlight the nuances that a generic statement may not capture. Therefore, upon invitation from the International Golf Federation, Prof. Murray and I developed an international working group with expertise in sports medicine, epidemiology, golf and sports science with a goal of creating an international consensus statement on the reporting of injuries and illnesses in golf which would be applicable to the elite and recreational game of golf.

Following the publication of the first two studies and with the research gaps better known, there was appetite to move to study injury epidemiology in the recreational
golfer. However, these plans were quickly altered with the arrival of the COVID-19 pandemic in March 2020. Sport including golf was initially restricted in most countries. Following many discussions amongst myself, Prof. Murray, senior government scientists and officials, we considered the safety of golf given it is played outdoors where socially distancing is possible. We therefore decided to write a narrative review relating to the health considerations of playing golf during the COVID-19 pandemic. This narrative review was written with Prof. Charlie Foster, the principal advisor on physical activity to the four Home Nations Chief Medical Officers and commissioned by the All-Parliamentary Group for Golf. The professional golf circuits including the DP World Tour restarted events in July 2020.

It was pertinent that protocols were put in place to maximise safety for players and support staff and these required evaluation. Thus, we prospectively collected data on rates of SARS-CoV-2 during the season as the infrastructure for recording data was already established for operational purposes.

The first COVID-19 study on the DP World Tour simply collected the incidence of COVID-19 and rates of transmission between players and essential support staff at 23 golf events for the 2020 season. It was clear from our experience of doing so that the incidence of COVID-19 was low and rates of transmission were very low. We had not seen any transmission in an outdoor environment. Meanwhile, standard isolation following contact tracing was contributing to distress in some persons (being isolated away from their families) and others unable to participate which therefore lead to less work opportunities for them, and diminished events. As background, large numbers of staff and players were traveling internationally each week to tournaments. The strict contact tracing policies by governments meant substantial numbers of players and personnel would have to isolate regardless of symptoms or risk factors. This could lead to the cancellation of professional golf
events. Therefore, in keeping with other industries, we developed a system for measuring risk in contacts of SARS-CoV-2 positive persons and recorded the efficacy of this across two events in Spain as a pilot study. The success of this study then led to such policies being adopted by the DP World Tour and it being piloted for wider use in countries such as the UK. We then set up a further study to measure the rates of SARS-CoV-2 transmission over the course of the 2021 season when daily testing was applied to contacts, as opposed to standard isolation.

Finally, as COVID-19 vaccination led to governments aiming to further prioritise a move back towards more normality, we decided to run a further pilot study to assess the tournament transmission rates when asymptomatic, positive players participated in two events in South Africa. The South African government had experience from Omicron, and were supportive of research looking at participation in settings where persons were outside and socially distanced. Therefore, it seemed wise to plan this study over two events in that country. As the effects of the COVID-19 pandemic began to ease on professional golf, my research interests turned to a different area of the golf medicine, golfing after joint replacement.

The second theme of the thesis explores the rate of returning to golf following orthopaedic surgery. Golf is very popular hobby for patients undergoing joint replacement in the United Kingdom. One study found 20% of their participants undergoing hip or knee arthroplasty were golfers.\textsuperscript{50} Similar to my approach in theme 1, I decided to initially conduct a systematic review of the available data on golf and arthroplasty. However, this time we were able to perform a meta-analysis of the data. We showed varying rates of returning to golf depending on whether patients underwent a hip, knee or shoulder replacement. I was now keeping a close eye on the current literature in this area and came across the study by Gorbaty et al\textsuperscript{41} which
I felt made some bold conclusions based on questionable methodology. This led to my letter to the editor of the journal in question.

The orthopaedic department that I work in have for many years collected pre and postoperative functional outcomes and health-related quality of life data on patients undergoing orthopaedic surgery. In particular, there is a large database of patients who have undergone hip or knee arthroplasty. I decided it would be interesting to assess the early and long-term rates of returning to golf in each cohort and add in more golf-specific questions regarding motivation and rehabilitation. As I continued to learn more regarding the importance of research dissemination and impact, I decided to turn the hip cohort study into an infographic which was welcomed by the Bone Joint Open journal and accepted for independent publication.

At this stage in the programme of research I had recognised the limitations of performing retrospective research in this field. I felt prospectively following patients up through their journey back to golf would uncover granular aspects to their recovery which would otherwise be difficult to appreciate. At the 2nd International Congress for Golf and Health I met with Dr Joel Press (Attending Physiatrist at the Hospital for Special Surgery, New York City) and Dr Roger Hawkes (Former Chief Medical Officer, European Tour). We were all in agreement that performing prospective research in this area would be novel and beneficial. Therefore, I led the development of a protocol for the first prospective, multicentre study evaluating the rates of return to golf following hip, knee, ankle or shoulder surgery where data collection commenced in January 2023 at the Royal Infirmary of Edinburgh and The Hospital for Special Surgery / Cornell Medical Center.
The work in this thesis has been challenging but hugely rewarding to undertake. The field of golf medicine is significantly under investigated however, this body of work progresses on from Dr. Hawkes and Prof. Murray’s work amongst others to explore this topic and also highlights the many aspects of further research that could be undertaken.

1.4 Aims

The aim of this thesis is to present a coherent body of research conducted over a number of years reflecting developments and understanding of golf within the medical literature. Initially in theme one, I intend to understand the current literature in relation to professional injuries and provide a framework for reporting injuries and illnesses in golf. The latter half of this theme will describe the rates of SARS-CoV-2 in professional European golf and the safety of protocols to decrease disruption to events through unnecessary isolation. The second theme of the thesis will explore the rates of returning to golf following orthopaedic surgery and the clinical and golf-related outcomes reported of such patients. The thesis will conclude with a prospective, multi-centre study protocol which addresses shortcomings of previously conducted research in this field.
Chapter 2 Critical review of theme 1: Injuries and illnesses in golf

2.1 Study 1: Systematic review of musculoskeletal injuries in professional golfers


2.1.1 Aims and objectives

There are approximately 17,500 golfers registered as professionals in Europe and the growing worldwide schedule for touring players is placing a considerable demand on their physical capability to perform. Injuries can have a major impact on a golfing career, including sporting absence, reduced performance and loss of income. While substantial attempts have been made to establish the most frequent injuries affecting amateur golfers, the epidemiology of musculoskeletal injuries affecting professional golfers is less well understood. The profile of injuries affecting amateur players differ when compared to those affecting professionals. Differences in swing biomechanics and characteristics, as well as club head speeds and playing volume, likely contribute to differences in the spectrum of injuries sustained between these groups. Professional golfers can hit up to 2000 balls per week with 73.3% striking 200 balls a day or more on average. In contrast, only 19.4% of amateurs hit more than 200 balls per week. As the game of golf has evolved, so too have the biomechanics of the golf swing.

The literature to date has focussed on injuries known to be prevalent among recreational or amateur golfers, with a paucity of literature focussing on injuries affecting professional golfers. The aim of our systematic review was to describe the epidemiology of musculoskeletal injuries in professional golfers. Specifically, the
objectives were to 1) collate and appraise articles reporting the epidemiology of professional golfers, 2) report the prevalence and/or incidence of injuries and their anatomical location 3) develop future goals for professional golf research.

2.1.2 Methodology

This systematic review followed the guidelines set out by within the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement. Search terms of “golf” and “injur*” were deliberately kept broad to give the greatest probability of identifying relevant studies, given the limited literature on golf-related injuries. Studies were excluded from analysis if they were case reports, opinion articles/magazines, grey literature, injuries not related to the physical activity of golfing i.e. golf cart injuries, ocular injuries or head injuries, or injuries occurring in recreational golfers. The criteria for inclusion were as follows:

1. Published epidemiological, observational research articles including cohort studies, case-control studies or cross-sectional studies using original data
2. Studies reporting the incidence or prevalence of musculoskeletal injuries in professional golfers
3. English Language studies
4. Not restricted by age or gender.

Pubmed, SportDiscus and Embase were used to search for articles. Titles and abstracts were initially reviewed and those meeting the inclusion criteria were included for full text review. Duplicates were removed from the database of articles using the Endnote software function. Full text studies were further evaluated against the inclusion & exclusion criteria. Additionally, a search of the references was conducted of the selected studies to ensure no other relevant studies were missed.
Key variables extracted from the included articles were demographic data, diagnosis (if reported), region of injury, side of injury, mechanism of injury and time to return to sport. Rates of injury were recorded as incidence or prevalence depending on the authors reporting. All studies were assessed by myself and a co-author using the Quality Assessment Tool for Observational Cohort and Cross-sectional Studies. The assessment tool uses 14 questions to enable allocation of a score to each article (poor, fair or good). If there was disagreement regarding the scoring of a study, consensus was met after discussion amongst both assessors. This tool was chosen for two reasons; 1) I was familiar with it, having previously used in it other systematic reviews and 2) Its function matched the study designs of the review well i.e. cohort and cross-sectional studies.

2.1.3 Results

Only five studies were included for final inclusion. There had been 23 studies which underwent full text review, however 18 were excluded, including 14 case reports. Due to the limited number of studies and heterogenous nature of the data reported i.e. a mix of incidence and prevalence, the data was presented descriptively, and no meta-analysis was attempted. Results were reported in the following categories; 1) Study characteristics and demographics 2) Quality assessment 3) Frequency and region of injuries and 4) Secondary outcomes e.g. time to return, side of injury, and mechanism of injury.

Each study’s injuries were presented as a percentage of total injuries (table 1) and spine followed by hand/wrist injuries were the most common. The overall quality of the studies were rated poor (n=3) and fair (n=2). There was significant heterogeneity regarding how injuries were defined, what the primary outcome measurement was, and who the overall exposure group was.
2.1.4 Conclusion

We concluded from this study that there was a paucity of quality literature reporting injuries in professional golfers. The data that was published was extremely heterogeneous in nature. The lumbar spine was the most frequent region of injury and there were a higher number of injuries in the region of the cervical spine in professional golfers than has been reported for amateur golfers. We found the hand/wrist region to be a poorly represented area of study in the professional golf literature despite how commonly it is reported to be injured in epidemiological studies. Injury nomenclature varies considerably within the existing literature making comparison between studies challenging. Standardisation of diagnosis and injury nomenclature within the golf literature would encourage a wider collaborative effort. The use of well-recognised epidemiological methods of reporting injuries are required to make useful comparisons moving forward.

2.1.5 Contribution to knowledge

This was the first study which attempted to systematically review the professional golf literature with regard to injury. We as a research group believed this was an important task given the different biomechanical and volume demands placed on these golfers compared to recreational golfers. This study has since be presented at international meetings, used to inform clinicians working in professional golf and has been cited 30 times. Around the time of this publication, the impact of research dissemination was becoming better recognised. This included mediums such as via infographics or social media. We were an early adopter of this trend and leveraged the experience and insight from co-authors to create an infographic which succinctly demonstrated the findings of the paper. This was then used in presentations and on social media platforms such as twitter to present our research.
This study was specifically referenced in the British Journal of Sports Medicine’s E-Edition on golf medicine.

2.1.6 Student contribution

My contribution to this study including the methodological design, data collection, data analysis and leading the manuscript writing. This study was the first efforts from researchers and clinicians in the field of golf medicine at the University of Edinburgh to collaborate across a number of sub-specialisms including sports medicine, sports science and orthopaedic surgery. Initially invited by Prof. Andrew Murray, I then led the in-person and virtual group discussions regarding the aims of this project. Professional experience from Prof. Murray and Dr. Roger Hawkes highlighted the limitations of the elite golf medical literature and the outdated nature of such studies. I familiarised myself with systematic review methodology and alongside senior clinical academic Dr. Andrew Duckworth, we adhered to PROSPERO guidelines and reviewed the literature. I then led regular research meetings to discuss the structure and delivery of the data collected. It became apparent that there was too much heterogeneity in the data to perform a meta-analysis and therefore the study remained descriptive as a systematic review.

This study was an impactful learning point on how to discuss research with journal editors. Initially, this study contained all articles reporting on golf injuries including case reports. In addition, there was a mix of data reporting with prevalence and incidence which was merged. Early feedback from the British Journal of Sports Medicine reviewers highlighted some of these flaws in interpretability of the results in their current format. This allowed for significant restructuring and presentation of the methods of the results prior to resubmission and ultimately acceptance.
Systematic review of musculoskeletal injuries in professional golfers

Patrick Robinson, Iain R Murray, Andrew D Duckworth, Roger Hawkes, Danny Glover, Nigel R Tilley, Rob Hillman, Christopher W Oliver, Andrew D Murray

ABSTRACT

Objective The distribution of injuries affecting professional golfers is yet to be fully understood. We performed a systematic review of the clinical literature to establish the epidemiology of musculoskeletal injuries affecting professional golfers.

Design Systematic review.

Data sources Search databases in July 2018 were PubMed, SPORTDiscus and Embase.

Eligibility criteria Published observational research articles relating to the incidence or prevalence of musculoskeletal injuries in professional golfers, which were written in the English language and not restricted by age or gender.

Results Of the 1683 studies identified on the initial search, 5 studies were found to satisfy the inclusion criteria for analysis. The mean age of the golfers in these studies was 34.8 (±3.6) years. The gender of patients in included studies comprised 72% males and 28% females. Four studies reported that lumbar spine injuries were the most common (range 27%–34%). Excluding injuries to the spine (lumbar, thoracic, and cervical), the hand/wrist was the next most common region of injury (range 6%–17%). The quality of the studies was relatively poor with no study satisfying >50% of the quality assessment tool questions and only one study giving a clear definition of how they defined injury.

Conclusion There is a paucity of well-designed epidemiological studies evaluating musculoskeletal injuries affecting professional golfers. Injuries to the spine are the most frequently affected region, followed by the hand/wrist. This study has identified targeted areas for future research that aims to improve the management of injuries among professional golfers.

INTRODUCTION

There are approximately 17 500 golfers registered as professionals in Europe1 and the growing worldwide schedule for these players is placing a considerable demand on their physical capability to perform.2 Injuries to high profile, professional players has commanded considerable media and popular attention. Injuries can have a major impact on a golfing career, including sporting absence, reduced performance and loss of income. While substantial attempts have been made to establish the most frequent injuries affecting amateur golfers,3–7 the epidemiology of musculoskeletal injuries affecting professional golfers is less well understood.

The profile of injuries affecting amateur players appears to differ when compared with those affecting professionals.4,8 This may be attributed to differences in swing characteristics and biomechanics in professional golfers such as creating more ‘‘factors’’ in greater rotation of the thoracic spine and restricted hip rotation at the top of the backswing.9,10 and the different use of the forearm muscles in the trail and lead arms.11 Furthermore, club head speeds and playing volume are on average much greater for the professional golfer.12 Professional golfers typically hit >2000 balls per week with 73.3% striking 200 balls or more per day on average. In contrast, only 19.4% of amateurs hit >200 balls per week.13 As the game of golf has evolved, so too have the biomechanics of the golf swing.14–16 It is speculated that a modern day professional swing generates increased torque, which may contribute to increased rates of lower back pain in professional golfers.14,15 Professionals and amateurs should therefore be considered as distinct patient groups sustaining differing injury profiles.

The literature to date has focused on injuries known to be prevalent among social or amateur golfers, with a paucity of literature focusing on injuries affecting professional golfers. Given the differences in amateur and professionals swing biomechanics and distribution of injuries we believe they should be analysed separately and therefore, the aim of our systematic review was to describe the epidemiology of musculoskeletal injuries in professional golfers.

METHODS

A search of PubMed, SPORTDiscus and Embase was performed in July 2018 in line with the 2009 Preferred Reporting Items for Systematic Review and Meta-Analysis statement.17 The study was registered using the PROSPERO International prospective register of systematic reviews (CRED2017077191).18

Titles and abstracts identified were independently reviewed by two authors (PG, ADD) and those not meeting the inclusion criteria were excluded before full-text review. On occasions when it was not clear from the abstract if studies were relevant, the full text of the article was reviewed. Attempts were made to contact the authors of articles when the data included were not clear. Unanimous consensus was met on the inclusion of proposed studies for full-text review among the authors (PG, ADD). Full-text studies were further evaluated against the inclusion and exclusion criteria. A search of the references of the selected studies was conducted to ensure no other relevant studies were missed.

2.1.7 Publication
Search terms and criteria for inclusion
Search terms were ‘golf AND (injury)’ OR back OR lumbar OR cervical OR thoracic OR shoulder OR elbow OR wrist OR hand OR hip OR knee OR ankle OR foot’. Grey literature was searched in each database in the form of conference proceedings and abstracts. Studies were excluded from analysis if they were case reports, reports not related to the physical activity of golfing, that is, golf cart injuries, ocular injuries or head injuries or injuries occurring in recreational golfers. The criteria for inclusion were as follows:
1. Published epidemiological, observational, research articles including cohort studies, case-control studies or cross-sectional studies using original data.
2. Studies reporting the incidence or prevalence of musculoskeletal injuries in professional golfers.
3. English language studies.
4. Not restricted by age or gender.
5. Year of publication between 1989 and present.

Data extraction
Data were collected from each study by two authors (PG, ADD) and included age, sex, data collection methods, diagnosis, region of injury, side of injury, incidence/prevalence of injury, definition of injury, nature of injury, severity of injury, mechanism of injury, risk factors, length of golf career, injury management and time to return to sport.

Data analysis and quality assessment
All studies were assessed by two authors (PG, ADD) using the Quality Assessment Tool for Observational Cohort and Cross-sectional Studies.24 The assessment tool uses 14 questions to give an evaluation of the internal validity of a study. If there was disagreement regarding the scoring of a study, consensus was met after discussion among both assessors. The authors of the Quality Assessment Tool for Observational Cohort and Cross-sectional Studies have discouraged users from attempting to tally up the scores from the tool. However, we have represented the number of applicable questions answered ‘yes’ for each study as a percentage. Data analysis was primarily in the form of reporting variables collected in the data extraction process and efforts were made to consolidate data if it was comparable, such as the players’ age. A meta-analysis was not performed due to the heterogeneous nature of the data in each included paper.

RESULTS
Of the 1863 articles identified in the initial search of databases and reference lists, 1014 studies remained following removal of duplicate studies. After initial screening of titles and abstracts, 23 articles met the inclusion criteria for review. On full-text screening, a further 18 studies were removed; 2 studies were review articles, 1 study analysed amateur golfers and 1 study lacked adequate information on injury distribution/frequency. Fourteen of the studies excluded were case reports or case series: two papers relating to the lumbar spine, three to the shoulder, two to the hand/wrist, two to the hip, three to the lower leg and two miscellaneous articles (Figure 1).

A list of studies meeting the inclusion criteria and details of each study can be seen in Table 1. The years of publication ranged from 1982 to 2012. Included in our review were five observational studies representing cohort data. There were no intervention studies assessing injury prevention efforts.

Participant demographics
The mean age of the golfers in those studies was 34.8 (±3.6) years. Of the 3 included studies, 2 did not report the age of the golfers. Three studies reported on the gender of players, which comprised 821 males (72%) and 320 females (28%). The studies were performed in the UK, Germany, Japan and the USA. The mean career length was reported in two studies (McCarroll and Goe, and Sugaya et al) (Table 1).

Quality assessment
The results of the quality assessment of included studies can be seen in online supplementary appendix 1. The studies were of overall poor quality with no study being able to answer >50% of the questions successfully and no study consistently reported exposure measures.

Data collection
Three studies (Gosheger et al, McCarroll and Goe and Sugaya et al) used questionnaires to acquire injury data. McCarroll and Goe collected data on professional golfers over 2 seasons and researchers were at hand to assist with the completion of the questionnaires. Sugaya et al distributed the questionnaires during four tournaments with 4 different groups of professional golfers (2 male and 2 female). They appear to report injuries sustained during an entire career, but this is not explicitly stated. McCarroll and Goe posted a questionnaire to a group of male and female professional players. All three studies asked players to retrospectively report injuries occurring during their past playing career.

Smith and Hillman analysed data retrospectively which was collected from male European Tour players visiting the mobile physiotherapy unit during two seasons. Injury data were collected by one of their medical practitioners during each player’s visit to the unit. The study by Hadden et al retrospectively analysed data collected on male golfers seeking medical attention who were competing in the Open Championship across 7 years.

Injury incidence and prevalence
Reporting of injury varied among all studies. Hadden et al described the incidence of injury that required medical attention over 7 different Open Championships. This was the only study to report ‘new’ injuries. We believe Gosheger et al, McCarroll and Goe and Sugaya et al all reported the prevalence of injuries across a career; however, Gosheger et al and McCarroll and Goe did not overly describe the type of injury frequency methodology used. Sugaya et al appeared to use the terms incidence and prevalence interchangeably to describe the same data. McCarroll and Goe, and Sugaya et al reported the mean length of a players’ career. Smith and Hillman reported the prevalence of injuries across 2 seasons on the European Tour but did not specify the rate of new injuries during the study period. Unfortunately, it was not possible to perform a synthesis of the data to give overall percentages of injuries given the lack of information from each study regarding time points and the at-risk population. Injuries were presented as percentage proportions of total injuries reported in each study and this is demonstrated in Table 2.

Definition of injury, nature of injury, severity of injury/time to return to sport
McCarroll and Goe, Hadden et al and Sugaya et al failed to give a definition of how they defined injury. Smith and Hillman defined injury as ‘an event or incident, which occurred during training or match play, which necessitated attention from the unit’s practitioners’. Gosheger et al defined severity of injury but not what constituted an injury itself. The severity of injury was classified as minor, moderate or major and loss of playing
time was the parameter used. A minor injury was one "requiring a golfer to sit out < 1 week" and a moderate injury resulted in "> 1 week to < 1-month-long layoff" and a major injury was "an absence from the golf course of 1 month or even longer". Sugaya et al reported 72% of players missed at least one tournament or played to an unsatisfactory level as a direct result of injury. Goshager et al reported "time lost from golf injury" and correlates it with region of injury; however, it is not clear if this time lost is competitive golf or practice and the authors did not separate out amateur and professional data. Smith and Hillman and Hadden et al did not report severity of injury. McCarroll and Gooe used time lost from the tour as a marker of severity and reported an average of 9.3 weeks for men and 2.8 weeks for women.

Table 1: Demographics and quality of studies reporting the epidemiology of professional golf injuries

<table>
<thead>
<tr>
<th>Author</th>
<th>Data collection</th>
<th>Setting</th>
<th>No. of participants</th>
<th>Questionnaire response rates (%)</th>
<th>Mean age (range)</th>
<th>Gender (%)</th>
<th>Mean length of career (years)</th>
<th>LoE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goshager et al</td>
<td>Retrospective</td>
<td>Randomly selected professional golfers in Germany</td>
<td>60</td>
<td>100</td>
<td>37 (23–40)</td>
<td>Male: 90%; Female: 10%</td>
<td>NR</td>
<td>III</td>
</tr>
<tr>
<td>Hadden et al</td>
<td>Retrospective</td>
<td>Injuries occurring at the Open Championships and reviewed by the on-call medical officer</td>
<td>88</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NR</td>
</tr>
<tr>
<td>McCarroll and Gooe</td>
<td>Retrospective questionnaire</td>
<td>Queensland PGA and PGA Tour players</td>
<td>45</td>
<td>30 (23–70)</td>
<td>Male: 56%; Female: 44%</td>
<td>Men: 18 (11–39) Women: 11–23</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>Smith and Hitchens</td>
<td>Prospective collection</td>
<td>Audit of the services delivered by the mobile physiotherapy unit on the European Tour</td>
<td>1328 injuries' NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>II</td>
</tr>
<tr>
<td>Sugaya et al</td>
<td>Retrospective</td>
<td>Queensland registered during four different professional events in Japan</td>
<td>281</td>
<td>57</td>
<td>40 (15–65)</td>
<td>Male: 60%; Female: 40%</td>
<td>Men: 27 Women: 14</td>
<td>III</td>
</tr>
</tbody>
</table>

LoE, level of evidence; MC, main only cohort; NA, not available; NR, not recorded.
Two studies (Hadden et al and McCarroll and Gieoe) reported the nature of the injury (whether it was a new injury or exacerbation of a long-standing injury). Hadden et al reported 43% new injuries and 37% were exacerbations of chronic injuries. McCarroll and Goeoe found 69% of injuries were caused by repetitive load and a further 24% of injuries were caused by hitting an object during the swing.

**Diagnosis, risk factors, mechanism and treatment/prognosis**

No study reported a specific diagnosis but instead reported injury by anatomical location. In relation to upper limb injuries, only McCarroll and Goeoe reported an injury of the shoulder and shoulder injuries sustained in the upper limb. They found the left side was injured 5 times more frequently than the right; 84.5% of injuries were left sided, which is the lead side in a right-handed golfer. When Sugaya et al reported the side of lumbar back injuries, 51% were right-sided pain, 28% reported left-sided pain and 21% reported central or generalised pain.

McCarroll and Goeoe reported risk factors for injury including years spent on tour, experience and age and concluded none of these were related to an increase in injury. Goshger et al reported the injury type and a variety of variables including gender, stretching/warming up, playing time, carrying the golf bag, body mass index and playing other sports. However, the authors did not differentiate between amateur and professionals. No other study reported risk factors for injury. The mechanism of injury was not adequately reported by any study. Goshger et al reported on the mechanism but did not differentiate between amateur and professional golfers.

The treatment of injuries was reported by 3 studies (Hadden et al, McCarroll and Goeoe and Smith and Hillmam). Hadden et al reported the types of treatments used but did not separate the management of spectators and competitors at a tournament. McCarroll and Goeoe reported 16% of players were managed with rest alone, 28% were given physical therapy or chiropractic treatment and 21% received anti-inflammatory medication or corticosteroid injections; 7% of players required surgery. Smith and Hillmam reported 71% of players received massages, manipulation or stretching. The reporting of key variables used to describe injuries in professional golfers in each study can be seen in Figure 2.

**Professional female golf injuries**

McCarroll and Goeoe, and Sugaya et al reported frequency and anatomical distribution of injuries in female golfers as well as male golfers. McCarroll and Goeoe found both sexes sustained approximately 2 injuries per year over a career. However, the average golfing career was 13 years shorter for females (table 1). They found female lumbar spine (22%) and hand/wrist injuries (38%) to be most common. However, cervical spine injuries only contributed 2% of injuries and there were no reports of thoracic spine injuries. Sugaya et al reported lumbar spine injuries (41%), cervical/theracic injuries (26%) and wrist injuries (9%) to be most common.

**Figure 2** A heatmap representing injury variables reported by each study.
The level of golf research published appears to be of relatively low quality. Gold standard methodology for sports injury surveillance (such as prospectively designed studies with injury assessment by experienced clinicians) was not seen among our included studies. Key aspects of injury reporting such as injury diagnosis, nature of injury, injury mechanism and injury severity were poorly reported (Figure 2). All studies were retrospective in nature and 3 studies required recall of the injuries by the players themselves. We hope that the findings of this study will act as a stepping-stone to methodologically precise epidemiological studies on professional golf injuries and further focused, high-quality research on the most common injuries in golf.

Despite the frequency of back injuries in professional golfers shown in our review of epidemiological studies, we could find only 7 pre-epidemiological studies in the current golf literature specifically studying back injuries in professional golfers.\(^\text{[12-18]}\) (all of which focus on the lumbar spine). In comparison to the prevalence of cervical spine injuries in amateur golfers (20%-40%),\(^\text{[12]}\) professionals appear to be burdened with injuries in this region more often. We could find no studies in the current golf literature focusing on articular, prevention or outcome of cervical spine injuries specifically.

The hand/wrist area was the second most commonly injured area of the body after the exclusion of all spine injuries. Unfortunately, the studies included in our review did not report on whether these represented lead or trail side injuries. Without knowing if the golfer was right or left handed, no definitive conclusions could be made with regards to the frequency of lead or trail sided injuries. However, it is probable that the majority of players in the included studies were right handed, and injuries are thus more frequent in the lead side (left side in a right handed golfer).

The severity and burden of injury was not well reported in the studies included in our review. Although knowledge of the most common regions of injury is important, knowledge of the effect of the injury on the golfer’s performance is equally necessary. Some injuries may require long periods away from the game, operations and have high risks of recurrence. One recent study has encouraged the utilisation of ‘injury burden’ as a more accurate description of the severity of injury.\(^\text{[12]}\)

**DISCUSSION**

This is the first study to systematically review the current literature reporting the epidemiology of musculoskeletal injuries in professional golfers. The principal finding is the limited number of robust studies evaluating the epidemiology of these injuries in this group. Given the variety of methods used in studies reporting on golfing injuries, as well as the inconsistent definition of injuries used, detailed comparison between studies was not possible.

The most frequently reported injury affecting professional golfers—lumbar spine injuries—appears to be relatively well represented by a range of studies (clinical reviews and outcome-based) in the literature; however, these studies generally relate to injuries in non-professional players.\(^\text{[12,13]}\) Despite being the second most commonly body region injured in professional golfers, cervical spine injuries do not appear to be the focus of any study in the current golf literature (Figure 3).

**Limitations**

This review should be interpreted with consideration of its limitations. The epidemiological studies included in our review lacked homogeneity in their reporting of injuries. Many of the studies did not provide information on the mechanism of injury, previous injuries or time to return to sport. Therefore, this made it difficult to make valid conclusions in these areas. Furthermore, there was heterogeneity in the definition of injury between all studies and 3 studies failed to give a precise definition at all. In all studies, classification of injury was limited to the region of injury rather than specific diagnosis. Clearly, this is only partially helpful when attempting to extract this information to plan future injury-specific research.

The study evolved over time and there are some loose differences in the registered PROSPERO report and the final paper. We used a different quality assessment tool, which we felt was more suited to analysing the data compared with the original tool. We decided not to include case reports/series in the analysis as this would have introduced bias in the reporting of the most common injuries sustained by professional golfers. Our review was initially intended to analyse elite golfers, which included collegiate golfers, and/or competitive amateur golfers, as well as professionals. However, there were no epidemiological papers...
analysing collegiate or competitive amateur golfers and hence only professional golf studies were included in final analysis. Finally, we had a relatively small number of studies meeting the inclusion criteria which ranged in date from 1982 to 2012. With the changes in swing mechanics and the more widespread adoption of the latest technology and conditioning programmes, the epimorphy of golf injuries may have also evolved.

**CONCLUSION**

The principal finding from this study is the current paucity of quality literature and the haphazard data included in studies reporting injuries in professional golfers. The lumbar spine was the most frequent region of injury and there were a higher number of injuries to the region of the cervical spine in professional golfers that has not been reported for amateur golfers. Injury nomenclature varies considerably within the existing literature making comparison between studies challenging. Standardisation of diagnosis and injury nomenclature within the golf literature would encourage a wider collaborative effort. The use of well-recognised epidemiological methods of reporting injuries are required to make useful comparisons moving forward.

**What is already known?**

- Professional golfers may sustain different patterns of injuries compared with amateurs.

**What are the new findings?**

- The most frequently injured region is the spine (cervical, thoracic and lumbar) and the hamstring.
- Regions of injuries in professional male and female golfers are similar.
- Definition of injury tends to not be clear and varies if it is present.
- Nature of injury, injury mechanism and severity of injury/time to return to sport poorly reported.

**Contributors**

FR: study design, data collection, data analysis, writing of manuscript. RM: study design, writing of manuscript. ADO: study design, data collection, data analysis, writing of manuscript. RM: study design, writing of manuscript. DG, NT, RR, CWO: writing of manuscript. AS: study design, writing of manuscript.

**Funding**

The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests**

More decent.

**Patient consent**

Not required.

**Prevascular and peer review**

Not commissioned; externally peer reviewed.

**REFERENCES**


2.2 Study 2: International consensus statement: methods for recording and reporting of epidemiological data on injuries and illnesses in golf


2.2.1 Aims and objectives

This paper was in response to the International Olympic Committee’s consensus statement entitled ‘International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020’. The core aims of that statement were to implement recent consensus in methodology and experience within the domains of sports injury and illness to provide hands on guidance for researchers on how to plan and conduct data collection in sport as well as how to report it. The authors of the consensus statement recognised that primary publication would benefit from sports-specific adaption in line with its core framework.

The aim of this present publication was therefore an adaptation of the original consensus, specific to the unique sporting characteristics related to golf. This golf-themed research group were the first to respond to the original consensus statement with a sports specific consensus. The objectives were to 1) identify and address golf-specific scenarios not covered by the generic IOC statement and 2) include such niche elements into newly designed data gathering tools (for example questionnaires) which are included as appendices to the research article.

2.2.2 Methodology
The methodology for this consensus statement followed a similar structure to the original consensus statement to ensure consistency. Six stages to the process were conducted. The chair, working group and consensus group were formed. A total of 21 experts with expertise in research, clinical medicine, epidemiology, sport and data management. The working group (which included myself) was subdivided and subsequently reviewed each of the previous sport-specific non-IOC consensus statements including a literature review of focused areas such as previous epidemiological studies in golf. The working group members then formulated drafts of one or more sections to the golf-specific consensus. There was then a virtual round of overall consensus amongst the wider expert group. The working group drafted the manuscript, and worked with the consensus group for approval and submission for publication.

2.2.3 Results

There were five main outputs from this consensus statement. They were:

1. Definition and characteristics of injury and illness
2. Recording exposure
3. Calculation of incidence, prevalence and burden of injury and illness
4. Study population characteristics
5. Forms and data collection methods

Definition and characteristics of injury and illness

There were some key aspects of golf which were required to be recognised in reporting of injuries. The biomechanics of golf are asymmetrical and it is known that there are differences in both injury prevalence and type of injuries between the lead (left side in a right handed golfer) and trail sides.\textsuperscript{18, 70, 71} Therefore, it is crucial to include the side of the injury in data collection.
Golfers commonly play with injuries and therefore when measuring the severity of the injury or illness we have suggested recording data on the time from initial injury to full recovery. We also provided golf related examples for new, subsequent, recurrent and exacerbation of injuries and illnesses.

**Recording exposure**

Golf specific exposure was divided into 1) competition, 2) golf practice and 3) wider training. With the increase in strength and conditioning performed by modern sub-elite and elite players, we decided to include training exposure to give a more thorough picture of the overall load sustained by golfers.

**Calculation of incidence, prevalence and burden of injury and illness**

We have outlined the recommended options for measuring injury or illnesses exposure and these are typically as a percentage of total golfers in the cohort, per 1000 hours of golf or even per holes played. During the off season, researchers may want to relate exposure to practice, for example injuries per 1000 balls hit on the driving range or practice holes played.

**Study population characteristics**

Golfing handicap/ability level and handedness must be recorded for the purposes of accurate data collection. Previous studies have demonstrated that recreational and professional golfers have differing injury patterns. Furthermore, the side of the injury and the handedness of the player are required to understand the lead and trail side of each player.

**Forms and data collection methods**
This paper contains appendices, five of which contain suggested forms by which to collect data in golf epidemiological studies. Appendix 2 contains a daily medical report for clinicians or researchers to complete during a golf tournament. Appendix 3 covers an in-season medical report for clinicians or researchers to complete while appendix 4 is a weekly report of exposure to competition, practice and/or training. Appendix 5 is a self-reported weekly medical report for participants to complete and appendix 6 is the baseline questionnaire which covers demographics, golf specific variables, current health complaints and medical history.

2.2.4 Conclusion

The purpose of this IOC-initiated, golf-specific consensus and its related appendices was to give researchers a structure and consistency in conducting golf related research. In particular, the ready-made data collection forms contain what we believe is the pertinent data required for conducting golf epidemiology. The hope is that this work leads to high quality, reproducible and comparable research in the field of golf medicine.

2.2.5 Contribution to knowledge base

Other sports have also added their own specific versions of the IOC consensus statement including parasports, tennis, cycling, and football.\textsuperscript{74-77} Examples of how these sports require participant and activity specific reporting guidelines include unique injuries in parasport such as pressure ulcers and phantom limb pain. For tennis, inertia measurement unit sensors have been suggested for collecting the number and velocity of strokes while in cycling, load can be measured by power metres attached to the bike. In golf, some sport specific examples which we identified for this consensus include a standardised way to categorise ability i.e. elite, sub-elite or recreational and types of exposure i.e. competition, driving range.
play, short game and putting as well as non-golf related exposure i.e. fitness training. The paper also gives many examples of how golf injury mechanisms might fit into the 2020 IOC consensus statement's classifications.

At the time of writing, this study has since been cited 20 times and has used as a foundation for data collection in the largest multi-centre prospective study of international golfers to date. It was specifically referenced in the British Journal of Sports Medicine’s E-Edition on golf medicine.

This study was also presented as a poster at the International Olympic Committee World Conference in Monaco, November 2021.

2.2.6 Student contribution

My role within this study included being a part of the core working group. This group also included the first, second and senior author. My role included reviewing previous sport specific consensus statements and relevant literature. In addition, my sub-section for first draft production was in the area of ‘definition and characteristics of injury and illness’ and ‘study population characteristics’. In particular, I drove the injury and illness specific examples for new and subsequent injuries and produced the definitions of performance levels in golf. I created the agendas for the virtual meetings and recorded the minutes and take away points for each discussion. I co-authored the initial first draft of the study and made subsequent revisions following both virtual meetings with the consensus group and following reviewers’ suggestions.
Consensus statement

International consensus statement: methods for recording and reporting of epidemiological data on injuries and illnesses in golf

Andrew Murray,1,2 Astrid Junge,3,4 Patrick Gordon Robinson,1,6 Mario Bizzini,7,8 Andrie Bossert,9 Benjamin Clarsen,10,11 Daniel Coughlan,1,11 Corey Cunningham,1,12 Tomos Drobny,15,16 Francois Gazzano,17 Lance Gill,18,19 Roger Hawkes,20 Tom Haspel21,22 Robert Neal23 Jonathan Lavelle24,25 Antony Scanlon26 Patrick Schamal27,28 Bruce Thomas,29 Mike Voight,30,31 Mark Wotherspoon,31,32 Jiri Dvorak15,33

2.2.7 Publication

ABSTRACT
Epidemiological studies of injury in elite and recreational golfers have lagged behind in methods and definitions employed and this limits comparison of results across studies. In their sports-specific statement, the Consensus Group recruited by the IOC (2020) called for sport-specific consensus statements. On invitation by International Golf Federation, a group of international experts in sport and exercise medicine, golf, and sports injury/illness epidemiology was selected to prepare a golf-specific consensus statement. Methodological stages included literature review and initial drafting, online feedback from the consensus group, revision and second draft, virtual consensus meetings and completion of final version. This consensus statement provides golf-specific recommendations for data collection and research reporting including: (i) injury and illness definitions, and characteristics with golf-specific examples, (ii) definitions of golf-specific exposure measurements and recommendations for the calculation of prevalence and incidence, (iii) injury, illness and exposure report forms for medical staff and for golfers, and (iv) a baseline questionnaire. Implementation of the consensus methodology will enable comparison among golf studies and with other sports. It facilitates analysis of causative factors for injuries and illness in golf and can also be used to evaluate the effects of prevention programmes to support the health of golfers.

INTRODUCTION
Golf is a sport played by more than 60 million people10 of all ages and abilities. It is played in every two-thirds of the world’s countries and in six continents.2 The best available evidence suggests golf is associated with overall improved health and has well-prescribed benefits.3,4 Golf can provide moderate-intensity aerobic physical activity, can help decrease non-occupational time, and may have muscle strengthening and balance benefits.5,6 However, injuries and illnesses can occur. Systematic reviews describe golf as a moderate-risk activity for injury compared with other sports.7,8 Prospective longitudinal studies report low injury rates compared with other sports, at 0.28 to 0.60 injuries per 1000 hours in amateurs.9,10 Musculoskeletal injuries are the largest group of injuries according to our scoping review of the associations between golf and health.11 Very few studies report on epidemiological studies of injury in golfers.12-16 A recent systematic review of professional golf injuries showed 66% of included studies failed to give a definition of injury and 86% did not report the mechanism of the injury.17

While epidemiological studies on golfers vary considerably in methods and quality,18 consensus statements on recording and reporting of injury/illness have been published for other sports19-24 and for multisport events25-31 since 2006. In 2019, the IOC published a consensus statement: Methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (referred to now as the 2020 IOC Consensus Statement) and called for “… sport-specific statements with more detailed recommendations relevant for the sports and/or settings.”26 In 2019, the International Golf Federation (IGF) invited a working group to develop golf-specific guidelines based on the 2020 IOC Consensus Statement.27 This consensus aims to guide and provide tools for researchers on how to collect data, and report injury and illness in golf. This will, in turn, help golfers, coaches, medical practitioners and policy makers to understand the typical pattern, severity and burden of health problems. It will provide a strong foundation for injury prevention programmes for golfers.

The objective of this consensus is to encourage consistency in recording and reporting epidemiological data on injury and illness in golf and to provide tools to assist in data collection and research. We reviewed the 2019 IOC Consensus Statement26 and aimed to obtain consensus among IGF medical commission members and invited experts on: (a) how that IOC Consensus needed to be modified for golf, (b) golf-specific exposure measurements and calculation of prevalence, incidence and burden, (c) adopting the 2020 IOC Consensus Statement medical report forms for golf and develop exposure report forms, (d) developing an athlete’s weekly health complaints and exposure report form for recreational and elite golfers, and (e) developing a baseline questionnaire for recreational and elite golfers.
METHODS
Our methods drew on those reported in the 2020 IOC Consensus Statement on injury and illness surveillance,17 our process had six stages:

Selection of chair, working group and consensus group members
The IGF Medical Commission appointed AM to chair the consensus group. He worked with JD and commissioners members to purposively select a consensus group of 21 individuals that would span a variety of expert disciplines (online supplementary appendix 1). These included three authors (JD, JD and AJ) from the recent 2020 IOC Consensus Statement17 with considerable expertise regarding sports injury/illness epidemiology and prevention, nine further members (GJ, CC, DC, TD, TH, AM, PR and MW) working primarily as researchers and practitioners within golf. In addition to the working group members, each IGF medical commission member was invited to the overall consensus group (RAH, TH, JL, AM, AX, PS, RT and MV), AB is a professional golfer, MR an experienced sports researcher, and FG and RN are technology and data management experts. This purposeful method ensured the consensus group members included expertise with diverse research and practical experience. Group members had experience working with golfers from diverse geographical settings and of varying performance level, age group, gender and disability. Four members of the consensus group (AM, AJ, PR and JD) were selected as the working group.

Literature review, discussion and initial draft by the working group
The working group reviewed the 2020 IOC Consensus Statement,17 all sport and setting-specific consensus statements,18-25 and other relevant literature. Key themes and needs were identified by this working group. The consensus statement was divided into subsections and each author from the working group was assigned one or more areas. They were then tasked with a further, more detailed literature review of the particular subject and construction of definitions and recommendations for the first draft. The working group collated the subsections, producing a complete initial draft of the text and report forms.

Review and feedback by consensus group members
The first draft of the consensus document and the related forms was shared with all consensus group members, who were asked to provide comments and potential modifications to the working group online and by conference call.

Revision and second draft by working group
The working group revised the text and related report forms based on the input and recommendations of the consensus group and produced a second draft.

Online consensus meetings and third draft
These meetings focused on achieving consensus, and discussion regarding collaboration and practical implementation.

Final revision by the working group and approval by the consensus group
Following the online consensus meetings, the working group incorporated the feedback and remarks, and the consensus was assessed for overall consistency among each topic. The third draft was created and circulated. Everyone in the consensus group agreed to accept the finalised consensus.

<table>
<thead>
<tr>
<th>Table 1A. The mode of onset of golf injury</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trama</strong></td>
</tr>
<tr>
<td>Acute</td>
</tr>
<tr>
<td>Repetitive</td>
</tr>
<tr>
<td>Gradual</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1B. The mode of onset of golf illnesses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode of onset</strong></td>
</tr>
<tr>
<td>Sudden</td>
</tr>
<tr>
<td>Gradual</td>
</tr>
</tbody>
</table>

**REVIEW AND ADAPTATION OF THE 2020 IOC CONSENSUS STATEMENT RECOMMENDATIONS FOR GOLF**
All consensus group members agreed that golf-specific adaptations of the 2020 IOC Consensus Statement17 were necessary regarding the following domains: (1) definition and characteristics of injury and illness; (2) recording of exposures; (3) calculation of incidence, prevalence and burden of injury and illness; (4) study population characteristics; and (5) forms and data collection methods.

**Definition and characteristics of injury and illness**
The definitions of injury and illness, categories of location, type, and mode of onset for injury as well as organ system and etiology for illness can be used for golf as described in the 2020 IOC Consensus Statement.20 However, golf-specific examples are needed for some variables (tables 1A–B).

Furthermore, as golf is an asymmetrical sport, and injury patterns are non-symmetrical,18,26 we recommend recording the side of the injured body part as well as the handedness of the golfer. It can then be evaluated whether the injury occurs on the ‘lead’ or ‘trail’ side of the body. In a right-handed golfer, the left side is known as the lead side and the right side as the trail side. The opposite is true for a left-handed golfer.

**Injury and illness surveillance programmes in golf** may be broad, studying all injuries/illnesses or they may have a narrower scope, focusing on only specific types of health problems (e.g., wrist injuries, mental health illness or time-loss injuries) in which case, data reporting and recording can be limited to specific and relevant data.

<table>
<thead>
<tr>
<th>Table 2. Mechanism of injuries in golf</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of contact</strong></td>
</tr>
<tr>
<td>No identifiable single event</td>
</tr>
<tr>
<td>Non-contact trauma (single event)</td>
</tr>
<tr>
<td>Direct contact with an object</td>
</tr>
<tr>
<td>Direct contact with the ground</td>
</tr>
<tr>
<td>Indirect contact with an object</td>
</tr>
<tr>
<td>Indirect contact with the ground</td>
</tr>
</tbody>
</table>

Consensus statement

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
<th>Injury example</th>
<th>Illness example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute</td>
<td>First recorded injury/illness</td>
<td>Golfer reports new right wrist pain after 4 days of competition and is diagnosed with dorsal rim impaction syndrome</td>
<td>Golfer develops a viral illness (influenza)</td>
</tr>
<tr>
<td>Subacute</td>
<td>Any injury/illness occurring after the index injury/illness</td>
<td>Golfer develops lateral back pain following easing of redness secondary to tight hip flex, which is due to irreversible impingement syndrome</td>
<td>Golfer develops depression following a long absence from competition due to low back pain</td>
</tr>
<tr>
<td>Recurrent</td>
<td>Injury to the same site and of the same type as the index injury/illness</td>
<td>Golfer recovers fully from rotator cuff tendinopathy and returns to play (recon)</td>
<td>Golfer recovers from 2 days of Magnus injury and returns to play (recon)</td>
</tr>
<tr>
<td></td>
<td>and type as the index illness after full recovery and return to sport.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exacerbation</td>
<td>Worsening of a not fully recovered index injury/illness</td>
<td>Golfer returns to play or practice before finishing rotator cuff rehabilitation and causes an exacerbation of the tear while hitting a shot</td>
<td>Golfer who generalized anxiety suffers with a worsening of the condition</td>
</tr>
</tbody>
</table>

The recently updated diagnostic coding systems for injury and illness in a sporting context can be used for the reporting and recording if medical staff are involved in the data collection and recording.

Mode of onset

The 2020 IOC Consensus Statement suggests that the transfer of energy causing an injury be described as either acute or repetitive. Repetitive impacts can result in sudden, gradual, or mixed onset of injury. The onset of illnesses can also be classified as sudden, gradual, or mixed. Table IA and B demonstrate golf-specific examples.

Mechanism of injury

Golf-specific modifications of the 2020 IOC Consensus Statement were necessary for mechanism of injury. Golf is a non-contact sport, and contact with another athlete is very unlikely and was therefore not listed in the report forms. However, we distinguish between contact with an object and contact with the ground. Contact can be further subdivided in direct and indirect contact. Golf-specific examples are provided in Table 2.

New and subsequent injuries and illnesses

New and subsequent injuries/illnesses are defined in the 2020 IOC Consensus Statement. In golf, subsequent injuries are likely to be a common scenario. They can be divided into exacerbations or recurrent injuries. For definitions and golf-specific example see Table 3.

Severity of injury and illness

The common method of recording/reporting ‘time loss from training/competition’ can be effective in the description of acute injuries; however, it may under-represent overuse injuries, chronic illnesses and in the context of a golfer being forced to retire. Furthermore, it does not account for injuries that have an impact on a golfer’s performance but do not stop further from practicing or competing; for example, 37% of professional golfers with wrist problems have continued to play while injured.

Therefore, we recommend recording (a) the number of days the player is unable to play and train as well as (b) the number of days from the onset of the injury or illness until full recovery. Following the 2020 Consensus Statement the number of days should be counted from the day after the onset as day one through to the day before the athlete is fully available for training and competition. If any injury event results in multiple injuries, the duration of the most severe injury should be recorded. The following categories can be used: 0 days, 1 to 7 days, 8 to 28 days and >28 days.

Athlete’s answers to the four questions of the Oslo Sports Trauma Research Center (OSTRC) questionnaire on health problems can be used as an additional tool to record severity of the health problem on a score from 0 to 100. This can then be tracked over time to give a cumulative severity score. This questionnaire has been shown to be sensitive to overuse injuries.

Recording of golf-specific exposure

Golf exposure can be divided into three categories: Competition, Golf practice and Training (Table 4). Competition is defined as any competitive rounds of golf. These include internal club competitions, interclub matches, collegiate/university matches, national or international amateur events as well as any professional competitions on any tour. Golf practice includes playing golf on the course (excluding competitions), practicing on the driving range and putting/shot game. Training includes all aspects of strength and conditioning/physical preparation for golf, for example, resistance training, cardiovascular training, stretching or mobility.

Calculation of prevalence, incidence and burden of the injury/illness in golf

Prevalence is the proportion of injured or ill golfers at one point in time or in a defined period of time (e.g., a golf season or a golf tournament) of all golfers in the study population, and can be expressed as percentage of or as number of injured/ill golfers per 1000 golfers. Prevalence can be also calculated for specific groups, for example, male and female golfers, or golfers with a specific handicap or a certain injury.

Incidence describes the number of new injuries/illnesses within a specified period of time (e.g., a season), and can be expressed as the number of new injuries/illnesses per golfer exposure (e.g., per holes played) or 1000 hours of playing golf. In principle, all injuries can be rated to the total number of golfers in the study population or the total time spent competing, playing, practicing and training (all injuries per 1000 hours or per season). Furthermore, injuries during specific activities can be related to the related exposure (Table 4), for example, injuries while hitting the ball on the driving range per 1000 balls hit.

Incidence can also be calculated for specific types of injuries, for example, shoulder injuries or time-loss injuries, or a combination, such as number of injuries/illnesses during a tournament.
specific incidence such as number of new wrist injuries incurred while practising on a driving range and resulting in time loss per 1000 balls hit on a driving range.

The preferred method for reporting of results depends on the research question and the available data. We recommend to relate competition injuries in golf to the number of holes played, and injuries during practice and training to hours or the specific exposure measures stated in Table 4. For comparison with other sport, golf injuries during competitions should be reported per 1000 rounds (strokes)27 or athlete competition days, and injuries in golf practice and training per total exposure hours of these activities. Illnesses can be best expressed in relation to athletes days, for example, of the competition or the season.

Burden of injuries/illnesses combines frequency and severity.27,15 We suggest using a visual aid such as a risk matrix to help communicate injury burden as described in the 2020 IOC Consensus Statement.27

Study population characteristics
In addition to the basic population characteristics (age, sex, level of competition and disability) listed in the 2020 IOC Consensus Statement,27 handicap (if applicable) and handedness are essential variables to be collected in golf.

The authors recognize the need for classifications and nosology of disability in golf. It is beyond the scope of this consensus to provide these; however, their future introduction would enable accurate and relevant reporting of injury and illness in the disabled golfer. Competitor levels in golf can be described as ‘elite’, ‘sub-elite’ and ‘recreational’ based on the individual golf handicap and participation in different levels of competition (Table 5). Based on the design and objectives of the study, player characteristics should include current and previous injuries/illnesses, any co-morbidities, surgeries, psychosocial variables, and if a touring professional, total travel time per year and the tour membership.

Table 4: Athlete exposure in golf

<table>
<thead>
<tr>
<th>Type of exposure</th>
<th>Definition</th>
<th>Exposure data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competition</td>
<td>Any on-course tournament play (looks like practice round)</td>
<td>Number, days and level of competitions, and holes played</td>
</tr>
<tr>
<td>Golf practice</td>
<td>Off-course practice, such as playing 9 or 18 holes</td>
<td>Hours played and hours</td>
</tr>
<tr>
<td>Golf course (incl. competition)</td>
<td>Player hitting full swings on the range</td>
<td>(per practice sessions and total)</td>
</tr>
<tr>
<td>Driving range</td>
<td>Player practicing on the putting green or short game area</td>
<td>Balls hit and hours</td>
</tr>
<tr>
<td>Putting/short game</td>
<td></td>
<td>(per practice sessions and total)</td>
</tr>
<tr>
<td>Training</td>
<td>Lifting weights or performing aerobic exercise (e.g., on stationary bike)</td>
<td>Hours</td>
</tr>
<tr>
<td>Fitness training</td>
<td>Intermittent flexibility/conditioning exercises</td>
<td>(per session and total)</td>
</tr>
<tr>
<td>Other training activities</td>
<td>Toning, strength, mobility, conditioning exercises</td>
<td>Hours</td>
</tr>
<tr>
<td>Warm-up and cool-down</td>
<td>Any warm-up prior to practice or playing, and/or cool-down</td>
<td>(per session and total)</td>
</tr>
</tbody>
</table>

Forms and data collection methods
Guidelines for data collection methods proposed by the 2020 IOC Consensus Statement27 are generally appropriate for golf. Thus, the two Medical Report of Injuries and Illnesses Forms published with the 2020 IOC Consensus Statement27 were modified for golf (online supplementary appendices 2 and 3) and a related exposure report form (online supplementary appendix 4) was developed. However, the report forms published with the 2020 IOC Consensus Statement27 are for medical staff only and injuries/illnesses that do not receive medical attention might be under-reported. Therefore, a weekly report of health complaints and exposure form for recreational and elite golfers, and a baseline questionnaire were developed in addition (online supplementary appendices 5 and 4).

Daily medical report of injuries and illnesses during a golf tournament
The golf-specific modification of the IOC Championships forms27 to be completed by medical staff is presented in online supplementary appendix 2. It is designed to facilitate standardised recording of the frequency and characteristics of golf-related injuries and illnesses during golf tournaments. It can be used for elite and recreational events, and enables comparison of data with other sport tournaments. Multiple players can be recorded on the one form which should aid in reduction of paperwork. The user should use the relevant codes on page 2 of the form and fill in the appropriate boxes on page 1.

In-season medical report for golf injuries and illnesses
The golf-specific modification of the IOC form for injuries and illnesses during the course of a season27 is presented in online supplementary appendix 3. This form is ideally used as a data collection tool within prospective epidemiological studies following up a group of research participants, where medical staff are available to complete a weekly or otherwise regular medical report on the golfers they look after. This may, for example, be a college/university/national elite squad.

Weekly registration of exposure to golf competition, practice and training
The 2020 IOC Consensus Statement27 does not present an exposure report form, most probably because meaningful exposure measurements vary substantially between sports. Thus, a golf-specific exposure record form is presented in online supplementary appendix 4. This form is designed to measure the exposure.
Consensus statement of a golfer to all activities related to golf and which are deemed to be relevant to load management. Ideally, the information in this form can then be used to correlate load to injury and/or illness.

Weekly self-report of health complaints and exposure to golf
For some elite golfers and the vast majority of sub-elite and recreational golfers, having researchers/medical staff available to conduct weekly monitoring is not practical. Furthermore, most injuries in golf are overuse in nature, 6,10-12,29 and these usually fluctuate in severity of symptoms and impact on practice load and performance. Thus, we developed a report form to be filled in by the athlete regarding health complaints that affect the athlete but might not require medical attention (online supplementary appendix 5). It includes the four questions of the OSTRICH questionnaire on health problems10 to help record and categorise severity of average injuries in golf. We recommend using an electronic questionnaire with logic as described in the online supplementary appendix 5.

Baseline questionnaire for golfers
We developed a comprehensive self-report baseline questionnaire to be used in epidemiological studies regarding injury and illness for golf players of all ages, gender and abilities (online supplementary appendix 6). It covers four main domains including: (1) athlete’s characteristics, (2) golf participation and training characteristics, (3) medical history, and (4) current health status. The questionnaire can be used to correlate these variables with injuries and illness, and short-term or extended depending on the specific objectives of a research project. It is designed for self-report, obviating the need for a medical researcher to be present.

Data capture and electronic monitoring tools
The forms can be either used as paper version or internet-based electronic system. While hand copies of forms have been historically popular, 57 electronic data capture can help avoid duplication of data entry, 58 and has been shown to facilitate high levels of compliance in athletes. 59,60 For individual golf event reports, having both paper-based and electronic solutions available is advantageous; however, researchers should work with what is available to them. For weekly monitoring, electronic data capture, where possible, is recommended.39

CONCLUSION
The international golf consensus should aid the development of prospective, epidemiological studies on injury and illness of male and female golf players of different ages and levels of skills worldwide. It enables consistent reporting and comparison between studies and facilitates the analysis of common factors for injuries and illness in golf, and thus, supports the development of injury/illness prevention programmes. Finally, the presented methods can also be used to evaluate the effects of prevention programmes to support the health of golfers.

Author affiliations
Medical Commission, International Golf Federation, Lausanne, Switzerland
European Tour Golfing Union, UK
Prevention, Health Promotion and Sports Medicine, MSH Medizinisch Schule Hamburg, Hamburg, Germany
Swiss Concussion Centre, Schaffhausen Klinik, Zurich, Switzerland
Swiss Orthopaedics, Royal Infirmary of Edinburgh, Edinburgh, UK
European Tour Performance Institute, European Tour (left), Virgina Water, UK
Research, Schiller Clinic Human Performance Lab, Joch, Zürich, Switzerland
Swiss Sport Physiotherapy Association, Luzern, Switzerland
South Africa/Switzerland, Professional Golf Touring, South Africa
Department of Sport Medicine, Norwegian School of Sport Sciences, Oslo Sports Trauma Research Centre, Oslo, Norway
Norsk Inst. of Public Health, Department of Health Promotion and Development, Bergen, Norway
School of Sport, Rehabilitation and Exercise Sciences, University of Essex, Colchester, UK
Medical New South Wales Institute of Sport, Sydney, New South Wales, Australia
Medical, Professional Golf Association Tour of Australia, Sydney, Melbourne, Australia
Swiss Golf Medical Centre, Zurich, Switzerland
Department of Lower Extremity Orthopaedics, Schaffhausen Clinic, Zurich, Switzerland
FSL/STEC Technologies, Inc, Menlo Park, California, USA
Tyrell Performance Institute, Oxnard, California, USA
Sports Medicine, European Disabled Golf Association, Usheld, UK
Medical Professional Golf Association Tour, Punta Vida Beach, Florida, USA
Medical, United States Golf Association, Far Hills, New Jersey, USA
Golf Biodynamics, Brisbane, Queensland, Australia
Medstar, The KAA, St Andrews, UK
Orthopaedics, Parity Clinic, London, UK
International Golf Federation, Lausanne, Switzerland
Medical and Rehabilitation Centre, Meyba, France
Medical, International Golf Federation, Lausanne, Switzerland
Medical, Ladies Professional Golf Association, Daytona Beach, Florida, USA
School of Physical Therapy, Belmont University, Nashville, Tennessee, USA
Sports Medicine and Science, Lady European Tour, London, UK
Sports and Exercise Medicine, North Hampshire Hospitals NHS Trust, Basingstoke, UK
Spine Unit, Schaffhausen Clinic, Zurich, Switzerland

Twitter: Andrew Murray (GolfConstatment). Benjamin Olsen (Cherian), Roger Hawkes (Dunedin), and Alrik Coswil (DFMBerlAU)

Acknowledgements: We acknowledge the support of the International Golf Federation in helping to plan and to deliver this consensus statement. We also acknowledge Babette Flin for her guidance in the structure and content of the consensus, and Timowa Mvoko, Director of Development at the ABF, for input regarding technical golf definitions within the consensus.

Contributors: This work was commissioned by the International Golf Federation. AM, AB, PEF, and CG formed a working group and reviewed the literature. Further groups involving all authors were formed to look at aspects of the consensus. The working group produced a first draft. All authors reviewed and gave feedback upon each iteration of the consensus, and reviewed the final manuscript and appendices.

Funding: This study was funded by International Golf Federation.

What is already known?
▶ The IOC and other sports have recommended methods for recording and reporting epidemiological data on injury and illness in sport for medical staff.
▶ The IOC’s consensus group called for sport-specific statements that should provide sport-specific recommendations.

What are the new findings?
▶ We present consensus recommendations for epidemiological study on the frequency and characteristics of injuries and illnesses of elite and recreational golfers.
▶ We provide an athlete’s baseline questionnaire, as well as injury, illness and exposure report forms for golfers and their medical support teams.
▶ We can help inform future injury/illness prevention interventions, and are recommended by the International Golf Federation, and the constituent members of its medical and scientific commission.


51
Competition interests. Authors declare no conflict of interest.

Consensus statement

Competing interests. Author declarations are provided in Appendix 1. François Gueguen is a Chief Executive Officer (CEO) and founder of FITTIS; Robert Neil is the CEO and founder of Golf Evolution.

Patient consent for publication. Not required.

Provenance and peer review. Not commissioned; externally peer-reviewed.

Data availability statement. Data are available upon request.

Open access. This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made are indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/. ORCID iDs

Stephen Murray http://orcid.org/0000-0003-3217-8028

Jeremy Clavens http://orcid.org/0000-0003-5743-1698

In Derek http://orcid.org/0000-0002-2178-2306

REFERENCES


**Appendix 1: Professional background and expertise of working and consensus group members**

<table>
<thead>
<tr>
<th>Initials</th>
<th>Country</th>
<th>Profession</th>
<th>Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM*</td>
<td>UK</td>
<td>Sports medicine physician</td>
<td>IGF medical commission member European Tour Chief Medical Officer Lead author International Consensus Golf and Health</td>
</tr>
<tr>
<td>JD*</td>
<td>Switzerland</td>
<td>Neurologist</td>
<td>Former FIFA Chief Medical Officer Consultant at Department of Neurology, Spine Unit, Schulthess Clinic, Zurich, Switzerland Co-author of the IOC injury/ illness consensus</td>
</tr>
<tr>
<td>AJ*</td>
<td>Germany</td>
<td>Psychologist</td>
<td>Epidemiology and prevention of sports injury Led and published several injury and illness studies in different international tournaments in different sports. Co-author of 6 previous consensus statements</td>
</tr>
<tr>
<td>PR*</td>
<td>UK</td>
<td>Orthopaedic Surgeon</td>
<td>Lead author of first systematic review on injuries in professional golfers</td>
</tr>
<tr>
<td>MB</td>
<td>Switzerland</td>
<td>Sports physiotherapist</td>
<td>Research associate at Schulthess Clinic, Zurich, Switzerland Co-author of multiple sports injury prevention programmes</td>
</tr>
<tr>
<td>AB</td>
<td>South Africa/ Switzerland</td>
<td>Golfer</td>
<td>Professional golfer currently competing on StaySure Tour with victories on European Tour, Challenge Tour and Senior Tour</td>
</tr>
<tr>
<td>BC</td>
<td>Norway</td>
<td>Physiotherapist</td>
<td>Lead author of the The Oslo Sports Trauma Research Center questionnaire on health problems Co-author of the IOC injury/ illness consensus and the tennis (2020), athletics and aquatics consensuses.</td>
</tr>
<tr>
<td>DC</td>
<td>UK</td>
<td>Strength and conditioning coach</td>
<td>Head of Strength and Conditioning for the European Tour PhD in physical preparation for golf</td>
</tr>
<tr>
<td>CC</td>
<td>Australia</td>
<td>Sports medicine physician</td>
<td>Chief Medical Officer PGA of Australasia</td>
</tr>
<tr>
<td>TD</td>
<td>Switzerland</td>
<td>Orthopaedic surgeon</td>
<td>Head of Swiss Golf Medical Center, Schulthess Clinic, Zurich, Switzerland</td>
</tr>
<tr>
<td>FG</td>
<td>USA</td>
<td>Entrepreneur</td>
<td>Founder and Chief Executive Officer FITSTATS Technology and data management expert</td>
</tr>
<tr>
<td>LG</td>
<td>USA</td>
<td>Athletic trainer certified</td>
<td>Co-director of Titleist Performance Institute Fitness Advisory Board</td>
</tr>
<tr>
<td>RH</td>
<td>UK</td>
<td>Sports medicine physician</td>
<td>IGF medical commission member Executive director of Golf and Health at World Golf Foundation</td>
</tr>
<tr>
<td>Name</td>
<td>Country</td>
<td>Occupation</td>
<td>Additional Information</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>TH</td>
<td>USA</td>
<td>Sports medicine physician</td>
<td>European Disabled Golf Association Chief Medical Officer, IGF medical commission member, Medical Director United States Golf Association, Medical Director PGA Tour</td>
</tr>
<tr>
<td>RN</td>
<td>Australia</td>
<td>Entrepreneur</td>
<td>Founder and Chief Executive Officer Golf BioDynamics, Technology and data management expert</td>
</tr>
<tr>
<td>JL</td>
<td>UK</td>
<td>Orthopaedic surgeon</td>
<td>IGF medical commission member (R&amp;A representative)</td>
</tr>
<tr>
<td>AS</td>
<td>USA</td>
<td>Executive director</td>
<td>IGF medical commission member, IGF Executive director</td>
</tr>
<tr>
<td>PS</td>
<td>France</td>
<td>Sports medicine physician</td>
<td>IGF Chief Medical Officer, Former IOC Medical and Scientific Director</td>
</tr>
<tr>
<td>BT</td>
<td>USA</td>
<td>Sports medicine physician</td>
<td>IGF medical commission member, Ladies PGA Chief Medical Officer</td>
</tr>
<tr>
<td>MV</td>
<td>USA</td>
<td>Physical therapist</td>
<td>Professor at Belmont University School of Physical Therapy, Director of Sports Medicine at the Nashville Hip Institute</td>
</tr>
<tr>
<td>MW</td>
<td>UK</td>
<td>Sports medicine physician</td>
<td>IGF medical commission member, Ladies European Tour Chief Medical Officer</td>
</tr>
</tbody>
</table>

*working group; IGF; International Golf Federation, USGA, United States Golf Association; IOC; International Olympic Committee; PGA, Professional Golf Association; LPGA, Ladies Professional Golf Association; LET, Ladies European Tour*
Appendix 2. Daily Medical Report of Injury and Illness during a Golf Tournament

Daily Medical Report of Injury and Illness During a Golf Tournament

<table>
<thead>
<tr>
<th>Country:</th>
<th>Date of report:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Form completed by: Name: Contact details:

Please report: (1) All sport injuries and (2) all illnesses of your athletes newly incurred, recurrent or an exacerbation of an underlying stable injury/illness during the name of the championship regardless of the consequences with respect to absence from competition or training. The information provided will be treated strictly confidential.

1. Injury – Example

<table>
<thead>
<tr>
<th>age</th>
<th>gender</th>
<th>date of injury</th>
<th>competition / training</th>
<th>code</th>
<th>onset code</th>
<th>new code</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>male</td>
<td>21 July</td>
<td>competition</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Injury mechanism</th>
<th>code</th>
<th>injured body region</th>
<th>code</th>
<th>injury type</th>
<th>code</th>
<th>time-loss</th>
<th>duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>slipped and fall</td>
<td>5</td>
<td>ankle</td>
<td>17</td>
<td>sprain</td>
<td>19</td>
<td>no/yes</td>
<td>28 days</td>
</tr>
</tbody>
</table>

2. Illness – Example

<table>
<thead>
<tr>
<th>age</th>
<th>gender</th>
<th>date of onset</th>
<th>onset code</th>
<th>organ system / region code</th>
<th>cause</th>
<th>new, recurrent or exacerbation code</th>
<th>time-loss</th>
<th>duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>male</td>
<td>24th July</td>
<td>2</td>
<td>respiratory system 13</td>
<td>code 3</td>
<td>new, recurrent or exacerbation code 1</td>
<td>no/yes</td>
<td>2 days</td>
</tr>
</tbody>
</table>

If space is not sufficient to report all injuries or illnesses, please use additional forms.

☐ no new injury or illness in any athlete of our team today
### Definitions and codes

**For injuries** (defined as tissue damage or other derangement of normal physical function due to participation in sports, resulting from rapid or repetitive transfer of kinetic energy)

<table>
<thead>
<tr>
<th>Competition or training</th>
<th>Mode of onset</th>
<th>Injury mechanism</th>
<th>Injured body region</th>
<th>Injury type</th>
<th>For illnesses (defined as a complaint or disorder not related to injury)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 golf competition</td>
<td>1 sudden</td>
<td>1 no identifiable single event</td>
<td>1 head</td>
<td>1 concussion / brain injury</td>
<td>Mode of onset</td>
</tr>
<tr>
<td>2 golf course (excl. competitions)</td>
<td>sudden but no acute trauma</td>
<td>2 acute non-contact trauma</td>
<td>2 neck / cervical spine</td>
<td>2 spinal cord injury</td>
<td>2 gradual</td>
</tr>
<tr>
<td>3 driving range</td>
<td>2 sudden</td>
<td>3 direct contact with an object</td>
<td>3 chest (incl. chest organs)</td>
<td>3 peripheral nerve injury</td>
<td>3 mixed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 direct contact with ground (e.g. fall)</td>
<td>4 thoracic spine / upper back</td>
<td>4 bone fracture</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 indirect contact with an object</td>
<td>5 lumbar-sacral spine / buttock</td>
<td>5 bone stress injury</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 indirect contact with ground</td>
<td>6 abdomen (incl. abdominal organs)</td>
<td>6 bone contusion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 shoulder</td>
<td>7 avascular necrosis</td>
<td>7 physes injury</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 upper arm</td>
<td>8 physeal injury</td>
<td>8 cartilage injury</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 elbow</td>
<td>9 retinopathy</td>
<td>9 abcession</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 forearm</td>
<td>10 joint sprain / ligament tear</td>
<td>10 laceration</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 elbow</td>
<td>11 chronic instability</td>
<td>11 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 hand</td>
<td>12 tendon rupture</td>
<td>12 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 hip / groin</td>
<td>13 tarsalopathy</td>
<td>13 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>14 elbow</td>
<td>14 muscle strain / rupture / tear</td>
<td>14 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 foot</td>
<td>15 muscle contusion</td>
<td>15 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 lower leg / Achilles tendon</td>
<td>16 muscle compartment syndrome</td>
<td>16 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>17 ankle</td>
<td>17 infection</td>
<td>17 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 foot</td>
<td>18 neurological</td>
<td>18 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>19 osteological</td>
<td>19 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20 respiratory</td>
<td>20 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>21 dermatological</td>
<td>21 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>22 musculoskeletal</td>
<td>22 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>23 endocrinological</td>
<td>23 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24 gastrointestinal</td>
<td>24 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25 allergic</td>
<td>25 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>26 environmental - exercise-related</td>
<td>26 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>27 environmental - non-exercise</td>
<td>27 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28 immunological/inflammatory</td>
<td>28 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>29 metabolic/nutritional</td>
<td>29 contusion / bruise (superficial)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30 thrombotic/hemorrhagic</td>
<td>30 contusion / bruise (superficial)</td>
<td></td>
</tr>
</tbody>
</table>

**For injuries and illnesses**

- **New, recurrent or exacerbation**
  - 1 newly incurred during the tournament
  - 2 recurrent after full recovery and return-to-sport
  - 3 exacerbation of a stable (not recovered) condition
  - 4 unknown, or not specified

**Time-loss in sport due to injury or illness**

- **No** - athlete continues to train or compete, even if not at usual level (duration, intensity, performance)
- **Yes** - athlete did not finish the training or competition when the problem occurred OR could not participate in sport later

**Duration of impaired participation/ limited performance in sport due to injury or illness (in days)**

Please provide an estimate of the number of days that the athlete will not be able to undertake his/her normal training or will not be able to compete as usual, counting the day after the onset of the injury/illness as day 1.

If an athlete is not expected to return to sport after the injury or illness, please state the reason: F=fatality, P=permanent disability, OR=reasons.
## Appendix 3. In-Season Medical Report Form for Golf Injuries and Illnesses

**In-Season Medical Report for Golf Injuries or Illnesses**

<table>
<thead>
<tr>
<th>Team:</th>
<th>Athlete Identification:</th>
<th>Date of report:</th>
<th>Date of onset:</th>
</tr>
</thead>
</table>

### For Injury

<table>
<thead>
<tr>
<th><strong>Competition or training</strong></th>
<th><strong>Mode of onset</strong></th>
<th><strong>Injury mechanism</strong></th>
<th><strong>Injured body region / side</strong></th>
<th><strong>Injury type</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>golf competition</td>
<td>sudden after acute trauma</td>
<td>no identifiable single event</td>
<td>left / right</td>
<td>concussion / brain injury</td>
</tr>
<tr>
<td>golf course (excl. competitions)</td>
<td>sudden but no acute trauma</td>
<td>indirect contact with an object</td>
<td>left / right</td>
<td>spinal cord injury</td>
</tr>
<tr>
<td>driving range</td>
<td>gradual</td>
<td>direct contact with an object</td>
<td>left / right</td>
<td>peripheral nerve injury</td>
</tr>
<tr>
<td>other training activities for golf</td>
<td>mixed</td>
<td>indirect contact with an object</td>
<td>left / right</td>
<td>bone fracture</td>
</tr>
</tbody>
</table>

### For Illness

<table>
<thead>
<tr>
<th><strong>Mode of onset</strong></th>
<th><strong>Organ system</strong></th>
<th><strong>Aetiology</strong></th>
<th><strong>For injury and illness</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>sudden</td>
<td>cardiovascular</td>
<td>allergic</td>
<td>new, recurrent or exacerbation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>environmental - exercise-related</td>
<td>new</td>
</tr>
<tr>
<td></td>
<td></td>
<td>environmental - non-exercise</td>
<td>recurrent after full recovery and return-to-sport</td>
</tr>
<tr>
<td></td>
<td></td>
<td>immunological / inflammatory</td>
<td>exacerbation of a stable (not recovered) condition</td>
</tr>
</tbody>
</table>

### Time-loss in sport due to injury / illness

<table>
<thead>
<tr>
<th><strong>Date of full return to normal training and competition</strong> (dd/mm/yyyy)</th>
</tr>
</thead>
</table>

**No return to sport possible:**
- fatality
- permanent disability
- other reasons
Appendix 4. Weekly Registration of Exposure to Golf Competition, Practice and Training

**Weekly Registration of Exposure to Golf Competition, Practice and Training**  
(to be completed by trainer, coach or athlete)

<table>
<thead>
<tr>
<th>Player:</th>
<th>Week:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>competition</strong></td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
</tr>
<tr>
<td><strong>golf course (excl. competitions)</strong></td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
<td>holes</td>
</tr>
<tr>
<td><strong>driving range</strong></td>
<td>balls hit</td>
<td>balls hit</td>
<td>balls hit</td>
<td>balls hit</td>
<td>balls hit</td>
<td>balls hit</td>
<td>balls hit</td>
</tr>
<tr>
<td><strong>putting / short game</strong></td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
</tr>
<tr>
<td><strong>fitness training for golf</strong></td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
</tr>
<tr>
<td><strong>other training incl. warm-up</strong></td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
<td>hours</td>
</tr>
</tbody>
</table>
Appendix 5. Weekly self-report of health complaints and exposure to golf

**Weekly Self-Report of Health Complaints and Exposure to Golf**

**Athlete identification:** ________________________________ **Date of report:** __________________

1. Have you played a golf competition in the last 7 days?
   - [ ] no
   - [ ] yes, please state how many competitive rounds have you played in golf tournaments in the last 7 days
     - international __________
     - national __________
     - regional __________
     - within my golf club / college / university __________

2. Have you played a golf course, or practiced or trained for golf in the last 7 days?
   - [ ] no
   - [ ] yes, please state on how many days and how many holes/balls/hours in total:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Days</th>
<th>Total in the last 7 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>golf course (excl. competitions)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>driving range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>putting / short game</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fitness training for golf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>others, please specify</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Have you had any difficulties participating in normal training, practice or competition due to injury, illness or other health problems during the past 7 days?
   - [ ] full participation without health problems
   - [ ] full participation, but with a health problem
   - [ ] reduced participation due to a health problem
   - [ ] could not participate due to a health problem (please go to question 6)
   - [ ] did not train, practice or compete due to other reasons (e.g. holidays) (go to Q6)

4. To what extent have you modified your training, practice or competition due to injury, illness or other health problems during the last 7 days?
   - [ ] no modification
   - [ ] to a minor extent
   - [ ] to a moderate extent
   - [ ] to a major extent

5. To what extent has injury, illness or other health problems affected your performance during the past 7 days?
   - [ ] no effect
   - [ ] to a minor extent
   - [ ] to a moderate extent
   - [ ] to a major extent

6. To what extent have you experienced symptoms/health complaints (e.g. pain, coughing, fever) during the past 7 days?
   - [ ] no symptoms/health complaints (if Q4, Q5 and Q6 "no", please go to "Thank you!")
   - [ ] to a minor extent
   - [ ] to a moderate extent
   - [ ] to a severe extent
7. Have you reported your current health problems last week?  
- [ ] no, I have a new health problem or a recurrent one after full recovery and return-to-sport  
- [ ] yes, I have already reported all my health problems last week (please go to question 34)  
- [ ] I have both a new health problem AND one already reported (please go to Q34)  

8. Is your health problem an injury or by an illness?  
- [ ] injury (acute or overuse)  
- [ ] illness or health complaints, such as headache, muscle cramps, or sleep problems (go to Q24)  
- [ ] both, injury AND illness or other health complaints  
- [ ] don’t know (please go to question 24)  

**Injury**  

9. Please state the day when your injury occurred or exacerbated: _____dd/mm/yy  

10. What were you doing when the injury occurred or exacerbated?  
- [ ] golf competition  
- [ ] golf course (excl. competitions)  
- [ ] driving range  
- [ ] putting / short game  
- [ ] fitness training for golf  
- [ ] warm-up or cool-down for golf or similar  
- [ ] other training activities for golf  
- [ ] not related to golf (please go to question 23)  
- [ ] unknown, or not specified (e.g. gradual onset)  

11. Is your injury new, recurrent or an exacerbation?  
- [ ] new  
- [ ] recurrent after full recovery and return-to-sport  
- [ ] exacerbation of a stable (not recovered) condition  
- [ ] don’t know  

12. How did your injury start?  
- [ ] sudden after acute trauma  
- [ ] gradual  
- [ ] sudden but no acute trauma  
- [ ] mixed  

13. How did your injury happen?  
- [ ] no identifiable single event  
- [ ] single event without contact (e.g. pain in the low back while making a swing without hitting anything other than the ball)  
- [ ] direct contact with an object (e.g. hit by another player’s golf ball)  
- [ ] direct contact ground (e.g. stumble and fall)  
- [ ] indirect contact with an object (e.g. hitting tree root with club while hitting shot)  
- [ ] indirect contact with ground (e.g. hitting the ground with club while taking shot/ divot)  

14. What body part was/is injured?  
*If more than one body part was injured, please tick the most severely injured body part first*  
- [ ] head  
- [ ] neck / cervical spine  
- [ ] chest (incl. chest organs)  
- [ ] thoracic spine / upper back  
- [ ] lumbo-sacral spine / buttock  
- [ ] abdomen (incl. abdominal organs)  
- [ ] shoulder  
- [ ] upper arm  
- [ ] elbow  
- [ ] forearm  
- [ ] wrist  
- [ ] hand  
- [ ] hip / groin  
- [ ] thigh  
- [ ] knee  
- [ ] lower leg / Achilles tendon  
- [ ] ankle  
- [ ] not applicable  

15. Which body side was/is injured? (except for head, neck, chest, spine, abdomen)  
- [ ] right  
- [ ] left  
- [ ] not applicable
16. What was/is the type of your injury?
☐ don’t know (go to question 17)
☐ bone fracture
☐ muscle strain / rupture / tear
☐ tendon rupture
☐ joint sprain / ligament tear
☐ meniscus or cartilage injury
☐ contusion / bruise
☐ abrasion / laceration / cut
☐ tendinosis / tendinopathy
☐ joint arthritis
☐ bursitis / synovitis
☐ concussion / brain injury
☐ nerve / spinal cord injury
☐ internal organ trauma
☐ dental injury
☐ other, please specify ______

17. Was this diagnosis made by a qualified medical person?
☐ no
☐ yes

18. Was an additional body part injured during this injury event?
☐ no
☐ yes (please go to question 14)

19. Did you see a physician, physiotherapist or another qualified medical person because of this injury?
☐ no
☐ yes, physician
☐ yes, physiotherapist
☐ yes, other qualified medical person

20. How was/is this injury treated?
☐ no treatment
☐ rest only
☐ self medication / self treatment
☐ massage, warm, cold or passive physiotherapy
☐ exercise therapy by a physiotherapist
☐ other therapy by qualified medical person

21. On how many of the last 7 days, would you have been completely unable to train, practice or compete due to this injury? (please consider all 7 days, even if no training, practice or competition was planned)

_____ days of the last 7 days (if 7, go question 23)

22. On how many of the last 7 days, did you have to modify or reduce your normal training, practise or competition due to this injury? (please consider all 7 days, even if no training, practice or competition was planned)

_____ days of the last 7 days

23. Did you have another injury, illness or health problem during the last 7 days?
☐ no (please go to “Thank you!”)
☐ yes, another injury (please go to Q9)
☐ yes, an illness or health complaints, such as headache, muscle cramps, or sleep problems (please go to question 24)
Non-injury related health problems (illness or unspecific health complaints)

24. Please state the day when your health problem occurred or exacerbated: ___dd/mm/yy

25. Is your health complaint new, recurrent or an exacerbation?
☐ new
☐ recurrent after full recovery and return-to-sport
☐ exacerbation of a stable (not recovered) condition
☐ unknown, or not specified

26. How did your health problem start?
☐ sudden
☐ gradual
☐ mixed

27. What kind of complaints or symptoms do/did you have?
☐ headache
☐ fever
☐ sleep problems
☐ muscle cramps
☐ symptoms of hay fever
☐ anxiety, depression, sadness
☐ abdominal / menstrual pain
☐ blocked / running nose
☐ nausea, vomiting
☐ sore throat
☐ wheeze, cough
☐ diarroea
☐ pain in other body parts
☐ others, please specify

28. Did you see a physician or another qualified medical person because of your complaints?
☐ no
☐ yes, general practitioner
☐ yes, medical specialist
☐ yes, other qualified medical person

29. Did a qualified medical person provide a diagnosis of your health problem?
☐ no
☐ yes, please specify

30. How was/is your health problem treated?
☐ no treatment
☐ self medication / self treatment
☐ rest only
☐ therapy by qualified medical person

31. On how many of the last 7 days, would you have been completely unable to train, practice or compete due to this health problem? (please consider all 7 days, even if no training, practice or competition was planned)

___ days of the last 7 days (if 7, go question 33)

32. On how many of the last 7 days, did you have to modify or reduce your normal training, practice or competition due to this health problem? (please consider all 7 days, even if no training, practice or competition was planned)

___ days of the last 7 days

33. Did you have another health problem during the last 7 days?
☐ no
☐ yes (please go to question 24 non-injury related health problem)

Thank you for taking the time to fill in the questionnaire!
Previously reported health problems

34. **When** did you report your health problem first? ________________________

35. Is your health problem a **golf-related injury** or an **illness** or an unspecified health problem?
   - ☐ golf-related injury
   - ☐ illness or health complaints (go to question 44)
   - ☐ both
   - ☐ injury not related to golf (Thank you!)
   - ☐ don’t know (go to question 44)

Previously reported golf-related injury

36. Have the **complaints** caused by your injury **changed**?
   - ☐ improved
   - ☐ unchanged
   - ☐ worsened

37. Did you see a **physician, physiotherapist or another qualified medical person** because of this injury in the last 7 days?
   - ☐ no
   - ☐ yes, physiotherapist
   - ☐ yes, physician
   - ☐ yes, other qualified medical person

38. Did a **qualified medical person** provide a **diagnosis** for your injury?
   - ☐ no
   - ☐ bone fracture
   - ☐ muscle strain / rupture / tear
   - ☐ tendon rupture
   - ☐ joint sprain / ligament tear
   - ☐ meniscus or cartilage injury
   - ☐ contusion / bruise
   - ☐ abrasion / laceration / cut
   - ☐ tendinosis / tendinopathy
   - ☐ joint arthritis
   - ☐ bursitis / synovitis
   - ☐ concussion / brain injury
   - ☐ nerve / spinal cord injury
   - ☐ internal organ trauma
   - ☐ dental injury
   - ☐ other, please specify _____

39. How was/is this injury **treated** in the last 7 days?
   - ☐ no treatment
   - ☐ rest only
   - ☐ self medication / self treatment
   - ☐ massage, warm, cold or passive physiotherapy
   - ☐ exercise therapy by a physiotherapist
   - ☐ other therapy by qualified medical person

40. On **how many of the last 7 days**, would you have been **completely unable to train, practice or compete** due to this injury? *(please consider all 7 days, even if no training, practice or competition was planned)*
   
   _____ days of the last 7 days (if 7, go question 42)

41. On **how many of the last 7 days**, did you have to **modify or reduce your normal training, practice or competition** due to this injury? *(please consider all 7 days, even if no training, practice or competition was planned)*

   _____ days of the last 7 days

42. Did you have **another health problem** during the last 7 days?
   - ☐ no (go to Thank you!)
   - ☐ yes, an injury already reported (please go to question 36)
   - ☐ yes, a new injury (please go to question 9)
   - ☐ yes, an illness or unspecified health complaint already reported (please go to next page)
   - ☐ yes, a new illness or unspecified health complaint (please go to question 24)
Previously reported non-injury related health problems (illness or unspecific health complaints)

44. Have the complaints caused by your health problem changed?
   □ improved □ unchanged □ worsened

45. What kind of complaints or symptoms do/did you have in the last 7 days?
   □ headache
   □ muscle cramps
   □ abdominal / menstrual pain
   □ sore throat
   □ pain in other body parts
   □ fever
   □ symptoms of hay fever
   □ blocked / running nose
   □ wheeze, cough
   □ others, please specify
   □ sleep problems
   □ anxiety, depression, sadness
   □ nausea, vomiting
   □ diarrhoeas

46. Did you see a physician or another qualified medical person because of your complaints in the last 7 days?
   □ no
   □ yes, general practitioner
   □ yes, medical specialist
   □ yes, other qualified medical person

47. Did a qualified medical person provide a diagnosis of your health problem?
   □ no
   □ yes, please specify

48. How was/is your health problem treated in the last 7 days?
   □ no treatment
   □ self medication / self treatment
   □ rest only
   □ therapy by qualified medical person

49. On how many of the last 7 days, would you have been unable to train, practice or compete due to this health problem? (please consider all 7 days, even if no training, practice or competition was planned)
   ____ days of the last 7 days (if 7, go question 51)

50. On how many of the last 7 days, did you have to modify or reduce your normal training, practice or competition due to this health problem? (please consider all 7 days, even if no training, practice or competition was planned)
   ____ days of the last 7 days

51. Did you have another health problem during the last 7 days?
   □ no (go to Thank you!)
   □ yes, an illness or unspecific health complaint already reported (please go to question 44)
   □ yes, a new illness or unspecific health complaint (please go to question 24)
   
   Thank you for your participation

End.
**Appendix 6. Golf Baseline Questionnaire**

- **The first questions relate to you.**

1. What is your gender?
   - male
   - female
   - diverse

2. How old are you? __________ years

3. In which country do you live and train? ____________________________

4. What is your highest level of education or professional training?
   - no qualifications
   - primary school
   - secondary school
   - high school
   - professional training / apprenticeship
   - college / university

5. What do you do in your everyday life? *(Please tick all answers that apply)*
   - work, _____ hours per week
   - military service
   - elite sport
   - school / university / college
   - vocational training
   - household with children or family members
   - household without children or family members
   - hobbies
   - other, please specify ____________________________

- **The next questions relate to your sport.**

6. At what age did you start playing golf? __________ years

7. Are you right or left handed?
   - in general
   - when I play golf
   - right handed
   - left handed

8. What is your current golfing handicap? ____________________________

9. At which level of golf do you currently compete?
   - elite (professional players competing on tour or amateurs competing in international/national amateur championships)
   - sub-elite (PGA teaching professionals, amateurs competing in regional/county/state tournaments or with handicap 5 or less)
   - recreational (handicap more than 5)
   - I have never participated in any golf competition (please to Q11)
10. How many golf competitions have you played in the last 12 months?

- international
- national
- regional
- within my golf club / college / university

11. How much have you trained for golf on average in the last 12 months?
Please state how many days and how many holes/balls/hours in total per week.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Days per week</th>
<th>Total per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golf course (excl. competitions)</td>
<td>days per week</td>
<td>holes played per week</td>
</tr>
<tr>
<td>Driving range</td>
<td>days per week</td>
<td>balls hit per week</td>
</tr>
<tr>
<td>Putting/short game</td>
<td>days per week</td>
<td>hours per week</td>
</tr>
<tr>
<td>Fitness training for golf</td>
<td>days per week</td>
<td>hours per week</td>
</tr>
<tr>
<td>Others, please specify</td>
<td>days per week</td>
<td>hours per week</td>
</tr>
</tbody>
</table>

12. Which of the following activities do you include in your physical fitness training for golf?

- [ ] I don't practise a specific fitness training for golf
- [ ] heavy load low volume resistance training (e.g. 3x3 back squats at 85%)
- [ ] low load/high volume resistance training (e.g. 3x10-15 lunges)
- [ ] weighted explosive training (e.g. weighted jump squats/medicine ball throws)
- [ ] body weight explosive work (e.g. box jumps/explosive press ups)
- [ ] resistance band exercises (e.g. crab walks)
- [ ] aerobic exercise (e.g. running/cycling/swimming)
- [ ] proprioception (e.g. balance/coordination)
- [ ] mobility (range of motion exercise/stretching)
- [ ] others, please specify

13. Are you currently working on a technical change in your golf swing?

- [ ] no
- [ ] yes

14. How often do you practise on golf mats?

- [ ] never
- [ ] rarely
- [ ] sometimes
- [ ] often
- [ ] always

15. Are you doing any specific injury prevention exercises or programmes?

- [ ] no
- [ ] yes, please specify for which body parts
  - neck
  - mid back
  - low back
  - shoulder
  - elbow
  - wrist
  - hip
  - thigh
  - knee
  - ankle

16. How often do you warm up before the following activities?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>Playing golf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driving range, putting/short game</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fitness training</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
17. Which kind of exercises do you include in your golf warm-up?
- never warm-up
- working through the clubs/pre-round golf practice
- explosive or strength exercises (e.g. weighted squats/jump squats)
- bodyweight resistance exercises (e.g. squats)
- resistance band exercises (e.g. crab walks)
- aerobic exercise (e.g. running/cycling/swimming)
- proprioception (e.g. balance/coordination)
- mobility (range of motion exercise/stretching)

18. Which other type(s) of sports do you practice on a regular basis?
- no other sport than golf
- general fitness training (e.g. gym)
- logging
- biking
- soccer
- tennis
- ski / snowboarding
- other, please specify

19. How often and many hours per week did you practice the other sport(s) on average in the last 12 months?
- regularly, ______ times per week, in total ________ hours per week
- irregularly, on average ______ times per week, in total between ______ and ______ hours per week

The following questions refer to your current complaints.

20. Do you currently have complaints, illnesses or injuries that prevent you training or playing golf as usual?
- no
- yes
What is the diagnosis? ________________________________

How long have you had these complaints? ___ days / ____ weeks

How long overall do you think you will be unable to carry out your daily activities in everyday life and/or at work as usual or to train and play golf as usual due to these problems?

___ days / ____ weeks

21. Overall, how severe were your pain / complaints in the last 7 days?
- no pain/complaints
- mild
- moderate
- severe
- very severe
22. How severe have your pains / complaints in the following body regions been in the last 7 days in everyday life and during / after training or playing golf?

(0= no complaints to 10= worst imaginable complaints)

<table>
<thead>
<tr>
<th></th>
<th>no</th>
<th>worst imaginable</th>
</tr>
</thead>
<tbody>
<tr>
<td>headache</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>neck (cervical)</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>upper back (thoracic)</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>lower back (lumbar)</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>right shoulder</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>left shoulder</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>right elbow</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>left elbow</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>right hand / wrist</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>left hand / wrist</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>right knee</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>left knee</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>right hip</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>left hip</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>other body parts, which?</td>
<td>in everyday life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>training or playing golf</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
</tbody>
</table>
Player-No.________________

The last questions refer to your medical history.

23. Please state your **body height** and **weight**: _____ cm _____ kg

24. Do you have any **disability**?
   - [ ] no
   - [ ] yes, please specify

25. Have you ever had an **injury** that prevented you training or playing **golf as usually** for more than four weeks?
   - [ ] no
   - [ ] yes, please indicate the date of injury, the diagnosis and how long you had complaints.

<table>
<thead>
<tr>
<th>when (month / year)</th>
<th>diagnosis</th>
<th>duration of complaints (in days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

26. Do you have **recurring complaints** that prevent you from training or playing **golf as usual**?
   - [ ] no
   - [ ] yes, please specify how often, type of complaints, and average duration of complaints

<table>
<thead>
<tr>
<th>how often</th>
<th>type of complaints</th>
<th>duration (in days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
27. Have you ever been diagnosed with and/or treated for arthrosis / osteoarthritis?  
☐ no  ☐ yes, please specify for which body parts:

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand/Finger joints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar spine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracic spine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical spine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others, please specify</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

28. Have you ever been diagnosed with and/or treated for the following illnesses or complaints?  

<table>
<thead>
<tr>
<th>Illness</th>
<th>No</th>
<th>Yes, Previously</th>
<th>Yes, Currently</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rheumatism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High blood pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression, anxiety, burnout or similar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others, please specify</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

29. Have you ever had any surgery upon your musculo-skeletal system (incl. bones, joints, muscles, tendon, fascia)?  

☐ no

<table>
<thead>
<tr>
<th>Body Part</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical spine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracic spine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar spine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others, please specify</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please provide details on all operations upon your musculo-skeletal system:

<table>
<thead>
<tr>
<th>When (month / year)</th>
<th>Diagnosis / Type of Operation</th>
<th>Duration until Full Recovery (in days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
30. How often have you taken the following medications in the last 12 months?

<table>
<thead>
<tr>
<th></th>
<th>(almost) daily</th>
<th>2-3 times per week</th>
<th>2-4 times per month</th>
<th>≤ 1x per months</th>
<th>never</th>
</tr>
</thead>
<tbody>
<tr>
<td>pain killers (e.g. Aspirin, ibuprofen)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>cortisone (pills / injections)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>medication for stress, anxiety, depression</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>other medication, please specify</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

31. On average, how many hours do you sleep per night?
☐ ≤6 hours ☐ 7 hours ☐ 8 hours ☐ 9 hours ☐ >9 hours

32. Have there been any special events during the past 12 months that have altered your life or that have affected you (such as relocation, marriage, death, or illness among your close family or friends, separation, difficulties / problems in the club / team)?
☐ no
☐ yes, please specify

33. Would you like to add anything to the questionnaire?

Thank you for completing the questionnaire!
2.3 Study 3: Public health considerations regarding golf during the COVID-19 pandemic: a narrative review


2.3.1 Aims and objectives

The COVID-19 pandemic had an enormous effect on the ability for recreational and professional sports to continue. Due to legal requirements for social distancing many sports, particularly involving physical contact or those played indoors were prohibited. Such interventions lead to an overall reduction in physical activity during the pandemic, particularly during periods of lockdown. Golf was in a position where it is played outdoors, where social distancing is possible. The aim of this narrative review was to explore and synthesise the current literature on the safety of playing golf during the COVID-19 pandemic and the potential benefits of such activity in both recreational and professional golfers. The objectives were to select several key health topics relevant to golf during the COVID-19 pandemic and expand on the key scientific messages within each domain.

2.3.2 Methodology

Narrative reviews typically choose a topic of importance, review the literature and give a viewpoint from the authors. They are classically not systematic in their approach. We chose this method of review given the variety of literature we were hoping to cover and the broad and emerging nature of the topic area.
This approach was discussed and agreed with senior policy officials who included the chair of the All-Party Parliamentary Group for Golf (Craig Tracey MP) and the principal advisor to the home nations Chief Medical Officers on physical activity (Prof. Charlie Foster). Covering the breadth of public health considerations for playing golf during the COVID-19 leant itself to a wider approach using a narrative review. An appropriate alternative approach that we could have applied would have been a scoping review which has previously been performed successfully in the field of golf and health.79

Having high level expertise in the co-authoring of this study, given the subjectivity of the methodology, was crucial. Prof. Charlie Foster is the Head of the Centre for Exercise, Nutrition and Health Sciences at the University of Bristol and additional to his role with the Chief Medical Officers he is a policy advisor on physical activity, sport and travel to the Department of Health and Social Care, UK Government. In addition, senior author Prof. Andrew Murray is a sports and exercise medicine consultant, chief medical and scientific officer for the European Tour Group and the most cited clinical researcher in the field of golf medicine. We therefore believed we had the correct clinical and academical expertise to undertake a balanced view of the subject.

Although not included in the published manuscript, the search of relevant research in the area of public health considerations while playing golf during the COVID-19 were performed via a search of PubMed using the following search terms:
Strategy 1

("sport s"[All Fields] OR "sports"[MeSH Terms] OR "sports"[All Fields] OR "sport"[All Fields] OR "sporting"[All Fields]) AND ("sars cov 2"[MeSH Terms] OR "sars cov 2"[All Fields] OR "covid"[All Fields] OR "covid 19"[MeSH Terms] OR "covid 19"[All Fields])

Strategy 2

("golf"[MeSH Terms] OR "golf"[All Fields]) AND ("health"[MeSH Terms] OR "health"[All Fields] OR "health s"[All Fields] OR "healthful"[All Fields] OR "healthfulness"[All Fields] OR "healths"[All Fields])

2.3.3 Results
The themes of the review were characterised into:

1. Golf and physical and mental health
2. Immune function
3. Benefits
4. COVID-19 transmission during golf
5. Mitigating risks
Some of the key findings from the review included highlighting the physical and mental health benefits of golf including reducing risk factors for cardiovascular disease and associations with physical activity improved immune system with specific defence against respiratory disease.\textsuperscript{80,81} Regarding mental health, we reported one study which demonstrated increased belonging, enjoyment and well-being amongst players when courses reopened for play.\textsuperscript{22} It was important to comment on the likely risk of transmission of COVID-19 while playing golf. There was limited research at this stage of the pandemic on transmission rates in sport. However, Jones \textit{et al} reported that transmission rates in elite rugby performed outdoors was very low\textsuperscript{82} while another study of elite football reported transmission rate highest in indoor spaces without social distancing.\textsuperscript{83} Transmission risk was low outdoors even if social distancing was not implemented. These findings mirror previous studies who reported outdoor environments had lower transmission risk than indoor environments and social distancing/hand washing is effective.\textsuperscript{84}

Golf specific mitigation strategies were summarised using input from other sports, governing bodies in golf and up to date evidence. We highlighted unpublished data on the European Tour’s success with a ‘bubble’ system to allow events to continue with maximal mitigating measures in place which achieved zero player to player transmission.

\textbf{2.3.4 Conclusion}
This piece of research summarised the safety and implications of playing golf during the COVID-19 pandemic based on expert opinion and up to date evidence. We concluded that golf could be undertaken safely provided social distancing and hand hygiene measures are in place. In addition, we felt it was important to facilitate the recommencement of golf by governing bodies and politicians to ensure the health benefits of golf could be realised by recreational golfers.

2.3.5 Contribution to knowledge

This research was the first to summarise the implications of playing golf during the COVID-19 pandemic. This summary was used to influence policy via its presentation to the UK All-Parliamentary Group for Golf, and shared with policy makers in countries including Australia, Canada, and Spain. This summary and guidance for policy makers may have contributed to the increased participation golf experienced throughout the pandemic.55

2.3.6 Student contribution

The idea to write this piece of work was a collective decision amongst myself, Prof. Foster and Prof. Murray in response to successful implementation of recommencing professional golf in Europe and through direct correspondence with the R&A (a global governing body). We hoped this article may then add value to governing bodies and working groups to engage with other policy makers to enable golf as a safe, recreational sport during the pandemic. I performed the literature search and wrote the first draft of the article, it was
then refined with Prof. Murray and Prof. Foster’s input. I submitted the article, revised it and drafted the response to the reviewers.
Public health considerations regarding golf during the COVID-19 pandemic: a narrative review

Patrick Gordon Robinson,1,2 Charlie Foster,3 Andrew Murray4,4

ABSTRACT
Background Golf is a sport played worldwide by >60 million people from a variety of backgrounds and abilities. Golf’s contribution to physical and mental health benefits are becoming increasingly recognised. Countries have adapted a range of restrictions to playing golf during the COVID-19 pandemic.

Aims The purpose of this narrative review was to (1) explore the literature related to the possible health benefits and risks of playing golf during the COVID-19 pandemic; and (2) provide recommendations on golf-related activity from the relevant available literature.

Results Golf can provide health-enhancing physical activity. Regular physical activity is associated with physiological health, immune system and longevity benefits. Sense of belonging and life satisfaction significantly improved when golfing restrictions were relaxed after the first lockdown in the UK. Golf is an outdoor sport, where social distancing is possible, and if followed, risk of COVID-19 transmission is likely to be low.

Conclusions Policy-makers and governing bodies should support the promotion of golf because participation brings wide-ranging benefits for physical health and mental well-being. While effective risk reduction measures are used, the benefits of playing golf in most circumstances outweigh the risk of transmission.

INTRODUCTION
Golf is played by nearly 60 million people worldwide,1 in 206 countries2 with ages ranging from 4 to 104 years.3 Its global reach was also evidenced by its re-inclusion into the 2016 Olympic Games. It allows those with varying levels of fitness and mobility to participate at a recreational level and it is one of the most popular games among middle-aged and older adults.4,5 Swinging the golf club requires the recruitment of a multitude of muscles6 and in the older population, it has been shown to improve balance, proprioception and muscle endurance.5,7 The sport has also shown favourable improvements in logical memory in the elderly.8,9 Golf is an inclusive sport and can be played with low financial costs when using municipal golf courses and new golf membership initiatives.10,11 In addition, significant efforts have been made recently to improve its accessibility for disabled golfers.12

The WHO promotes physical activity across the life course, stating strong evidence for physical health, mental health and longevity benefits,13 while inactivity is a known risk factor for premature mortality.14 Playing golf can provide moderate intensity activity (with a reported general metabolic equivalents of 4.83)15 while one ‘round’ of 18 holes can, on average, burn 1200 kcal and a player can take approximately 11 000–16 000 steps over 4–8 miles.16,17 Energy expenditure is significantly lower for players who ride in carts;18 however, they will still walk approximately 5 km per round.19 The sport helps children and adults meet the WHO recommendations for physical activity20 and the health benefits of golf have been well described in a scoping review by Murray et al.21 The authors studied 301 articles related to golf and health and concluded that practitioners and policymakers should be encouraged to support more people to play golf despite its associations with improved physical and mental well-being.22 Injury rates within golf are low.
compared with other sports and have been reported as 0.28–6.00 injuries per 1000 hours played.\textsuperscript{1,2} However, rates are higher in elite/professional golfers.\textsuperscript{3,4}

The COVID-19 pandemic has had a significant impact on all recreational, amateur and professional sports. With the introduction of social distancing globally, sporting activities were significantly inhibited, even if performed outdoors. There has been a reduction in physical activity during COVID-19,\textsuperscript{5,6} and suggestions have been made on how to best introduce people back to an active lifestyle.\textsuperscript{7} Golf is likely to be a suitable sport for patients looking to achieve health-enhancing physical activity in an outdoor environment during the COVID-19 pandemic.

The purpose of this narrative review was to (1) explore the literature related to the health benefits and risks of playing golf during the COVID-19 pandemic and (2) to provide recommendations on golf-related activity from the relevant available literature.

Golf and physical and mental health

Golf has been associated with an increase in life expectancy and physical health benefits. A Swedish study which analysed 390,818 golfers and non-golfers reported a 40% lower mortality rate in the golfers, correlating to a 5-year increase in life expectancy regardless of gender, age or socioeconomic status.\textsuperscript{8} Methods deployed for this study demonstrate correlation, but not causation. Golfing is associated with reductions in known risk factors for cardiovascular disease including blood lipid and insulin-glucose levels\textsuperscript{9} as well as body composition.\textsuperscript{10,11,12}

Immune function

Regular physical activity benefits immune function which is important in the context of COVID-19. Klettro et al.\textsuperscript{13} studied the IGA concentration of the upper airways as the primary outcome following regular moderate physical activity and showed those undergoing exercise had significantly increased rates.\textsuperscript{14} Furthermore, it has been shown that regular exercise of moderate intensity is associated with a reduction in respiratory infections.\textsuperscript{15} Although there is limited evidence that physical activity directly reduces the rates of morbidity and mortality associated with COVID-19, this has been true for other viral illnesses\textsuperscript{16} and may be applicable to COVID-19.

Benefits of golf during COVID-19 and for rehabilitation from illness

It is known that COVID-19 has both direct and indirect effects on mental health.\textsuperscript{17} Sochie et al.\textsuperscript{18} studied the impact of golf course closure and opening during the pandemic on well-being and life satisfaction. The authors reported that belonging, enjoyment and well-being were significantly associated with outdoor course activity and a sense of belonging and satisfaction increased following golf course reopening.\textsuperscript{19} Previous studies have shown improvements in stress and anxiety by playing golf\textsuperscript{20} and it is feasible that the green space and physical activity facilitated by golf could benefit health and well-being for some people.

Some physical activities during the COVID-19 pandemic likely have higher risk of transmission than golf, where these factors are indoors or where social distancing is not possible. Some may find golf a suitable substitute during times where COVID-19 prevalence is high and/or restrictions preclude these other activities. This may be particularly important for groups considered at higher risk, for example older adults. Golf has been shown to be associated with improved balance,\textsuperscript{21} muscular function\textsuperscript{22} and strength in older adults.\textsuperscript{23} Furthermore, it has been reported to be a suitable exercise for patients with cardiovascular disease.\textsuperscript{24}

The authors of this review advise a phased return to golf with fewer holes and suitable warm-up activities prior to playing. It has been shown that a sudden increase in training load will predispose to injury\textsuperscript{25} and a graded return to sport should be advised.\textsuperscript{26}

Evidence of COVID-19 transmission associated with golf

Since the COVID-19 pandemic was declared in March 2020, many countries restricted many activities, including sport, while work was done to better understand and contain transmission of the disease.\textsuperscript{27,28}

Factors affecting risk of transmission include local prevalence of COVID-19, vaccination status of participants and the local population and the knowledge and behaviours of individuals and populations. Methods of transmission of COVID-19 are mainly human-to-human spread via droplets, aerosol, fomites or direct contact.\textsuperscript{29} It has been recognised that outdoor environments have lower transmission risk than indoor\textsuperscript{30} and non-pharmaceutical interventions including social distancing/hand hygiene are effective in lowering transmission.\textsuperscript{31}

Jones et al.\textsuperscript{32} were the first to analyse the COVID-19 transmission during elite sport. The authors concluded that the risk of transmission during rugby matches was very low but that efforts should be made to further mitigate disease transmission within the environment.\textsuperscript{33} A prospective study was performed in professional football over seven weeks while implementing a tailored infection control programme. The authors concluded that the infection risk was highest with unprotected exposure in closed spaces and was lowest outdoors, even without social distancing.\textsuperscript{34}

Golf is an equipment-based sport and there may be concerns regarding the risk of transmission via fomites on equipment. However, Edwards et al.\textsuperscript{35} showed that only 0.75% of COVID-19 virus was recoverable at 1 min in high inoculum when applied so a variety of sports equipment (including a golf ball). Unpublished data from 52 professional golf events on the European Tour, Ladies European Tour and Challenge Tour which regularly tested participants found no transmission from golfer to golfer in outdoor environments. Although community golfers and golf clubs may not have the resources available to organisations such as the European Tour, each
of the success of suppressing COVID-19 transmission is likely associated with the strict compliance with simple measures which have previously been shown to be effective such as social distancing, wearing masks, reducing time indoors and good hand hygiene. As an outdoor sport, where physical distancing is possible, risk of transmission may be low, if appropriate measures are followed. However, there is currently no published evidence regarding the rate of COVID-19 transmission when playing golf.

Mitigating risks in golf

Enhanced hygiene and social distancing measures have been shown to reduce incidence of COVID-19. Social distancing decreases the risk of transmission by reducing the incidence of close contact, while improved hygiene reduces disease transmission, if a contact does indeed occur. A number of countries have constructed guidance for returning to both recreational and professional sport during the pandemic. These include golf-specific examples from The R&A and the United States Golf Association (who together govern golf globally) and the key facets are summarised in box 1.

Professional golf events have incorporated these measures and operated in protected ‘bubbles’, with no player-to-player transmission seen on the European Tour, Ladies European Tour or Challenge Tour in 2020, despite weekly testing of all on course.

The R&A has made provisions within the rules of golf to mitigate the risk of transmission. These include the encouragement of non-competition play and if competition play does occur, there is no handling or exchanging of scorecards. Rakes have been removed from bunkers and players are subsequently allowed to use a preferred lie in light of this. The flagstick is not to be touched or removed and the hole is to be shallow to ease the retrieval of the ball from within it, minimising contact around the rim.

Community golf should continue to implement measures to mitigate risks enabling golfers to gain ‘green exercise’ while encouraging hand hygiene and social distancing. Time spent at golf facilities should be kept to a minimum before and after the act of playing golf and group playing numbers should be minimised where possible. Carmody et al have designed risk assessments and factors to consider for COVID-19 transmission. The authors describe measures which can be implemented to decrease transmission risk in sport and suggest these could be applied to local competition golf and are supported by the UK All-Parliamentary Group for Golf, The R&A and the United States Golf Association. In addition, the Australian Institute of Sport has developed guidelines applicable to all levels of golf for the re-introduction of play. They advise a three-stage approach of increasing participant numbers and level of competition which is mirrored at both the community and elite level and emphasises a minimum of 1.5 m social distancing throughout.

CONCLUSION

Golf can provide health-enhancing physical activity to persons of all ages and is associated with physical and mental health benefits. Policymakers are encouraged to assess the benefits as well as the risks and work with the golf industry to permit golf when suitable control measures are in place. Players should maintain social distancing, use effective hygiene measures and respect all COVID-19 protocols put in place by golf facilities, the golf industry and local and national governments.

REFERENCES

2. The Royal and Ancient, Golf around the world. The Royal and Ancient, 2019.
2.4 Study 4: Assessing the risk of SARS-CoV-2 transmission in international professional golf


2.4.1 Aims and objectives
When the COVID-19 pandemic was declared in March 2020 all professional sports were immediately subject to restrictions. However, as global understanding of risk mitigating strategies were shown to be effective in the general public, some professional sports began to restart. Recommencing professional golf required balance between the economic and social benefits of conducting tournaments versus the risk of virus transmission between players, caddies, staff and spectators. On the 9th July 2020, the PGA European Tour recommenced events with risk mitigating strategies in place. The aim of this prospective study was to report the viral infective status of professional golfers competing on the PGA European Tour. The objectives were to report the rates and circumstances of positive cases of COVID-19 during the 2020 season of the PGA European Tour.

2.4.2 Methodology
The study design was a prospective, observational cohort study. The purpose of this was to follow participants over time to monitor the rates of COVID-19 and the prognosis and transmission associated with the virus. This study design benefits from greater empirical evidence compared to retrospective
designs however limited conclusions can be made around associations of exposures and outcomes. The study lasted 6 months from 6th July 2020 to 13th December 2020 and the included subject participants were any players competing in the 23 PGA European Tour events during the study period. Reverse transcriptase polymerase chain reaction (RT-PCR) testing was performed immediately prior to travelling to the event and re-tested on arrival. Each player completed a symptom and contact history checklist as well as having a temperature check daily prior to access to the event. Any abnormalities were referred to the onsite doctor and COVID-19 team at the event. Players, caddies and staff created a bubble by staying in isolation at designated hotels and events were limited to essential personnel only with no fans. All test results were communicated via text message to the individual players and any positive tests required immediate isolation, confirmatory testing and notification to the local public health authority. Contact tracing was then performed.

2.4.3 Results
There were 195 players included in the study. The mean number of events per player was 15 with a mean number of players per event being 132. There were four positive tests across the 23 events. Two of which were asymptomatic individuals identified at routine testing and two were contacts of a confirmed case on site, however ‘contact’ had occurred outside the tournament bubble
prior to the event. All cases were initially symptomatic but three developed symptoms subsequently. Testing was negative on day 11 for two players and day 14 for two. There were 9 other players were declared themselves ‘contacts’ at daily checking but remained negative throughout follow up testing. Four of which were deemed high risk. Encounters were typically between player and caddy outside or shared meals at <2m. There overall rate of positive tests during the season was 0.14% and there was no player-to-player transmission.

2.4.4 Conclusion
This was the first study in individual professional sport to report the incidence of COVID-19 during the course of a season. The authors believe the low rates of COVID-19 was achieved by strict risk mitigating protocols including the ‘bubble’ system, use of outdoor spaces, hand hygiene and social distancing (see Figure 3), education and engagement of players, caddies and staff, rapid access to testing results via on-site testing and efficient actions taken by medical staff regarding contacts and positive cases. Despite each event including international players and events being held in countries where rates of COVID-19 were considered to be relatively high, rates in the tournament bubble were lower than that of the public.

2.4.5 Contribution to knowledge base
This study was instrumental in supporting the recommencement of professional golf in Europe. This data could then be utilised in subsequent
event planning to inform local health authorities and governments to provide comfort and confidence in the delivery of further tournaments. However, the number of players having to isolate due to being a contact, even if this was in a low-risk environment proved detrimental to the well-being and mental health of those affected, and even those at risk of being isolated. This was an area the authors and European Tour executives felt needed to addressed. As the pandemic evolved, and as vaccines were introduced, golf continued to answer research questions, and implement policy based on scientific evidence in conjunction with host public health authorities.

This study was presented as a poster at the International Olympic Committee World Conference in Monaco, November 2021. It was also presented as a podium presentation in a workshop during the 2nd International Congress on Golf and Health in Edinburgh, July 2021.

2.4.6 Student contribution

My involvement in this paper included study idea, structuring of data collection and the analysis of the data. I wrote and revised each draft of the manuscript under the guidance from Prof. Denis Kinane and Prof. Andrew Murray and made the appropriate amendments to the article following the reviewers’ suggestions.
2.4.7 Publication

**Assessing the risk of SARS-CoV-2 transmission in international professional golf**

Patrick G Robinson 1,2, Andrew Murray 2,3, Graeme Close,4 Denis F Kinane 5,6

**ABSTRACT**

There is no published data on the incidence or risk of SARS-CoV-2 transmission during professional golf. The purpose of this prospective study was to report incidence and transmission regarding SARS-CoV-2, of professional golfers competing on the PGA European Tour across 23 events in 11 countries.

**Methods**

Daily symptom and temperature checks and weekly reverse transcriptase PCR (RT-PCR) screening were performed to determine potential carriage of SARS-CoV-2. Onset and type of symptoms were recorded. Gene expression and cycle thresholds (Ct) were measured for all positive cases. Repeat PCR testing was performed on all positive players. RT-PCR analysis included human housekeeping genes and various SARS-CoV-2-specific genes.

**Results**

During the study period, there were 2900 RT-PCR tests performed on 195 professional golfers competing on the European Tour. Four players tested positive on-site during the study period (0.41% of tests), positive results were declared with Ct <40. Two positive tests were returned as part of routine protocols, while two were asymptomatic at time of testing, with three developing symptoms subsequently. None required hospital admission. There was no transmission from player to player.

**Conclusion**

Golf is an outdoor sport where social distancing is possible, meaning risks can be low if guidance is followed by participants. Risk of transmission of SARS-CoV-2 can be mitigated by highly accurate RT-PCR testing of participants and by setting up a safe bubble that includes testing players and support staff, as well as all personnel coming into contact with them during the course of the tournament, for example, drivers and hotel staff. This report can also provide reassurance for participants and policy makers regarding community golf, which can be encouraged for the health benefits it provides, in a relatively low-risk environment, with minimal risk of transmission by observing sensible viral hygiene protocols.

**INTRODUCTION**

Golf is a sport played by nearly 600 million people worldwide,1 in 206 countries,2 and its global reach was evidenced by its re-inclusion into the 2016 and subsequent Olympic Games.

The COVID-19 pandemic has led to restrictions on both recreational and professional sport.

Major sporting events have considerable economic, social and wider benefits which, in the context of the COVID-19 pandemic, need to be balanced by any infection risks associated with the sport, as well as any concerns with associated mass gathering, travel and accommodation.2,3 Golf at the professional level is played on a number of different circuits globally. The European Tour is one of the two major men’s circuits globally, with competitors from six continents and events conducted on five continents.

For every event, the European Tour’s medical, safety and operations teams conducted a risk assessment and put in place measures to decrease risk in line with WHO best practice.2,3 Risk mitigation strategies were implemented in collaboration with the host’s national governments and public health leaders and are summarised in figure 1 (adapted with consent from Carmody et al).4 There were 23 tournaments conducted in the 2020 season from 9 July to 13 December.
following a period of cessation due to the COVID-19 pandemic. All constituents (players, caddies and essential support staff) were required to remain in a ‘tour bubble’ during the event week, which comprises the designated golf facilities, accommodation and transfer between these (self-drive preferred).

Key non-pharmaceutical interventions that were implemented at European Tour events included mandatory online education for all players, social distancing both on and off the golf course, enhanced hygiene measures, mask use when inside, and daily symptom and temperature checking. An external testing and diagnostics company (Cignpost Diagnostics) was invited to deliver reverse transcriptase PCR (RT-PCR) onsite testing using a mobile laboratory (figure 2).

To the best of our knowledge, there are no previous data on the degree of SARS-CoV-2 transmission when playing golf or indeed any outdoor individual sport. Therefore, the purpose of this prospective study was to report the viral infective status of professional golfers competing on the PGA European Tour. These data may further inform the 60 million global golf players and policy makers regarding the risk of transmission while playing golf and highlight immediate strategies to mitigate this risk.

**METHODS**

This prospective, observational cohort study included all players competing during 25 European Tour events during the 2020 season across 11 countries. The study period was 6 July 2020-15 December 2020. Each included player used a caddy and was allowed to forgo social distancing with this one person only. All players, including three reserves, required a minimum of one negative RT-PCR test prior to travelling to each tournament, except those attending within 90 days of a confirmed positive PCR test.

All event attendees were required to retest, on site, prior to admission. This was performed using a nasopharyngeal or oropharyngeal swab taken by a trained professional. Each day, a symptom and contact history checklist (table 1) and temperature check were performed prior to admission, and abnormalities (one answer of yes or a temperature >37.8°C) were followed up by the medical team (figure 3). Pretreatment and pretournament testing, daily symptom and contact checks, and daily temperature checks were tracked through an event accreditation and tracking application (RFID, London, UK). Any abnormality was referred to the tournament infection control officer and doctor.

**Testing and processing**

Testing was conducted by Cignpost Diagnostics on the MicroBioMed (Seoul, South Korea), or Co-Diagnostics (Salt Lake City, USA) platforms, except in two countries (South Africa (Innotech) and United Arab Emirates (Mediclinic)) where testing was provided by established local laboratories. The MicroBioMed and CoDx reagent kits and thermocyclers were used and had the ability to detect virus with high sensitivity and specificity (≥98%) and a limit of detection of 2.1 viral particles per microlitre. Typical run times and reporting were within 2-4 hours of swabbing. Each test assessed multiple target genes (a combination of ORF, N, and RdRp) up to a cycle threshold (Ct) of 40 cycles. Viral levels below Ct 90 were considered positive. Indeterminate samples were...
Positive tests notification and contact tracing

All negative results were communicated by email or text to each individual. The lead technician/event doctor informed the person and host public health authority of each positive result and ensured immediate isolation and confirmatory testing. Contact tracing was conducted in line with WHO and local public health guidelines/requirements, with each contact informed and quarantined.\(^7\)

Local population COVID-19 rates

All local rates of COVID-19 were reported as new cases per day per 100,000. UK data were extracted from the Office for National Statistics (ONS).\(^5\) When new cases were reported using the percentage of the population at risk, the conversion to individual daily cases per 100,000 was calculated using census data from the ONS for 2020. This applied to the tournament in Northern Ireland and the first tournament in Scotland. The national percentage was then converted into cases per 100,000 of the population. Non-UK data were extracted from the Our World in Data website in association with the University of Oxford.\(^18\)

RESULTS

One hundred and ninety-five different players representing 32 different countries entered European Tour event ‘bubbles’. Players played a mean of 15 events following recommencement of the playing season. The median number of players per event was 132 (range 65–156).

Twelve players declared a ‘contact’ on daily checking. Of these, five met the host national public health guidelines for contact tracing and were isolated and excluded from participation. Of these, three were stratified as ‘high risk’, due to sustained indoor contact (shared hotel room, shared prolonged contact at residential address and shared a meal at 1 m for >1 hour indoors). Two of these subsequently tested positive for SARS-CoV-2. The other ‘high risk’ contact had previously tested positive and subsequently tested negative throughout the remainder of the season. All other contacts, including all the players who only had outdoor contact, remained negative and asymptomatic despite enhanced medical monitoring and PCR testing.

Regarding symptom checking, three out of four players who tested positive on site developed symptoms, although none required hospitalisation. A further five players declared symptoms requiring assessment but on medical assessment tested negative via RT-PCR, and a clear alternative diagnosis was made.

Over the course of 23 events, four players tested positive at an event, representing 0.18% of tests, excluding testing of known positive cases to monitor Ct values for risk stratification. Of the four positive cases, two were detected as asymptomatic individuals on routine testing, while two players were informed they were a contact of a confirmed case (informed while on site but contact had been from prior to the event) and tested positive. One of these tested positive initially, while the other initially tested negative but became positive 2 days into isolation. All were initially asymptomatic, with three subsequently developing symptoms. All were interval tested, with the lowest Ct values for each of these four being 21.4, 24.2, 28.4 and 31.8, and all testing positive for multiple gene makers. Testing was negative for two cases on day 11, with two cases (Ct value 21.4, 24.2) returning negative on day 14 but returning intermittent results with a single positive gene (N) and Ct values 36–40 for 86 and 36 days, respectively.

Strict guidelines were provided to all players to maximise social distancing and minimising creation of contacts. There were consequently four on-site persons deemed ‘high risk contacts’ of these positive cases. They all tested negative for the SARS-CoV-2. This exposure was largely outdoor player-caddy encounters or shared meals at closer than 2 m. Further contacts were established in off-site personnel including through contact tracing of airlines in collaboration with the host public health authority. None of the players that tested positive had been inside an event tour ‘bubble’ in the week prior to their positive test.

The number of players per event and local rates of COVID-19 at the time of the tournament can be seen in table 2. Local COVID-19 rates were reported on the date of the first day of the event. If this was not available, a weekly average was used. The median number of daily cases per 100,000 of the population across 23 events was 13 (range 1–192).

Discussion and comparison with the literature

Professional sporting events can have health, social and economic benefits for individuals and the wider society.\(^3\) The WHO recommended to conduct a risk assessment for COVID-19 transmission and proceed if benefits outweigh risks and if risks can be adequately controlled.\(^5\) For each event, the European Tour conducted a risk assessment consistent with WHO best practice and implemented...
strict measures in collaboration with national governments, public health authorities and other leading sports organisations. These data have immediate translational benefit highlighting that international, competitive golf can be conducted safely, achieving low rates of COVID-19 with minimal player-to-player transmission when appropriate mitigating factors are established and adhered to.

This is the first study to report on the incidence of SARS-CoV-2 detected in golf players. We have shown a very low incidence of positive RT-PCR COVID-19 tests among professional golfers competing in the European Tour. There was no evidence of any player-to-player transmission, and although numbers appeared to be small, cases were typically related to sustained indoor contact with close proximity prior to on site arrival. The median rate of SARS-CoV-2 carriage at each event was lower than the host country national incidence at the time of the event. Three studies have reported the viral rates in professional team sports since the outbreak of the COVID-19 pandemic, reporting low player-to-player and in-competition transmission rates in outdoor sports in managed environments. In contrast to rugby and football, golf does not typically involve high-intensity levels of exercise, and therefore, heavy breathing is not present. This has been regarded as a known risk factor through increased production of aerosol droplets. In addition, the aforementioned sports involve player-to-player contact, which is not typically experienced in golf. One study assessing viral transmission from an individual, non-contact sport (squash) reported a cluster of five positive COVID-19 cases secondary to indirect transmission playing squash. All players shared the same court and squash ball. These findings may not be directly applicable to golf given the indoor, high-intensity nature of squash. Previous literature has reported the rate of viral recovery from contaminated sports equipment to be low, and we did not associate any positive cases with fomite transmission via golfing equipment.

Detection rate of SARS-CoV-2 among players in our study did not appear to be related to the national rates of detection in the host country. This confirms the success of the 'tour bubble' concept and the effectiveness of evidence-based, non-pharmaceutical interventions. Previous studies have conducted team sporting events in countries with daily rates of 57 and 45 per 100,000 of the population. The median daily national rate of COVID-19 in our study was 13 with only three events taking place with rates greater than 45/100,000 and four events less than 5/100,000. When a clear link was found, cases were typically due to shared indoor space including housing or car sharing. This is in keeping with the transmission routes in professional team sports where transmission was thought to be minimal during training or matches but shared indoor environments presented higher risk than outdoor
CONCLUSION

This study is the first to report SARS-CoV-2 incidence within a professional golf environment. Using WHO and national public health guidance, events were hosted with incidence similar or lower than the general population. Adherence to non-pharmaceutical interventions such as avoiding discretionary social contacts is very important. There was no evidence of player-to-player transmission during the sporting activity, and this shows golfers can participate safely in outdoor environments. There are transmissions risks associated with tournament golf; however, these are largely away from the sport itself, related to transport and accommodation, and can be mitigated substantially. Golf itself intuitively represents a low-risk environment.

Twitter Andrew Murray @golfandscience

Acknowledgements Colleagues at the WHO and various international governing bodies for sport (IGF, IF, the IOC, R&A Tour and World Rugby) were instrumental in shaping risk assessment and risk mitigation policies.

Contributors PCG: data collection, data analysis, writing manuscript and final approval. AM: study idea, data collection, data analysis, writing manuscript and final approval. SC and DPK: writing manuscript and final approval.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial, or not-for-profit sector.

Competing interests PCG, AM and SC have paint roles with The IGA, the European Tour and The Ladies European Tour. DPK is founder and chief medical officer at CignaSport Diagnostics Ltd.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval Ethical approval was granted by the local ethics committee of Liverpool John Moores University (C19PHE059).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made are indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

ORCID iD

Patricia J Robinson http://orcid.org/0000-0002-0117-2568

REFERENCES


2.5 Study 5: Pilot evaluation of risk assessment and enhanced protocols regarding contacts at an international professional golf event


2.5.1 Aims and objectives

Contact tracing, along with robust testing, isolation and care of cases, is a key strategy for interrupting chains of transmission of SARS-CoV-2. The definition of a ‘close contact’ during the COVID-19 pandemic varied between countries and there was a degree of subjectivity left to the discretion of the medical practitioner in some circumstances. However, the blanket application of contact tracing, without considering risks, had been very disruptive for public events including professional golf tournaments. In particular, contact tracing and mandatory isolation following aeroplane travel, regardless of proximity or other mitigating factors had been affecting the traveling players, caddies and staff attending professional golf tournaments.

One group of researchers from the United States developed a ‘risk-based quarantine’ which was shown to be safe and effective in reducing unnecessary quarantine times for individuals.86 Discussions regarding risk assessing athletes who have been in contact with SARS-CoV-2 individuals were conducted with the International Chief Medical Officer Group for Sport, the WHO Mass Gatherings team, and public health teams. From these
discussions The European Tour Group medical team decided to undertake a pilot study using this strategy, given the immediate availability of medical doctors and contact tracing personnel on site at events. The aim of this study was to assess whether a risk assessed approach was safe and practical to implement at a professional golf event. The objectives were to 1) measure rates of SARS-CoV-2 amongst professional golfers as well as those who were deemed ‘contacts’ 2) describe the mechanisms of transmission and 3) classify the levels of risk of contacts.

2.5.2 Methodology
This study was conducted at the Gran Canaria Lopesan Open between 17\textsuperscript{th} and 28\textsuperscript{th} April 2021. The study design was a pilot, feasibility study of a protocol which I intended to use in the subsequent study in this thesis. The smaller study design meant the research group could assess the study processes for efficiency and most importantly, safety. The data used from this study was carried over into the main, definitive study and therefore could be described as an internal pilot. Participants included all players, caddies and staff attending the event. Protocols for RT-PCR testing and daily symptom checks were as per the Robinson \textit{et al.}\textsuperscript{87} Risk was categorised as high, moderate or low. High risk reflected the WHO guidelines including those who were direct contacts.\textsuperscript{88} Moderate risk contacts were those who were asymptomatic and where all protocols had been followed, including the wearing of filtering face piece (FFP2) masks on flights with high-efficiency particulate absorbing filtration and
were within two rows in any direction. Low risk contacts were those on the same aircraft but not within two rows of the index case.

Processes for each individual contact depending on their risk category were as follows: High risk contacts were typically asked to isolate for 10 days or according to the host government advice. Moderate risk contacts received education regarding enhanced medical surveillance, had daily rapid antigen testing for 5 days, with RT-PCR on day 5, mandated mask use and access to outside space for work purposes only. Low risk contacts received rapid antigen testing every 48 hours and RT-PCR testing on day 5 only.

Given the unknown effects of amending protocols regarding isolation of close contacts infected with SARS-CoV-2 I believe a pilot, feasibility study was a safe and sensible way to approach this study. It then allowed for safe escalation of the protocols which were evidenced based.

2.5.3 Results

Two tests were positive (0.36%) on arrival to the event. Case 1 had one high-risk contact (shared indoor space in a car and within a hotel room for >15 min), 23 moderate risk contacts from two commercial flights (shared flight within two rows in all directions) while 48 were considered low-risk contacts, having been on the same aeroplane, but not within the two rows in all directions. Case 1 wore an FFP2 mask throughout the flight and did not move within the cabin
and did not have any COVID-19 defining symptoms at the time of the positive test.

Case 2 did not have any significant travel history within 2 days of positive test and had one high-risk contact from shared outdoor and indoor space (dining but not room share) within 48 hours. Case 2 was asymptomatic at the time of testing and subsequently developed minor symptoms. Of the two high-risk contacts (one from exposure to case 1 and one from exposure to case 2), both remained negative by RT-PCR on day 10 and were discharged from further investigations. Neither had been vaccinated nor had a previous COVID-19 diagnosis. Of the 23 moderate risk contacts, all had RT-PCR testing on day 0 and day 5 following exposure and rapid antigen testing on day 1 through to day 4. All tests were negative. There were a total of 48 low-risk contacts, which received RT-PCR testing on day 0 and day 5 (or 6) and rapid antigen testing on day 2 and day 4. All tests were negative. Attendance for routine and additional testing was 100% indicating the approach was feasible in the golf event setting.

2.5.4 Conclusion

This pilot study demonstrated the feasibility of a risk-assessed approach to contact tracing measures at a professional golf event. When individual assessments takes place and risk mitigating strategies including enhanced testing measures are implemented, players, caddies and staff are able to participate safely at events where they would have otherwise had to self-
isolate. Similar protocols have been introduced in American sports.\textsuperscript{89} It is worth acknowledging that the reproducibility of these methods in other sports requires a high degree of compliance from participants and an efficient onsite testing facility with capacity to do so.

\textbf{2.5.5 Contribution to knowledge base}

This study contributed to the knowledge base of managing COVID-19 contacts in both sporting events and the workplace. The tournament director for the Gran Canaria Lopesan Open expressed their concerns regarding the potential loss of 75 individuals (2 cases and 73 contacts), which would have compromised the integrity of the event and in many instances lead to cancellation. This would directly impact the ability of those 550 persons to work and would have a substantial impact on each individual, the host venue and its infrastructure. In addition, such late notice cancellations would be extremely disruptive and have significant ramifications on the professional golf calendar.

The successful outcomes of the protocols in this study led to the pilot of a multi-sport approach in countries such as England, where the research was taken forward in collaboration with the Department of Health and Social Care.

This work was presented as a podium presentation in a workshop during the 2\textsuperscript{nd} International Congress on Golf and Health in Edinburgh, July 2021.

\textbf{2.5.6 Student contribution}
My involvement in this paper included the study idea, structuring of data collection and the analysis of the data. I wrote and revised each draft of the manuscript under the guidance from Profs. Scheer, Kinane and Murray and made the appropriate amendments to the article following the reviewers’ suggestions.
Pilot evaluation of risk assessment and enhanced protocols regarding contacts at an international professional golf event

Patrick G Robinson 1,2, Andrew Murray 2,3,4, Volker Sheer 2,5,6, Graeme Close 7,7, Denis F Kinane 5,6

ABSTRACT
Objectives The aim of this study was to assess whether a risk assessment and managed risk approach to contact tracing was practical and feasible at the Gran Canaria Lopesan Open 2021 and could inform further pilot work regarding disease transmission during elite sporting events.

Methods This prospective cohort study included all international attendees. All participants required a minimum of one negative reverse transcriptase PCR (RT-PCR) test prior to travelling to each tournament. High-risk contacts were isolated for 10 days. Moderate-risk contacts received education regarding enhanced medical surveillance, had daily rapid antigen testing for 5 days, with RT-PCR day 5, mandating mask use and access to Outside space for work purposes only. Low-risk contacts received rapid antigen testing every 48 hours and PCR testing on day 5.

Results A total of 550 persons were accredited and were required to undergo RT-PCR testing before the event. Two of these tests were positive (0.36%). Of these, case 1 had 1 high, 2 moderate and 48 low-risk contacts. Case 2 did not have any significant travel history within 2 weeks of positive test and had only one high-risk contact. There were no further positive tests on site in the wider cohort of attendees, from a total of 670 RT-PCR and 516 rapid antigen tests.

Conclusions This pilot study showed it is practical, feasible and well accepted to provide enhanced daily viral testing and risk mitigating measures at a professional golf event. Further study is required to assess the efficacy of these interventions; however, no transmission was found in this pilot study.

INTRODUCTION
The WHO have been consistent in their support and encouragement for the physical and mental health benefits that physical activity and sport can provide. In the face of a pandemic, this has been supported by evidence regarding the benefits of physical activity for immune function. Elite and professional sport can provide economic, social and wider benefits. However, such events can only be conducted with risk assessment and appropriate measures regarding transmission of COVID-19.

Assessing the risk of disease contraction and transmission is a dynamic process, with consideration required of (1) local incidence of COVID-19, (2) vaccination rates and (3) the infrastructure to support sporting events. The WHO has provided key recommendations regarding mass gatherings, event organisation and risk assessment specific to sport. These documents can continue to serve as a foundational framework, with more detailed guidance appropriate to a specific country by governing sporting bodies. In addition to ‘the science’, decisions regarding sporting events are also informed by wider societal and political factors.

Elite and professional sports have put in place risk assessment and control measures,
which have been shown to be effective in returning risk to the below baseline population levels, even with international travel.\textsuperscript{8,10} Collaborative work has seen a return in most countries to training and competition, and in some, a return to cross-border competition and/ or spectator attendance. Contact tracing, along with robust testing, isolation and care of cases, is a key strategy for interrupting chains of transmission of SARS-CoV2 and reducing COVID-19-associated mortality.\textsuperscript{12} Given an increased knowledge of factors related to transmission,\textsuperscript{12} and the enhanced medical and other resources available to elite sport, there may be instances where individuals who meet criteria as a close contact could participate, if the risk of onward transmission to the public is very low. This would only be appropriated with approval from the event medical director and host public health authority.

The track and trace system implemented globally has been effective in curbing the spread of COVID-19,\textsuperscript{13-15} however, its blanket application, regardless of risk, has had significant disruption on society including the conduct of elite sporting events. Nuanced approaches based on individual risk have been proposed by public health authorities and experts in public health.\textsuperscript{16} One research group from the USA has designed and proven the efficacy of a ‘risk-based quarantine’ model, developing contact tracing policies that are effective in reducing disease transmission while requiring less quarantine.\textsuperscript{17}

Following conversations with the International Chief Medical Officer Group for Sport, the WHO Mass Gathering task force and host public health teams, a risk assessment and managed risk approach were piloted for professional golf at the Gran Canaria Lopesan Open 17-25 April 2021. The aim of this study was to assess whether a risk-assessed approach was practical to undertake at a major sporting event while also enabling a safe environment for those participating. Specifically, we aim to establish whether using a risk-assessed approach to guide testing and isolation of event attendees who were COVID-19 contacts can be performed safely and subsequently inform further research regarding disease transmission during elite sporting events.

METHODS

This prospective, cohort study included all national and international attendees of the Gran Canaria Lopesan Open. The study period was commenced on 17 April 2021 and concluded on 28 April 2021. Players attended from 22 countries of which 84% were from European countries. All participants required a minimum of one negative reverse transcription PCR (RT-PCR) test prior to travelling to each tournament, except those attending within 90 days of a confirmed positive RT-PCR test.\textsuperscript{18} All event attendees were also required to retest on site. This was performed using a nasopharyngeal and oropharyngeal swab taken by a trained professional. Testing was conducted by Cignpost Diagnostics for RT-PCR on the MicrolabMed (MicrolabMed, Seoul, South Korea) or Co-Diagnostics (Salt Lake City, USA) platforms. Each test assessed multiple target genes (a combination of ORF, N, S, RdRp) up to a cycle threshold (Ct) of 40 cycles. Rapid antigen testing was conducted using COVID-19 Ag Rapid Test Device (Abbott Rapid Diagnostics Jena GmbH; Oranweg 1, 07743 Jena, Germany). In asymptomatic individuals, the rapid antigen testing (lateral flow test) has been reported to have a specificity of 100% and a sensitivity of 66% (sensitivity is 94% with Ct values $<$50).\textsuperscript{19} The RT-PCR testing used is reported to have specificity of $>$99% and sensitivity of $>$98%.\textsuperscript{20}

Testing, daily symptoms and contact checks, and daily temperature checks were tracked through an event accreditation and tracking application (RFID, London, UK) (table 1). Any abnormality was referred to the tournament infection control officer and doctor, who in turn consulted with the public health authority and both conducted contact tracing (figure 1). When a case was identified, a full travel and contact history was taken as well as a risk assessment of the initial contact. Persons considered high-risk or direct contacts (as per the WHO guidelines) were isolated. Where all protocols had been followed, including the wearing of filtering face piece (FFP2) masks on flights with high-frequency particulate absorbing filtration; persons within two rows in any direction in an asymptomatic individual were considered moderate-risk contacts. Persons on the same aircraft but not within two rows in any direction were considered low-risk contacts.

High-risk contacts were usually asked to isolate for 10 days or according to host government advice.\textsuperscript{27} Moderate-risk contacts received education regarding enhanced medical surveillance, had daily rapid antigen testing for 5 days, with RT-PCR day 5, mandated mask use and access to outside space for work purposes only. Low-risk contacts received rapid antigen testing every 48 hours and RT-PCR testing on day 5. The close contact testing for those who were asymptomatic is seen in figure 2. COVID-19 officers and social distancing officers educated and engaged the affected person regarding adherence to protocols and non-pharmaceutical interventions (NPIs).

Following the quantitative data collection (using systems within Cignpost Diagnostics), interviews were conducted with the operational leads from testing,
COVID-19 response, the medical director and the tournament director to understand operational feasibility, behavioural factors and the societal impact of the intervention.

**Patient and public involvement**
Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

**RESULTS**
A total of 550 persons were accredited and required to take PCR tests for the event (age range 18-69 years old). Two of these tests were positive (0.36%). Of these, case 1 had one high-risk contact (shared indoor space in a car and within a hotel room for >15 min), 23 moderate-risk contacts from two commercial flights (shared flight within two rows in all directions) while 48 were considered...
low-risk contacts, having been on the same aeroplane, had a positive test on the same day. Case 2 was not tested for COVID-19. We have no further positive tests on site in the wider cohort of attendees, including 11 other attendees with no exposure to case 2, who remained negative by RT-PCR on day 6 and day 5 of follow-up.

The incidence, prevalence and transmission of COVID-19 is an important consideration for the planning and delivery of sports events. The key factor is the initial 'contact' exposure and (b) the risk of onward transmission. Similar tiered, risk-mitigating strategies have been implemented in North America across their national professional leagues of football, soccer, hockey, basketball and baseball. However, their tiers were based on a person's role within the organization/setting, for example, player/team staff versus event staff versus housekeeping. This is in comparison to the present study where risk was categorised on an individual, situational basis with specific consideration given to the circumstances of contacts on transport to the event (eg, air travel) and where the level of enhanced testing for such persons was based on the risk of the contact episode. This pilot evaluation assessed whether it is feasible and practical to put in place daily testing and enhanced protocols to allow participants to continue to work in a professional sports setting. Participants were compliant with measures attending for 100% of the required testing and without any significant breach of protocol. The tournament director was clear that the additional testing, although causing extra workload, was worthwhile in ensuring the event could continue. Delivery leads were clear that the work could be accommodated, and a continuation of the programme is feasible and practical.

This pilot study has shown that daily testing and minimised risk environment protocols are practical and feasible at a professional golf event with 550 attendees. Initial tests of 0.36% were positive with no transmission or subsequent positive tests in other contacts regardless of risk. This model was held during high/very high prevalence rates of COVID-19 in Europe, when judged by WHO criteria (≥200 per 100 000 persons). Both attendees testing positive had arrived from locations of high prevalence (judged by ≥500/100 000 cases/day) and external to golf tournament "hotspots". A blanket strategy to isolate all known contacts would have caused serious disruption and possible cancellation of the golf tournament.

**Operational feasibility**

Elite and professional sport have put in place risk assessment and comprehensive measures aimed at reducing the incidence, prevalence and transmission of COVID-19. Key factors to take into account are related to (a) the initial 'contact' exposure and (b) the risk of onward transmission. Similar tiered, risk-mitigating strategies have been implemented in North America across their national professional leagues of football, soccer, hockey, basketball and baseball. However, their tiers were based on a person's role within the organization/setting, for example, player/team staff versus event staff versus housekeeping. This is in comparison to the present study where risk was categorised on an individual, situational basis with specific consideration given to the circumstances of contacts on transport to the event (eg, air travel) and where the level of enhanced testing for such persons was based on the risk of the contact episode. This pilot evaluation assessed whether it is feasible and practical to put in place daily testing and enhanced protocols to allow participants to continue to work in a professional sports setting. Participants were compliant with measures attending for 100% of the required testing and without any significant breach of protocol. The tournament director was clear that the additional testing, although causing extra workload, was worthwhile in ensuring the event could continue. Delivery leads were clear that the work could be accommodated, and a continuation of the programme is feasible and practical.

Professional golfers are generally used to following strict rules as part of the sport and have developed a level of trust in protocols, having used the same operations and testing team throughout the pandemic. This may or may not be applicable in other settings. Staff and players were aware that the sanction for non-compliance was strict isolation and disqualification from participation. Although not required in this pilot, confirmatory RT-PCR testing following positive rapid antigen testing was immediately available and would have been employed if necessary. The tournament director expressed his concerns regarding the loss of 75 individuals (2 cases and 73 contacts) out of 550, which would compromise the integrity of the event and in many instances lead to cancellation. This would directly impact the ability of those 550 persons to work and would have a substantial impact on each individual, the host venue and its infrastructure. In addition, such late notice cancellations would be extremely disruptive and have significant ramifications on the professional golf calendar.
permit sporting and other events to occur and, therefore, ensure the social and economic benefits available.

Accurate risk assessment, protocols to limit risk during travel, testing and vaccination strategies to facilitate events while minimising risk are necessary to allow sport to continue without disruption. With international travel, and increased attendance at events, the number of contacts sports persons and their essential support personnel may accrue can be large, even if all reasonable precautions are taken. In some regions, there is a legal requirement to self-isolate, while in other settings, there is consideration for vaccine status, initial contact status, risk and impact of transmission and the measures that can be deployed to reduce transmission risk. This study did not demonstrate any transmission related to exposure to a case on an aircraft. While this is reassuring, further conclusions cannot be drawn given the low case numbers included. However, this study did demonstrate that protocols regarding risk-mitigated travel can be put in place and can be adhered to. It also demonstrated that enhanced protocols and daily rapid antigen testing are practical, feasible and well accepted in this setting.

Risk minimisation and daily testing may enable persons to be able to continue sporting or work activity, rather than to self-isolate. Public health rationale is additionally based on modelling, which shows daily testing without quarantine after testing may avert a similar proportion of onward disease transmission from secondary cases compared with that of a 14-day quarantine (50%, 95% UI 23-81); RR 0.88, 0.60-1.43). The modelling was based on at least 5 days of daily testing. A risk assessment and enhanced testing may be appropriate if the following conditions are met:
- Agreement is reached with the public health authority and event organiser.
- Risk is assessed.
- Control measures can return risk to a baseline or acceptable level.
- Daily testing is immediately available.
- Medical oversight is strong and immediately available.

Further pilot work at golf and other professional sporting events could inform a strategy by which when a positive case is detected in an international sporting setting, risk is assessed, risk mitigations including NPIs are enhanced, and close contacts are tested daily using rapid antigen testing instead of self-isolation of individuals who test negative. If a person has a negative rapid antigen test within 24 hours, this will then provide a ‘passport’ for that person to undertake their normal or modified daily activities. It is reassuring that an event based in a region of high daily rates of COVID-19 had positive cases in only 0.56% of the attendees. However, we recognise that this is not absolutely comparable to local rates given our entire study population was tested.

This proposed process is reliant on the ability to obtain a rapid test result, such as what has been possible in this current study. Antigen lateral flow devices currently give the quickest result turnaround of all the COVID-19 tests with results typically available in under an hour. RT-PCR tests have a greater sensitivity than rapid antigen testing and could also be used in this setting with the turnaround time for RTPCR 4-6 hours in 90% of cases where on site labs are available on European Tour. The optimal interval between tests is still being evaluated, but it is anticipated that daily testing will occur until such time as this needs to change in the light of experience. If a person tests positive during this process, they will then be required to undergo take a confirmatory RT-PCR test and self-isolate for 10 days from the date of the positive test result in the normal way. In addition, risk mitigation efforts may require to be heightened or relaxed depending on evolving features of the pandemic such as new variants or an increase in double-vaccinated persons. Clinicians designing risk-mitigating processes must be flexible to change as factors of the pandemic progress such as new variants escaping current vaccine protection.

CONCLUSION
Accurate risk assessment, implementation of risk-mitigating measures, testing, contact tracing and support of cases and contacts are of paramount importance in stopping transmission of SARS-CoV-2. This pilot study showed it is practical, feasible and well accepted to provide enhanced (daily) virus testing and risk-mitigating measures at a professional golf event. Further study is required to assess the efficacy of these interventions. However, no transmission was found in this pilot study with these enhanced measures. These interventions are reliant on suitably trained staff, a cohort of participants willing to undertake daily testing. The protocols established in this study have led to a pilot multisport approach in countries such as England, where the research is being taken forward in collaboration with the Department of Health and Social Care. It may inform further study and implementation regarding contact tracing for elite sport.

Twitter Andrew Murray @iscocandrewmurray

Acknowledgements. Colleagues at the World Health Organization, and various international governing bodies for sport (WTA, ITF, ATP, AFL, UEFA, FIVB) were instrumental in shaping the assessment and risk mitigation policies.

Contributors.
PGR—data analysis, manuscript writing, final approval of manuscript; AB—research idea, data analysis, manuscript writing, final approval of manuscript; GM—manuscript writing, final approval of manuscript; RG—manuscript writing, final approval of manuscript; DPC—manuscript writing, final approval of manuscript; TF—manuscript writing, final approval of manuscript.

Funding. The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests. All authors have no known conflict of interest.

Patient consent for publication. Not required.

Ethics approval. Ethical approval was provided by the local ethics committee of Liverpool John Moores University (21/ST/0232).

Provenance and peer review. Not commissioned; externally peer reviewed.

Data availability statement. Data are available upon reasonable request. The data can be accessed on request of the senior author.
2.6 Study 6: Risk assessment and implementation of risk reduction measures is not associated with increased transmission of SARS-CoV-2 compared to standard isolation at professional golf events

Robinson PG, Murray A, Watson M, Close G, Kinane DF. Risk assessment and implementation of risk reduction measures is not associated with increased transmission of SARS-CoV-2 compared to standard isolation at professional golf events. BMJ Open Sport Exerc Med. 2022;8:e001324. PMID: 35601139

2.6.1 Aims and objectives

During 2021, globally the understanding of SARS-CoV-2 prevention, transmission, and morbidity improved. In particular, governments permitted closer working provided that regular testing was undertaken. This included the more frequent and self-administered use of rapid antigen testing. The previous pilot study showed that a risk assessment and a risk reduction approach to contact tracing can be safe, and allowed persons to participate at a professional golf event, where otherwise they would have been required to isolate. The evolving approach to contact tracing in elite sport was also discussed by leading medical officers from other sports such as football and tennis in a blog via the British Journal of Sports Medicine.

The aim of this current, prospective study was to apply the protocol from the previous pilot study across an event season. The objectives were to 1) measure rates of SARS-COV-2 amongst professional golfers and essential
support staff as well as those who were deemed ‘contacts’ and 2) describe the mechanisms of transmission.

2.6.2 Methodology
This study was conducted from 18th April 2021 to 21 November 2021 covering 26 DP World Tour (previously PGA European Tour) events. This study was a pre-experimental cohort study. The methods of which had been shown to be efficient and safe in the previous pilot, feasibility study. This methodology suffers from a lack of control/comparative group and thus claims regarding the effects of the protocol on the outcome (i.e. COVID-19 rates) must be made with caution. However, given the rapid and dynamic nature of the COVID-19 pandemic and the expedited need for evidence to assess the safety of conducting professional golf events, such a choice of methodology was deemed satisfactory. Furthermore, mitigating biases was attempted by first conducting a pilot trial and having data from the previous seasons COVID-19 rates.

The participant cohort included all players and essential support staff at each event. Those persons included; caddies, operational personnel, scoring personnel and television. The methods of this prospective study mirrored the previous pilot study performed91 except for the addition of vaccination status into the risk calculation. Those who were deemed to have high risk exposure but were vaccinated were downgraded to moderate risk at a time where vaccination was decreasing risk of transmission as well as decreasing case
fatality rates. Each golf event lasted 7-8 days. A person-episode was defined as attendance at the golf facility for the duration of the week.

Operational definitions of close contact risk, and mitigating risk factors were all near identical to the pilot study. The national daily COVID-19 incidence during the first day of each tournament was reported as per 100,000 of the population using the United Kingdom Office for National Statistics\textsuperscript{93} or Our World in Data.\textsuperscript{94} If this was not available, an average across 7 days was used.

2.6.3 Results
There were 13,394 person-episodes over the 26 events. The included participants were 3707 players (including reserves), 3629 caddies, 2808 television personnel, 1950 scoring personnel and 1300 DP World Tour operational staff. The total number of positive cases over the course of the study was 30. There were a total of 163 contacts which met the public health guidelines for contact tracing. There were 11 high risk, 79 moderate risk and 73 low risk. Of the contacts, two high risk and one moderate risk contact tested positive. No low-risk contacts tested positive.

2.6.4 Conclusion
This study demonstrated the scalability of the pilot study methods which were safe and reproducible across multiple events. Using the risk assessment and risk reduction approach in this study, the DP World Tour avoided the unnecessary isolation of participants. One of the limitations to this study was
the change in vaccination status across the course of the study. At the beginning of the study it was <20% which rose to >94% by the end of the study. However, there did not appear to be any skewed distribution of the cases during the course of the season when plotted on a histogram. In addition, the predominant variants in Europe, North America and Asia at the time of this study were Alpha and Delta. Therefore, the findings of this study are applicable to these variants and not necessarily Omicron or other variants.

2.6.5 Contribution to knowledge base
This study provided evidence for the safety and efficacy of a risk assessment and reduction approach to COVID-19 contacts at professional sporting events. This research led to ongoing implementation of risk strategies for contacts in professional sport. In particular, it led to further studies in golf considering the safety of allowing asymptomatic, SARS-CoV-2 positive players to compete with risk mitigating strategies in place.

This work was presented as a podium presentation in a workshop during the 2nd International Congress on Golf and Health in Edinburgh, July 2021.

2.6.6 Student contribution
My involvement in this paper included the study idea, structuring of data collection and the analysis of the data. I wrote and revised each draft of the manuscript under the guidance from Profs. Kinane and Murray and made the appropriate amendments to the article following the reviewers’ suggestions.
Risk assessment and implementation of risk reduction measures is not associated with increased transmission of SARS-CoV-2 compared with standard isolation at professional golf events

Patrick Gordon Robinson,1,2 Andrew Murray,1,2 Matt Watson,1 Graeme Close,3,4 Denis F Kiran5,6

ABSTRACT

Objectives: The purpose of this prospective study was to report incidence and transmission of SARS-CoV-2, among professional golfers and essential support staff undergoing risk assessment and enhanced risk reduction measures when compared to a control cohort at-opposed to standard isolation while competing on the DP World Tour during the 2021 season.

Methods: This prospective cohort study included all players and essential support staff participating in 26 DP World Tour events from 18 April 2021 to 21 November 2021. High-risk contacts were isolated for 10 days. Moderate-risk contacts received education regarding enhanced medical surveillance, had daily rapid antigen testing for 5 days, with reverse transcription-polymerase chain reaction (RT-PCR) testing on day 5, mandated mask use and access to outside space for work purposes only. Low-risk contacts typically received rapid antigen testing every 48 hours and RT-PCR testing on day 5.

Results: The total study cohort comprised 13,394 person-weeks of exposure. There was a total of 30 positive cases over the study period. Eleven contacts were stratified as high-risk. Two of these subsequently tested positive for SARS-CoV-2. There were 79 moderate-risk contact and 73 low-risk contacts. One moderate-risk contact subsequently tested positive for SARS-CoV-2 but did not transmit the virus. All other contacts, remained negative and asymptomatic to the end of the tournament week.

Conclusions: A risk assessment and risk reduction-based approach to contact tracing was safe in this professional golf event setting when Alpha and Delta were the predominant variants. It enabled professional golfers and essential support staff to work.

INTRODUCTION

The COVID-19 pandemic had a profound effect on the delivery of international sporting and cultural events. Golf is an outdoor sport where social distancing is always possible and it has been shown to be a relatively low-risk environment for viral transmission.1 At a societal level, although initial risk mitigating measures centered around national lockdowns, restrictions were adapted to allow outdoor activities with an emphasis on social distancing, hand hygiene and the use of face coverings if in indoor facilities.2-6 Following guidance from the WHO7-9 and with collaboration between leading sports organisations and national governments, international sport was able to return, without negative impact on public health.7-9

Key non-pharmaceutical interventions were implemented at the DP World Tour events when competition resumed on 9 July 2020. These included mandatory online education for all players, social distancing both on and
off the golf course, enhanced hygiene measures, mask use when inside, and daily symptom and temperature checking. Reverse transcriptase polymerase chain reaction (RT-PCR) testing was conducted prior to events and on site using a mobile laboratory. With advances in scientific knowledge, and the mass deployment of vaccines, regulations and protocols changed regarding daily life, but also for sporting events. Knowledge has evolved that the virus is predominantly transmitted via droplet/airborne spread\textsuperscript{13,14} and less through surface fomites.\textsuperscript{15,16} Vaccines were shown to decrease transmission against both alpha and delta, which were the predominant variants during the period of study.\textsuperscript{15}

During 2021, pilot studies took place to permit close contacts to work in essential sectors with regular testing.\textsuperscript{17,18} Some countries moved to a model where fully vaccinated individuals could avoid standard isolation, with or without regular testing based on the efficacy of vaccines against transmission, severe illness and death. The 2021 year also saw an increased role for Rapid Antigen Testing, as an adjunct to RT-PCR at major outdoor sporting events, and in other sectors and settings.\textsuperscript{17,18} Further studies have highlighted outdoor sports as a low-risk environment.\textsuperscript{19,20}

Recognising these changes, major sporting organisations worked with technical experts from the WHO and host national governments to put in place guidance for the management of close contacts in a sports setting, with the intention of providing consistency across borders for international sporting competition.\textsuperscript{21-24} A pilot study showed that a risk assessment and a risk reduction approach to contact tracing can be safe, and allowed persons to participate in a professional golf event, where otherwise they would have been required to isolate.\textsuperscript{25}

The purpose of this prospective study was to apply this protocol across an event season and additionally report incidence and transmission of SARS-CoV-2 among professional golfers and essential support staff.

### Methods

This prospective cohort study included all players and essential support staff participating in 26 DP World Tour events from 18 April 2021 to 21 November 2021. Essential support staff were caddies, television and scoring personnel and DP World Tour operational staff. These events took place in 13 countries on 3 different continents (Europe, Asia and North America) (table 1). Persons not holding annual accreditation for DP World Tour were not included. The US PGA, the US Open, the Olympic Golf Competition and the WGC FedEx competitions were not included as tournament and testing operations were run by other organisations for these events. Accredited persons were required to follow host country public health laws, while further guidelines were provided regarding:

i. Maximising use of outdoor space.
ii. Avoiding discretionary contacts, and crowded areas, especially indoors.

### Table 1: Participant questionnaires completed before attending venue each day

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes/no</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Any new continuous cough?</td>
<td></td>
</tr>
<tr>
<td>2. Any new shortness of breath?</td>
<td></td>
</tr>
<tr>
<td>3. Any new fever (i.e., feeling hot or cold to touch)?</td>
<td></td>
</tr>
<tr>
<td>4. Any new loss of taste or smell?</td>
<td></td>
</tr>
<tr>
<td>5. Any positive test for COVID-19 within the previous 14 days?</td>
<td></td>
</tr>
<tr>
<td>6. Any contact with confirmed COVID-19 cases in the last 14 days?</td>
<td></td>
</tr>
</tbody>
</table>

Questions designed by DP World Tour medical team using WHO and European public health recommendations.

i. Wearing a 3 ply or medical mask in any shared indoor space.
iv. Observing excellent hand hygiene.

v. Reporting any symptoms or contact to the COVID-19 support team or the medical doctors on site.

Each event duration was 7-8 days. A person episode was defined as attendance at the golf facility for the duration of the tournament.

### Defining risk

When a case was identified, a full travel and contact history was taken, as well as a risk assessment of the initial contact. Persons considered high risk or direct contacts (as per the WHO guidelines)\textsuperscript{26} were isolated. Where someone was considered a high-risk contact by WHO definition, but had completed a course of vaccination with a WHO-approved vaccine course, they were considered a moderate-risk contact. Where all protocols had been followed, including the wearing of filtering face piece (F2) masks on flights with high-efficiency particulate absorbing filtration, persons within two rows in any direction in an asymptomatic individual were considered moderate-risk contacts. Persons on the same aircraft but not within two rows in any direction were considered low-risk contacts.

For the majority of events, participants required a minimum of one negative RT-PCR test prior to traveling to each tournament or on arrival. High-risk contacts were isolated for 10 days.\textsuperscript{27} If the host country permitted it, moderate-risk contacts received education regarding enhanced medical surveillance, had daily rapid antigen testing for 5 days, with RT-PCR day 5, mandated mask use and access to outside space for work purposes only. Low-risk contacts typically received rapid antigen testing every 48 hours and RT-PCR testing on day 5.

Testing was performed using a nasopharyngeal and oropharyngeal swab taken by a trained professional. For events from 1 October onwards, persons were permitted to self-swab if they had completed in-person and online training regarding the conduct of rapid antigen testing.
Each day, a symptom and contact history checklist (Table 1) were performed prior to admission to the event. Pre-travel and pre-tournament testing, daily symptom and contact checks were tracked through an event accreditation and tracking application (RIHD, London, UK). Abnormalities were followed up by the medical team.

Testing and processing
Testing was conducted by Cepheid Diagnostics (Farnborough, UK) on CO-RADx (Salt Lake City, USA) platforms, or through established local laboratories. The CO-RADx reagents kits and thermocyclers were utilised and had the ability to detect virus with high sensitivity and specificity (>99%) and a limit of detection of 2.4 viral particles/μL. Typical turn around times and reporting were within 2–4 hours of swabbing. Each test assessed target genes up to a cycle threshold (Ct) of 40 cycles. Viral levels below Ct 40 were considered positive. Indeterminate samples were repeated, where necessary. Cepheid diagnostics or local laboratories also provided rapid antigen testing, using Abbott PanBio (Berkshire, UK), Innova (California, USA) or SD Biosensor (Suwon, South Korea). Antibody testing was not conducted systematically on DP World Tour. Contact tracing was conducted in line with WHO and local public health guidelines/requirements, with each contact informed and appropriate action taken.20

Local population COVID-19 rates
All local rates of COVID-19 were reported as new cases per day per 100,000. UK data were extracted from the Office for National Statistics.21 Rates were presented as the number of cases on the date of commencement of the tournament. Non-UK data were extracted from the Our World in Data website in association with the University of Oxford.22

RESULTS
There were a total of 26 events during the study period with 13,594 persons episodes involved. Players compartmentalized 3,507 (including reserves), caddies 3,602, television personnel 2,988, scoring personnel 1,950 and DP World

<table>
<thead>
<tr>
<th>Event</th>
<th>Location</th>
<th>Players (n)</th>
<th>Date of event</th>
<th>National daily COVID-19 incidence per 100,000 of population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gran Canaria Lopesan Open</td>
<td>Gran Canaria, Spain</td>
<td>151</td>
<td>22–25 April 2021</td>
<td>18.4</td>
</tr>
<tr>
<td>Tenerife Open</td>
<td>Tenerife, Spain</td>
<td>151</td>
<td>29–2 May 2021</td>
<td>17.7</td>
</tr>
<tr>
<td>Canary Islands Championship</td>
<td>Tenerife, Spain</td>
<td>151</td>
<td>6–9 May 2021</td>
<td>14.9</td>
</tr>
<tr>
<td>Bathed British Masters</td>
<td>Sutton Coldfield, England</td>
<td>156</td>
<td>12–15 May 2021</td>
<td>3.4</td>
</tr>
<tr>
<td>Made in Himmerland</td>
<td>Fano, Denmark</td>
<td>156</td>
<td>27–30 May 2021</td>
<td>16.8</td>
</tr>
<tr>
<td>Porsche European Open</td>
<td>Hamburg, Germany</td>
<td>153</td>
<td>5–7 June 2021</td>
<td>3.8</td>
</tr>
<tr>
<td>BMW International Open</td>
<td>Munich, Germany</td>
<td>156</td>
<td>24–27 June 2021</td>
<td>1</td>
</tr>
<tr>
<td>Dubai Duty Free Irish Open</td>
<td>Co. Kilkenny, Ireland</td>
<td>155</td>
<td>1–4 July 2021</td>
<td>7.7</td>
</tr>
<tr>
<td>Aberdeen Scottish Open</td>
<td>North Berwick, Scotland</td>
<td>156</td>
<td>8–11 July 2021</td>
<td>40.8</td>
</tr>
<tr>
<td>The Open Championship</td>
<td>Kent, England</td>
<td>156</td>
<td>15–18 July 2021</td>
<td>64.4</td>
</tr>
<tr>
<td>Cazoo Classic</td>
<td>City of Newport, Wales</td>
<td>153</td>
<td>22–26 July 2021</td>
<td>13.2</td>
</tr>
<tr>
<td>ISPS HANDA World Invitational</td>
<td>Co. Antrim, Northern Ireland</td>
<td>143</td>
<td>29–1 August 2021</td>
<td>41.5</td>
</tr>
<tr>
<td>Hero Open</td>
<td>Fife, Scotland</td>
<td>143</td>
<td>05–8 August 2021</td>
<td>38</td>
</tr>
<tr>
<td>Cazoo Classic</td>
<td>Kent, England</td>
<td>144</td>
<td>12–16 August 2021</td>
<td>40.7</td>
</tr>
<tr>
<td>D+D Real Czech Masters</td>
<td>Prague, Czech Republic</td>
<td>124</td>
<td>19–22 August 2021</td>
<td>1.8</td>
</tr>
<tr>
<td>Omega European Masters</td>
<td>Crans Montana, Switzerland</td>
<td>156</td>
<td>26–29 August 2021</td>
<td>29.2</td>
</tr>
<tr>
<td>DS Automobiles Italian Open</td>
<td>Rome, Italy</td>
<td>156</td>
<td>2–5 September 2021</td>
<td>10.8</td>
</tr>
<tr>
<td>BMW PGA Championship</td>
<td>Surrey, England</td>
<td>144</td>
<td>9–12 September 2021</td>
<td>56.4</td>
</tr>
<tr>
<td>Dutch Open</td>
<td>Cromvoirt, Netherlands</td>
<td>144</td>
<td>16–19 September 2021</td>
<td>12.7</td>
</tr>
<tr>
<td>Alfred Dunhill Links Championship</td>
<td>Fife, Scotland</td>
<td>168</td>
<td>30–03 October 2021</td>
<td>50.6</td>
</tr>
<tr>
<td>ACCIÓNA Open de España</td>
<td>Madrid, Spain</td>
<td>132</td>
<td>07–10 October 2021</td>
<td>3.7</td>
</tr>
<tr>
<td>Estrella Damm N.A. Andalucia Masters</td>
<td>Sotogrande, Spain</td>
<td>126</td>
<td>14–17 October 2021</td>
<td>3.3</td>
</tr>
<tr>
<td>Mallorca Golf Open</td>
<td>Balearics Islands, Spain</td>
<td>120</td>
<td>21–24 October 2021</td>
<td>4</td>
</tr>
<tr>
<td>Portugal Masters</td>
<td>Vilamoura, Portugal</td>
<td>108</td>
<td>4–7 November 2021</td>
<td>8.3</td>
</tr>
<tr>
<td>AVIV Dubai Championship</td>
<td>Dubai, UAE</td>
<td>114</td>
<td>11–14 November 2021</td>
<td>1</td>
</tr>
<tr>
<td>DP World Tour Championship</td>
<td>Dubai, UAE</td>
<td>53</td>
<td>18–21 November 2021</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3 Description of positive cases and contact risk by relevant events

<table>
<thead>
<tr>
<th>Event</th>
<th>Cases (n=30)</th>
<th>High (n=11)</th>
<th>Moderate (n=79)</th>
<th>Low (n=73)</th>
<th>Outcome of contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gran Canaria Lopesan Open</td>
<td>2</td>
<td>2</td>
<td>25</td>
<td>48</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>Betfred British Masters</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>Made in Himmerland</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>Dubai Duty Free Irish Open</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>Abu Dhabi Scottish Open</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>The Open Championship</td>
<td>4</td>
<td>3</td>
<td>9</td>
<td>5</td>
<td>1 high risk tested positive</td>
</tr>
<tr>
<td>ISPS HANDA World Invitational</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>Hero Open</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1 high risk tested positive</td>
</tr>
<tr>
<td>DiD Real Czech Masters</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>Omega European Masters</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>BMW PGA Championship</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>1 moderate risk positive</td>
</tr>
<tr>
<td>Dutch Open</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>Alfred Dunhill Links Championship</td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>6</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>Portugal Masters</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>All contacts negative</td>
</tr>
<tr>
<td>RWM Dubai Championship</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>All contacts negative</td>
</tr>
</tbody>
</table>

Tour operational staff 1500. The mean number of travelling group was 516 persons per event (140 players, with 3 travelling reserves and 140 caddies, 108 TV, 75 scoring and 50 ESS. There were a total of 30 positive cases over the entire season.

Contacts

There were 163 persons who were declared a 'contact' and met the host national public health guidelines for contact tracing (table 2). Of these, 11 were stratified as 'high risk', due to sustained indoor contact (shared hotel room, shared prolonged contact at residential address, shared meal at 1m for >4-hour indoors, without sufficient mitigation. Two (18%) of these subsequently tested positive for SARS-CoV-2. There were 79 moderate-risk contacts and 73 low-risk contacts. One moderate-risk contact (1%) subsequently tested positive for SARS-CoV-2 but did not transmit the virus. All other contacts remained negative.

High-risk exposure was typically shared indoor space (hotel room) or shared transport without completed vaccination course or wearing of personal protective equipment. Moderate-risk exposure was largely outdoor player-caddy encounters, outdoor interaction between event personnel, or shared outdoor meals at closer than 2 m, or high-risk exposure where a course of vaccination had been completed. Further contacts were established in off-site personnel including through contact tracing of airlines in collaboration with the host public health authority. It is estimated by the DP World Tour executives and medical team that the use of the risk assessment and risk reduction approach prevented the postponement or cancellation of three events during the 2021 season.

The number of players per event and local rates of COVID-19 at the time of the tournament can be seen in table 3. Local COVID-19 rates were reported on the date of the first day of the event. If this was not available, a weekly average was used. The mean number of daily cases per 100,000 of the population across 26 events was 12.5 (SD 15.6). The full vaccination rate (as per WHO definition) of the included participants in this study was >99% at the beginning of the study (18 April 2021) and increased, to >94% when polled on 1 November 2021.

Discussion and comparison to the literature

This study has shown the successful scaling up of previous pilot work regarding a risk assessed and risk reduction approach to contact testing at professional golf events. At an international, multievent scale this protocol was shown to be effective in minimizing the transmission of SARS-CoV-2 and allowing a significant number of players, caddies and staff to safely participate in events despite being COVID-19 contacts and otherwise having to self-isolate and miss events.

Professional sport has been required to be dynamic in its health protocols and strategies due to the evolving nature of the COVID-19 pandemic. With variations in international SARS-CoV-2 rates and policy responses, elite sport has been required to liaise closely with public health organisations and government to abide by differences in legislation and ensure the safety of participants and staff as well as the wider population. Using the risk assessment and risk reduction approach in this study, the DP World Tour avoided the unnecessary isolation of 151 participants. The ability for persons to participate in these events was beneficial for them and for the
events themselves. In addition, quarantine or isolation in foreign countries, due to travel restrictions, may have potential negative effects on mental and physical health. The DP World Tour chief medical officer and executives estimated that the protocol implemented in this study avoided the unnecessary postponement or cancellation of three events.

Comparison to literature

Initial modelling of testing schemes utilising daily lateral flow testing demonstrates an effective way of minimising viral transmission risk while maximising worker availability and isolation avoidance. A pilot scheme undertaken by Public Health England enabled contacts of positive cases to undergo daily lateral flow testing instead of adhering to the previous national guidance of isolation. In addition, a follow-up study showed 52% of those tested positive would be more likely to share details of those they had been in contact with, if they knew daily testing would be implemented as opposed to self-isolation. These protocols are supported by recent evidence showing the recalibrated absolute sensitivity of lateral flow testing to be much higher than previous thought with values greater than 80% and this has been translated to a population level in Slovakia where rapid antigen screening was reported to have reduced COVID-19 incidence by 83%. Population data in England has shown lateral flow testing to be useful for identifying infections among asymptomatic adults, particularly those with high viral loads who are more likely to transmit the disease.

In a randomised controlled trial of COVID-19 contacts at English secondary schools and colleges, the authors showed daily lateral flow testing to be non-inferior to self-isolation in regards to disease transmission, with similar rates of symptomatic infections in both groups. It was reported that daily lateral flow testing, reduced COVID-19-related school absences by 59%. With evolving knowledge of the benefits of daily lateral flow testing, the Department of Health and Social Care currently recommends daily lateral flow testing and additional cautious for the general population of England if a fully vaccinated person has been in contact with a person who is positive for COVID-19.

The pilot study from the Gran Canaria Open 2021 demonstrated that a risk-assessed and risk reduction protocol was both feasible and effective in allowing a tournament to run safely while minimising the wider risk on a public health level to the host country. This strategy was scalable to a full season on the DP World Tour. Enhanced measures of hygiene for those not legally required to isolate were also encouraged in this study. On the DP World Tour this included, minimising shared indoor space, making attractive outdoor space available, mandating masks when indoors, and daily symptom and contact checking at arrival to events. Although there have been encouraging findings in both the pilot study and this study, other research has found daily antigen testing in collegiate athletes to be less effective, with false-negative results leading to COVID-19 outbreaks.

Limitations

This study should be interpreted in light of its limitations. The reporting of contacts was primarily through self-reporting, which has typically been shown to be a underestimation of true contacts. During the period of study, there was a significant change in the number of participants who were fully vaccinated. However, it would appear rates of COVID-19 across the course of the season were not particularly skewed to the beginning or the end of the season. The predominant variants in Europe, North America and Asia at the time of this study were Alpha and Delta. Therefore, the findings of this study are applicable to these variants. The Omicron variant has shown to have different genotypic characteristics with potential vaccine evasion, and therefore, a different approach may be appropriate.

CONCLUSION

A risk assessment and risk reduction approach to contact tracing as compared with standard isolation did not lead to increased transmission of SARS-CoV-2 in this cohort. Its implementation avoided unnecessary self-isolation for players and other participants and enabled events to proceed. This approach can be implemented effectively when medical, operational support and testing infrastructure are immediately available at events.

Acknowledgements

Colleagues of the World Health Organisation, and various international governing bodies for open (ATP, WTA, PGA Tour, and World Rugby) were instrumental in shaping risk assessment and risk mitigation policies. We thank Dr. Walter Schaff for his contribution to the data collection.

Contributions

PSO: wrote manuscript. AM (guarantor): study idea, data collection, wrote manuscript, final manuscript approval. UK: final manuscript approval. DH: data collection, final manuscript approval.

Funding

The authors have not declared a specific grant for this research from any funding agency in the public, commercial, or not-for-profit sectors.

Competing interests

None declared.

Patient and public involvement

Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Patient consent for publication

Not applicable.

Ethics approval

Ethical approval was granted by the local ethics committee of Liverpool John Moores University (20/005/026).

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

Data are available on request.

Open access

This is an open-access article distributed in accordance with the Creative Commons Attribution Non-commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

ORCID iD

Patrick Gordon Robb: http://orcid.org/0000-0002-0117-2968
REFERENCES

13. Ludvig T, Key SH, Novy G. SARS-CoV-2 transmission risk from sports equipment (field hockey), medRxiv 2021;
38. Mereno GN, Brian KM, Prey HI, et al. SARS-CoV-2 transmission in intensively active athletes not fully mitigated with daily antigen testing. medRxiv 2021:2021.05.03.21250383.
Open access

21 Yu J, Coller JH, Rowe M. Comparators neutralization of the SARS-CoV-2 omicron BA.1 and BA.2 variants, medRxiv 2022.
22 Veroli L, Balas H, Brattain Kristoffersen A, et al. Reduced risk of hospitalisation among reported COVID-19 cases infected with the SARS-CoV-2 omicron BA.1 variant compared with the delta variant, Norway, December 2021 to January 2022. Euro Surveill 2022;27:2200277.
2.7 Study 7: Returning persons with SARS-CoV-2 to the field of play in professional golf: A risk assessment and risk reduction approach


2.7.1 Aims and objectives

Professional golf events, competition and health policies continued to dynamically adapt during the COVID-19 pandemic as we learned more regarding the effectiveness of risk mitigation strategies, viral transmission, managing contacts and vaccinations. Understanding of the Omicron variant improved with knowledge that its clinical severity was less than that of the Delta variant and a completed vaccinations status was effective in reducing both disease severity and mortality. As a sport, golf was in a fortuitous position as it is an individual sport, played outside in vast landscapes, where social distancing is possible. In general, professional golfers have proven very obedient to restrictive health measures. Therefore, the next logical step in this journey of returning to near-normal golf events was to assess whether it was safe and feasible to allow asymptomatic, SARS-CoV-2 positive golfers to compete in events provided they are fully vaccinated and adhere to enhanced risk mitigating strategies. The aim of this pilot study was to assess whether such protocols were feasible, effective and safe. The objectives were to report the rates and circumstances of positive cases of COVID-19 during two
professional golf events, and any transmission associated with known positive cases being permitted to play.

2.7.2 Methodology

The study design for this study combined the methods from study 5 and 6. It could be described as a pilot, pre-experimental cohort study. Again, the purpose of this was to assess the processes and safety of a new protocol at professional golf events in relation to isolation measures during COVID-19. Given the pilot nature of the study, results should be taken with caution and not applied to a widespread population without performing an appropriate larger, well-powered study first. Following discussion with the National Institute of Communicable Disease in South Africa, this prospective cohort study was conducted during two professional golf events from 7 February to 20 February 2021 in South Africa; Dimension Data Pro Am and the Bain’s Whiskey Cape Town Open. Participants included all players and their caddies competing in the event. Incidence was again measured in ‘person-episodes’ defined as attendance at the golf facility for the duration of the event. Rapid antigen testing was required on entry into the event and an RT-PCR was performed if any person later developed symptoms. Daily symptom and contact history checklists were completed online prior to admission to the event. Abnormalities were followed up by the COVID-19 operations team which was led by the tournament doctor.

A full symptom and contact history was taken when a person returned a positive SARS-CoV-2 test. Confirmatory RT-PCR testing was performed.
Where someone was positive and asymptomatic but had completed a course of vaccination with a WHO approved vaccine course, they were permitted to participate while being outdoor and socially distanced but would isolate at all other times. Contact tracing was conducted in line with WHO guidelines, with risk mitigation policies put in place. Although South African legislation did not require additional measures for close contacts, the legislation did specify that event organisers should take appropriate measures to reduce risk.

Symptomatic players with a positive result were informed as well as the host public health authority and ensured immediate isolation was undertaken. For vaccinated, asymptomatic players with a positive result, they were allowed to compete with encouragement of hand hygiene, social distancing and using outdoor spaces and would isolate when not competing. For unvaccinated players, they were asked to isolate if they returned a positive test, regardless of symptom status.

2.7.3 Results
There was a total of 378 player episodes and 378 caddie episodes during the study period. No players or caddies voiced any opposition to their implementation. Three accredited persons (0.4% of person episodes) tested positive during the study period. This included two players and one caddie, all of whom were asymptomatic at the time of testing. Follow up RT-PCR testing was also positive. They were able to compete and required no medical treatment. There was one high risk contact identified who had shared
accommodation with a positive player immediately prior to the event. This contact was fully vaccinated and returned seven consecutive negative tests and was able to compete. There were no further positive tests associated with the event.

2.7.4 Conclusion
While complying with the law, this study demonstrated that with risk assessment and risk mitigation in place, asymptomatic SARS-CoV-2 positive players and caddies can compete in professional golf events safely. This led to less disruption for both the players, caddies and tournament organisers. This study must be considered in light of its limitations. The daily incidence of COVID-19 in George and Cape Town at the time was 2 per 100,000 of the population. This was lower than previous studies and some other countries at the time. Therefore, these results may not be transferable to other regions. In addition, a longer follow up study would be required to validate these methods. Golfers have also demonstrated throughout the pandemic a general ability to comply with guidelines and regulations, which may or may not apply to other sporting populations.

2.7.5 Contribution to knowledge base
We demonstrated from this study that a risk assessment and risk reduction approach was practical and feasible in a controlled setting, and allowed fully vaccinated, asymptomatic persons with SARS-CoV-2 to participate in golf compared with standard isolation. Risk assessment and control measures can
enable persons to work or compete in professional golf events, where previously this may not have been possible. This did not appear to be associated with increased transmission, or other negative health outcomes and previous research has shown there to be no health risk to the positive individual during light-to-moderate physical activity when asymptomatic for the disease.\textsuperscript{97}

It is possible that the findings of this study encouraged other sports and countries to allow asymptomatic persons with SARS-CoV-2 to participate in activities that are outside and socially distanced. Unforeseen benefits of this strategy may also encourage workers and the general public to be more willing to declare positive tests and engage in screening if they appreciate they will not have to fully isolate if asymptomatic, but rather modify behaviours.

2.7.6 Student contribution

My involvement in this paper included study idea, structuring of data collection and the analysis of the data. I wrote and revised each draft of the manuscript under the guidance from Prof. Murray and made the appropriate amendments to the article following the reviewers’ suggestions.
Retuning persons with SARS-CoV-2 to the field of play in professional golf: a risk assessment and risk reduction approach

Patrick Gordon Robinson,1,2 Andrew Murray,2 Graeme Close,1 Danny Glover,1 Wimpie J Du Plessis1

ABSTRACT

Objectives This pilot study aimed to see whether a risk assessment and risk reduction approach was a practical and feasible approach, as compared with standard isolation for fully vaccinated, asymptomatic persons positive for SARS-CoV-2.

Methods This prospective cohort study included all players and caddies participating in two large professional golf events from 7 to 26 February 2022 in South Africa. Fully vaccinated persons testing positive who were asymptomatic were subject to risk assessment and risk reduction measures to prevent the integrity of the event. Asymptomatic individuals who could socially distance in outdoor areas were allowed to participate. Close contacts were subject to daily rapid antigen tests and asked to prioritise outdoor space.

Results The protocols put in place for the events were practical, feasible, and well accepted by event participants and staff during the study period. There was a total of 376 player-week episodes and 379 caddie-week episodes during the study period. Three persons tested positive while registered at events during the study period (9.4% of person episodes). The positive tests were returned from two players and one caddie, all of which were asymptomatic at the time of testing. There was one high-risk contact who consistently returned negative antigen tests. There was no evidence of transmission.

Conclusions The approach was practical and feasible. A risk assessment and risk reduction approach allowed fully vaccinated asymptomatic persons with SARS-CoV-2 to participate in golf, an outdoor sport where social distancing is possible, compared with standard isolation.

INTRODUCTION

SARS-CoV-2 was identified in December 2019 following an outbreak in Wuhan, China.1 The WHO declared a Public Health Emergency of International Concern in January 2020, and as of April 2022, the virus continues to spread rapidly. The policy response has been to embark on the development and deployment of vaccines and tests, and place restrictions aiming to mitigate the effect of the virus and limit its spread while dynamically assessing risk. In the absence of effective vaccines and with limited testing, initial restrictions were extensive, labelled as ‘lockdown’, in many countries and territories. Many countries recognised that socially distanced outdoor activities were low risk and reintroduced these ahead of the release of other restrictions.4 Although societal levels of physical activity have decreased during the pandemic,7 golf participation has increased globally by nearly
10% during this period,

adopts an outdoor sport where social distancing is possible. Recent reviews have shown golf to be a low-risk environment for viral transmission and this has been supported at a policy level.

Golf provides on average 4.5 METs, with tasks equating to a moderate intensity level of activity. Early measures to participate in sport during the COVID-19 pandemic began with outdoor, socially distanced physical activity being permitted when tight restrictions ‘lockdown’ were in place, recognising the health benefits of physical activity and low risk associated with outdoor sports.

International sport then returned behind closed doors, following WHO and Sport Specific Guidance with risk assessment and risk reduction measures helping avoid any excess transmission. Events then allowed spectatorship, with the 149th Open Championship and other golf events generally found not to be associated with excess transmission when participants were subject to COVID-19 status certification (proof of vaccination or recent negative test).

In parallel to this, daily testing and risk mitigation for close contacts of those with COVID-19 were introduced in golf sport and wider workplace settings. This was not associated with excess transmission compared with standard isolation.

International sporting and cultural events organised events managed to follow WHO guidance on mass gatherings following careful risk assessment and risk reduction strategies. Typically, these events returned in 2020 “behind closed doors”, with no live audience, and very high levels of risk mitigation, oversight and testing, and without contributing to increased transmission.

Key non-pharmaceutical interventions have been implemented at international golf events since golf returned in 2020. These included social distancing, mask use in all shared indoor areas, enhanced hygiene, mandatory online education, daily symptom and contact history checks, and regular reverse transcriptase PCR (RT-PCR) testing. Rates of SARS-CoV-2 infection and transmission were extremely low during 2020, with closed-loop or ‘bubble’ environments.

With vaccines being deployed at scale, restrictions to daily life and sporting events changed, live audiences returned and international travel was limited in 2021 than it had been in 2020. Studies showed European Tour Group events maintained low rates of transmission, and in keeping with other sport sectors, were able to safely allow close contacts to work (as opposed to standard isolation) with enhanced protocols in place.

The Omicron variant led to further uncertainty for professional sporting events. This variant was fast spreading with a degree of vaccine escape. However, its clinical impact for each case was less severe than the Delta variant and overall, three doses of vaccine were shown to be effective against reducing illness severity and death. In 2022, some countries altered policy whereby persons testing positive for SARS-CoV-2 are not required to isolate, but are advised to follow specific guidelines to decrease viral transmission risk. South Africa announced that effective from 1 February 2022, persons who were asymptomatic and tested positive would not be required to isolate.

Recognising these changes, the Sunshine Tour, Challenge Tour, DP World Tour and Ladies European Tour worked with the host national government, health authorities and technical experts to permit asymptomatic persons testing positive for SARS-CoV-2 to participate and work at their professional golf events. While this benefits persons in being able to do their job, protocols and safe management practices were applied, to mitigate risk to others at the event. The purpose of this prospective study was to apply these protocols across two events, piloting whether the protocols were feasible and practical, and assessing transmission, outcomes of contacts, hospitalisation and serious health outcomes from available data among participants at the events.

METHODS

Protocols to permit asymptomatic, vaccinated persons positive for SARS-CoV-2 were developed by health and safety, and medical professionals working for the Sunshine Tour and European Tour Group, in collaboration with the Ministerial Advisory Committee and National Institute for Communicable Diseases (NICD) in South Africa. This prospective cohort study implemented these protocols and included all players and caddies participating in two professional golf events from 7 February to 20 February in South Africa. Persons not holding accreditation for the Sunshine Tour or Challenge Tour were not included.

For these events, baseline mitigation policies against COVID-19 were in place including:

1. Optimising the use of outdoor space.
2. Advice regarding social distancing.
3. Mask use in shared indoor space and where social distancing is not possible.
4. Maximal ventilation of indoor areas.
5. Daily checking of symptoms and contact history.
6. Encouragement of vaccine uptake by players and caddies, and mandate of vaccine to all others on-site.

Each event duration (practice and competition) was 6-8 days. A ‘person episode’ was defined as attendance at the golf facility for the duration of the tournament.

Screening, testing and processing

Rapid antigen testing was performed on entry into the event and an RPP-PCR was performed if players later developed symptoms. Each day, a symptom and contact history checklist were completed online through an application (HealthDocs, South Africa) prior to admission to the event. Abnormalities, or positive COVID-19 were followed up by the COVID-19 operations team.

Feasibility and practicality

Players, caddies and event staff were briefed on the protocols. Daily meetings were conducted to maintain
protocols. Event COVID-19 team and medical officers were interviewed to determine practicality and feasibility.

Positive cases

When a person returning a positive SARS-CoV-2 test was identified, a full symptom and contact history was taken. Persons considered high risk or direct contacts (as per the WHO guidelines) were required to do daily lateral flow testing and to maximise the use of outdoor areas. Where someone was positive and asymptomatic but had completed a course of vaccination with a WHO-approved vaccine course, they were permitted to participate using the "asymptomatic positive case protocol" (online supplemental appendix 1). COVID-19 symptoms were defined as per NICD and Ministerial Advisory Committee in South Africa which included a new continuous cough, a fever and new shortness of breath. Screening was performed using a nasal swab taken by supervised self-swabbing. For any positive rapid antigen test in an asymptomatic individual, confirmatory PCR testing was performed. Contact tracing was conducted in line with WHO guidelines, with risk mitigation policies put in place. Although South African legislation did not require additional measures for close contacts, the legislation does specify that event organisers should take appropriate measures to reduce risk. For these events, local guidance required all participants to take a minimum of one negative rapid antigen test on arrival. For symptomatic players with a positive result, the lead technician/event doctor informed the person and host public health authority and ensured immediate isolation was undertaken. For symptomatic players with a negative result, they were allowed to compete with encouragement of hand hygiene, social distancing and using outdoor spaces. For unvaccinated players, they were asked to isolate if they returned a positive test, regardless of symptoms status.

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Population COVID-19 rates

All national rates of COVID-19 were reported as new cases per day per 100,000 and extracted from the Our World in Data/University of Oxford site.

RESULTS

During the study period, there were two professional golf events conducted in South Africa. There was a total of 378 player episodes and 378 caddie episodes during the study period.

Feasibility and practicality

Players, caddies and event staff were briefed on the protocols, with no players or caddies voicing any opposition to their implementation. COVID-19 team and medical officers did not report any increased burden of work beyond the initial briefings.

SARS-CoV-2 transmission

Three accredited persons tested positive while at events during the study period (0.4% of person episodes). The positive tests were returned from two players and one caddie, all of whom were asymptomatic at the time of testing. Positive antigen tests were confirmed with RT-PCR on-site. During these events, there were 15 players who declared non-defining symptoms, for example, headache or sore throat. All tested negative on rapid antigen testing. There was no transmission of COVID-19 during the first event, with all subjects testing negative on entry testing for subsequent events, and no playing partners developing symptoms. Three positive participants were provided with medical surveillance but did not require any treatment or required hospital admission.

Contacts

One person was classified as a high-risk contact, while monitoring was conducted on the caddies and playing group of the positive participants (despite these persons being socially distanced). The individual defined as a high-risk contact had shared accommodation with a positive player immediately prior to the first event of the study. They were fully vaccinated, asymptomatic and tested negative on antigen testing daily for 7 consecutive days post-exposure. A summary of findings can be seen in figure 1.

Local COVID-19 rates

The number of players per event and local rates of COVID-19 at the time of the tournament can be seen in table 1. Local COVID-19 rates were reported on the date of the first day of the event. If this was not available, a weekly average was used. The number of daily cases per 100,000 of the population during the first and second event was 2 per 100,000 (table 1), although case ascertainment is thought to be <20% in this phase of the pandemic in South Africa.

DISCUSSION AND COMPARISON WITH THE LITERATURE

In this study, we have piloted the feasibility and practicality of returning persons positive for SARS-CoV-2 to an outdoor and socially distanced field of play in a low-humidity environment. Preliminary safety and transmission data were also collected. This follows a gradual decrease in restrictions from an initial lockdown, by reviewing available literature, studying knowledge gaps and implementing evidence-based strategies based on this science while also considering how to support the viability of sports events. Risk assessment and risk reduction measures can allow persons to work and professional sports to function optimally, where standard isolation may be substantially disruptive and where human and technical resource is sufficient to support these processes. When the current study protocol was described to athletes, there was very strong support. They frequently highlighted the outdoor nature of the sport and their nervousness regarding
antigen/RT-PCR screening which had caused many persons to miss events due to asymptomatic positive tests. This has been a cause for clinical anxiety in some.

To our knowledge, this is the first study to assess the return of athletes who are positive for SARS-CoV-2 to the field of play. There has been much discussion about long-term strategy regarding COVID-19 and the balance between minimising risk of transmission and the harms that restricting individuals and society has. For a sportsperson, periods of isolation, when feeling entirely well, is reported to negatively impact the well-being and ability to work for athletes.

Professional sport has collaborated with the WHO, national governments and across different sports to recognise the requirement to continuously review and update health protocols and strategies. SARS-CoV-2 rates, vaccination rates and the policy response of governments have varied, and sports participants have abided by differences in regulations/guidelines in the host country of competition. Sport has worked with governments to study a proposed change and implement them in practice. Using the risk assessment and risk reduction approach in this study, three persons positive for SARS-CoV-2 were able to participate. The ability for persons to participate in these events was beneficial for them and for the events themselves. Isolation in foreign countries, distant from families and friends, may have potential negative effects on participants mental and physical health. There is no evidence of health risk to the positive individual during light to moderate physical activity when asymptomatic for the disease.

It is possible that the findings of this study will encourage other sports and countries to allow asymptomatic persons with SARS-CoV-2 to participate in activities that are outside and socially distanced. The available evidence suggests outdoor sporting environments carry very little risk of transmission. Unforeseen benefits of this strategy may also encourage workers and the general public to be more willing to declare positive tests and engage in screening if they appreciate they will not have to fully isolate if asymptomatic, but rather modify behaviours. However, the physiological demands of exercising while SARS-CoV-2 positive must be considered in the light of disease severity as well as the environmental conditions such as heat and humidity.

Limitations

This study has a number of limitations. It has been shown to be practical and feasible in a setting where COVID-19 officers are immediately available, and able to put in place risk assessment and risk reduction measures, in a country where it is legal not to self-isolate if asymptomatic. The dominant variant during this period of study was Omicron, which has many differences to previous variants. Rates of full vaccination according to WHO criteria among attendees were >90%. In environments where this is not the case, rates of hospitalisation or negative health outcomes may increase. Furthermore, we acknowledge that case ascertainment was lower in South Africa during the time of this study compared with some European countries, as the NICD prioritised asymptomatic screening, which has subsequently been mirrored in many European countries.

This study also assessed only two sporting events, with 756 subject episodes weeks and a larger, long-term follow-up study would be required to better explore

![Figure 1 Visual summary of the results of returning persons with SARS-CoV-2 to the field of play in professional golf.](image)

Table 1 Schedule of included events and local COVID-19 rates

<table>
<thead>
<tr>
<th>Event</th>
<th>Location</th>
<th>Players (no)</th>
<th>Date of event</th>
<th>National daily COVID-19 incidence per 100 000 of population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension Data Pro Am</td>
<td>George, South Africa</td>
<td>162</td>
<td>7–13 Feb 2022</td>
<td>2</td>
</tr>
<tr>
<td>Bain’s Whisky Cape Town Open</td>
<td>Cape Town, South Africa</td>
<td>216</td>
<td>14–20 Feb 2022</td>
<td>2</td>
</tr>
</tbody>
</table>

effects on transmission, hospitalisation and death as well as achieving a longer follow-up of participants to understand the true health implications of the protocol such as long COVID. Golf is a sport where the athletes are generally rules-oriented and compliant, and where social distancing is possible, so conclusions should be drawn with caution for other sports and settings, and would not apply to indoor settings where risk of airborne spread has been demonstrated to be much higher than outdoors environments. In addition, careful consideration should be made on a case-by-case basis particularly if the sporting activity requires vigorous intensity physical activity.

CONCLUSION
A risk assessment and risk reduction approach was practical and feasible in this setting, and allowed fully vaccinated, asymptomatic persons with SARS-CoV-2 to participate in golf compared with standard isolation. Risk assessment and control measures can enable persons to work and professional sports events to go ahead, where previously this may not have been possible. This did not appear to be associated with increased transmission, hospital admissions or other negative health outcomes.

Twitter Andre Murray @CowanMurray

Acknowledgements
Colleagues at ATP, PPA, PA, the ICI, PGA Tour and World Rugby have been instrumental in shaping risk assessment and risk mitigation policies with professional golf throughout the pandemic. Colleagues at the Ministerial Advisory Committee (MAC) and the National Institute for Communicable Diseases (NICD) ensured cooperation with legislation in South Africa. We thank Justin Taylor and Joanne Durman for their contribution to the data collection.

Contributions: PA wrote the manuscript; PA, and reviewed the final manuscript. AR conceived the study idea, wrote the manuscript; collected, reviewed the final manuscript. GC edited and reviewed the final manuscript. WEP was responsible for data collection, edited and reviewed the final manuscript.

Funding
The authors have not declared a specific grant for this research from any funding agency in the public, commercial, or not-for-profit sectors.

Competing interests
ARC, GC and WEP have paid roles with the DP World Tour, Ladies European Tour and Challenge Tour. WEP has a paid role on the Sunshine Tour.

Patient and public involvement
Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Patient consent for publication
Obtained.

Ethics approval
The study including human participants and ethical approval was granted by the local ethics committees of Liverpool John Moores University (121/08/006). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review
Not commissioned; externally peer reviewed.

Data availability statement
Data are available upon reasonable request.

Supplemental material
This content has been supplied by the authors. It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the authors and not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error or omission resulting from translation and adaptation or otherwise.

Open access
This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon the work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.
Appendix 1. Protocol Development for fully vaccinated asymptomatic SARS-CoV-2 positive participants in Professional Golf tournaments.

1. Background

An amendment of the Regulations, government notice R1715, to the Disaster Management Act was published in the Government Gazette no. 45855 on February 01, 2022
Regulation 7 (1) was amended as follows:
“Any person who is a confirmed laboratory positive COVID-19 case and is asymptomatic is not required to isolate”
Professional Golf Tournaments resumed from August 2020 and have been safely played during the peaks of the four COVID-19 waves in South Africa and countries throughout the world.
Research conducted throughout two seasons on the DP World Tour Golf, showed no evidence of transmission on the Field of Play, but rather from shared accommodation, shared transport, and shared indoor space.
The observations by scientists during and after the Omicron wave were that, despite the contagiousness of the variant, fully vaccinated persons who became infected, were in the main asymptomatic or experienced minor symptoms.
Professional athletes are currently withdrawn from participation when a positive test result is returned and are not allowed to participate in a tournament.
The withdrawal of an asymptomatic, healthy athlete due to a positive COVID-19 test has resulted in mental health concerns to the point where the athletes experience anxiety symptoms when tested because feeling healthy does not guarantee participation. The determination for participation is the outcome of a SARS-CoV-2 Antigen/PCR test.
The nature of the sport of golf lends itself to implement a protocol for positive participants being an outdoor sport where physical distancing from other persons is possible.
The Sunshine Tour/Challenge Tour/DP World Tour have developed the protocol below which will allow for the participation of fully vaccinated athletes and caddies who are asymptomatic but tested positive at its tournaments.

2. Protocol Development

2.1 Risk assessment and Risk mitigating processes

2.1.1 Health risk and Vaccination status.
Only fully vaccinated participants can be enrolled in the Asymptomatic SARS-CoV-2 Positive Participant Protocol.

2.2.2 Protection of Personal Health Information (PHI)
The positive participant must give informed consent for his/her SARS-CoV-2 status to be revealed to, his/her caddie, other participants in the group in which he/she plays, and the Rules Officials assigned to the tournament.
2.2.3 Areas/situations where physical distancing criteria are stipulated

(i) Warm-up areas
Driving range and practice greens.
The positive participant MUST maintain physical distancing of > 3 metres from any other individual when on the practice range
The positive participant may only use the practice green when physical distancing of > 3 metres is possible.

(ii) On the course
Golf courses span over approximately 36 hectares and there are only two areas on the course where the golfers congregate which are addressed below.
- **Teeing area**
The positive participant must ensure that physical distancing of > 5 m is maintained at all times between him/her and the fellow participants. In order to achieve this the positive status of the participant must be divulged to the fellow participants to assist the positive participant in maintaining this distance
- **Greens/ Putting areas**
The positive participant must ensure that physical distancing of > 5 m is maintained at all times between him/her and the fellow participants. In order to achieve this the positive status of the participant must be divulged to the fellow participants to assist the positive participant in maintaining this distance

(iii) Interaction during a round where physical distancing will be less than 5 metres
- **Rules Officials**
The positive participant’s SARS-CoV-2 status must be shared with the Rules Officials assigned to the tournament. Should the positive participant need a ruling the participant and the Rules Official must adhere strictly to the NPI requirements with the additional precaution that physical distancing of not less than 3 metres are maintained during this process.
- **Caddie of Positive Player**
The caddie must be informed of the SARS-CoV-2 status of the player. The player’s caddie MUST be fully vaccinated to continue with his/her duties. The caddie has the option to elect not to continue with his/her duties. Should the caddie not be vaccinated or do not wish to continue, the player can use a different caddie.
The caddie and the player must maintain a physical distancing of >5 metres except during the period of shot preparation on the course. During this period the caddie must wear his/her mask. The duration of the interaction during shot preparation where physical distancing of < 5 metres will occur may not be exceed 2 minutes.
- **Player of Positive Caddie**
The player must be informed of the COVID-19 status of the caddie. A fully vaccinated player has the option to elect not to continue using the caddie. An unvaccinated player must select a new caddie.
The caddie and the player must maintain a physical distancing of >5 metres except during the period of shot preparation on the course. During this period the caddie must wear his/her mask. The duration of the interaction during shot preparation where physical distancing of < 5 metres will occur may not exceed 2 minutes.

- Score recording

Score recording is normally set-up indoors and a positive participant may not enter any closed environments. Alternative methods to submit scores such as an electronic copy of the signed scorecard to be submitted and telephonically verification the score should be considered. The Tournament Director to communicate to the CMO/CCO the procedure to be followed at the event.

3. Positive test result

Should a participant in a professional golf tournament return a positive Antigen/PCR test result and is assessed to be asymptomatic and physically unaffected by the infection, the participant will be given the option to follow the Protocol for fully vaccinated asymptomatic SARS-CoV-2 positive participants and continue with participation in the event. The Medical Officer/Compliance Officer is responsible to ensure strict adherence to the protocol and responsible to obtain the informed consent as required for the sharing of PHI.

1. Process
   - Positive test result

Should a Participant in a professional golf event tests positive using an Antigen/PCR test the symptomatology needs to be assessed and should the participant be asymptomatic he/she will be allowed to participate in the event.

- The Chief Medical Officer (CMO)/Covid Compliance Officer (CCO) must inform the participant of the requirements for further participation and obtain the informed consent from the participant that his/her SARS-CoV-2 positive status may be shared with selected persons in the event.

2. Protocol requirements:

- Participant must be vaccinated
- Participant must give informed consent that his/her SARS-CoV-2 status may be shared with pre-determined individuals
- May not share a room
- Must self-drive
- May only commute between their accommodation and the tournament venue
- May not enter any closed environments while at the course.
- Must ensure that > 3 metre physical distancing is maintained on the practice range and the practice green
- Must adhere to the physical distancing requirements of > 5 m while on the course, except
• during a Ruling where the Rules Official must adhere strictly to the NPI requirements with the additional precaution that physical distancing of not less than 3 metres is maintained during this process.
• during the shot preparation with his/her caddie. During this period the caddie is required to wear his/her mask. The duration of the interaction during shot preparation where physical distancing of < 5 metres will occur may not be exceed 2 minutes.

3.1 Sharing of positive status of participant during the event.
The CMO/CCO must inform the TD the positive case and clarify
• the process of communication with relevant role players who need to be informed.
• the process to be followed for scoring and score recording

3.2 At the start.
Verbatim to participants in the positive participant’s group by CMO/CCO or alternative
➢ If the positive participant is a player:
XXX tested positive for SARS-CoV-2/ COVID-19 and must adhere to the following protocol to ensure a safe environment for all
• Maintain Physical distancing of > 5 metres from other members in the group
• He/she is not required to wear a mask
• He/she is not allowed to exchange scorecards
• We request that you assist the player to maintain his/her physical distancing especially on the teeing area and on the greens

➢ If the positive participant is a Caddie:
XXX caddie of player YYY tested positive for SARS-CoV-2/ COVID-19 and must adhere to the following protocol
• Physical distancing of >5 metres from other members in the group
• When necessary to touch the flag stick or rake will sanitise prior and post touching
• Will wear a mask when < 5 m from any person on the course

3.3 Communication to Officials, Scorers, Starter on the course
XXX on the course in match no YYY tested positive for SARS-CoV-2/ COVID-19.
In terms of the ST protocol for fully vaccinated asymptomatic SARS-CoV-2 positive participants he/she is allowed to play/caddie
The following NPI protocol to be followed by officials when interacting with the player
• Official must wear a mask at all times when interacting with the player
• Maintain physical distancing of > 3 metres when interacting with the player
• Minimise interaction time with the player.
Note: should duration of Interacting with the player exceeds 15 minutes the CMO/CCO must be informed.

This protocol will remain in place until a negative Antigen/PCR test result is returned. The CMO/CCO is responsible to inform the TD of the change in the status of the participant.
2.8 Summary of theme 1

The overarching premise of theme 1 covered a summary and critical analysis of the current literature, recommending methods of golf medicine epidemiology and exploring exposure to illness on the DP World Tour. This theme has contributed novel understandings and data to the field of golf medicine which will add value to future research both locally at our institution but also internationally. The systematic review in study 1 seemed like a practical starting point for injuries in elite golfers. This gave me a solid understanding of the volume and quality of research that was currently published in this area. Other methods such as a scoping review may have been appropriate if there was a less clear research question and the topic was more broad. The review was beneficial in presenting the current research and identifying shortcomings however, the potential take home points of the study were limited by the quality of the research. This manuscript was significantly improved during the reviewer process at BJSM where my own understanding of both incidence and prevalence in sport was greatly strengthened. We did not however, cover the amateur or recreational side of the game and perhaps this would be a more helpful and relevant study to have performed given the volume of players in this cohort compared to elite golf. Previous amateur systematic reviews have been performed and are over 10 years out of date and would likely benefit from being updated. None the less, this was an excellent starting point for understanding injuries in professional golfers.
Study 2 has the potential to have the largest impact of the studies presented in this first theme. The framework and pre-made questionnaires in this consensus statement can be applied to any golf-related study analysing injuries and illnesses in golf. If uptake is successful, it will hopefully facilitate high-level research with homogeneity amongst studies and therefore lead to reliable future work in the form of meta-analyses.

Studies 3 to 7 were not originally planned in my research agenda. I had hoped to move onto epidemiological research in both amateur and professional golf. However, the significance of the COVID-19 pandemic and the impact to both amateur and professional golf meant there was a need to focus our efforts in a way which would have value to the golfing community and the field of public health. It was the goal of myself and Prof. Murray to address some areas we felt could be beneficial to researchers, clinicians, golfing organisations, governing bodies and policy makers. The subjective nature of a narrative review meant I decided to cover golf-related health topics which I felt were most relevant to COVID-19. These included the impact on mental health, risk of transmission, the health benefits of golf during the pandemic and expert advice on mitigating risk specific to the game of golf. One of the most interesting studies highlighted from the review was the impact of well-being and belonging when unable to play golf.\textsuperscript{22} This study nicely highlighted the substantial impact that closing golf courses had on the non-physical aspects of players health. It was an important piece of research to present in the review and it reflected work done at a similar time showing the relationship between
Another key aspect of the review was highlighting the in-vitro study demonstrating the rapid loss of viral load of SARS-CoV-2 on sporting equipment and therefore, the unlikely risk of transmission via such mediums during sport. This research was informative in designing recommendations for the rules of golf during the pandemic.

Studies 4 through 7 evolved from one study to the next based on the most pertinent findings as well as the dynamic nature of the rules and legislation surrounding international professional golf. The first of the epidemiological studies leveraged the infrastructure in place on the DP World Tour to collect rates of COVID-19 at professional golf events across the course of an entire season. The evolution of the following study was born out of the concerns regarding potentially avoidable contact tracing and its disruption on events. A pilot study was initially conducted given the concerns regarding SARS-CoV-2 transmission with more lenient isolation rules, however this was combatted by significant risk-mitigating factors such as day testing, temperature checks, and socially distancing. Once we had confirmation that this study was safe, we then scaled that to the entire season and showed similar reassuring data. The final study was again a pilot of allowing asymptomatic positive patients to participate in professional golf events. This study seemed the natural progression in this theme as we envisaged at some stage players would be allowed to compete provided they were asymptomatic, similar to that of other viral illnesses. Future work would benefit from considerations related to the
impact on mental health during social interaction restrictions and isolation protocols. Feedback from the research highlighted the mental health impact of players not being able to see family for long stretches while in the ‘bubble’ system that was operated.
Chapter 3 Critical review of theme 2: Returning to golf following orthopaedic surgery

3.1 Introduction to theme 2

3.1.1 Introduction

Working in the research fields of injury and illness in golf was exciting and in particular, the work related to COVID-19 on the DP World Tour was an opportunity I was glad to have taken. However, my day job in orthopaedics meant more easily accessible opportunities for research in golf were in this area. As previously mentioned, the link from theme 1 to theme 2 of this thesis came during the 2nd International Congress for Golf and Health when Dr Joel Press, Dr Roger Hawkes and I discussed the possibilities of a prospective study following golfers recovery back to playing following joint replacement. Much of the drive for this was patient lead. By that I mean, patients who play golf commonly ask the physicians and surgeons who are managing their arthritis, if and when they can return to golf following surgery.

Given the large volume of joint replacement performed at the Royal Infirmary of Edinburgh where I work, I felt I was well suited to exploring the research questions regarding how and when patients returned to golf after joint replacement and if golfers themselves were more functional or had greater quality of life before and after surgery compared to non-golfers. Continuing in the similar format to theme 1, my first port of call was to perform a systematic
review of this area of the literature to get a better understanding of what had been done thus far and where the opportunities lay.
3.2 Study 8: Rate and timing of return to golf after hip, knee or shoulder arthroplasty: A systematic review and meta-analysis

Robinson PG, TR Williamson, AD Creighton, J Cheng, AD Murray et al. Rate and timing of returning to golf after hip, knee or shoulder arthroplasty: A systematic review and meta-analysis. AJSM. 2022. Jan 12. PMID: 35019735

3.2.1 Aims and objectives

Joint replacement for osteoarthritis is one of the most effective operations for improving a patient’s quality of life. Osteoarthritis can become debilitating and lead to the inability to participate in golf and it is estimated that up to one in five patients who undergo lower limb joint replacement in Europe are golfers. The lack of participation in golf for those unable to play has been shown to have a significant impact on their belonging, enjoyment and well-being. Although the participants in the aforementioned study were unable to play golf due to the COVID-19 and not because of osteoarthritis, the findings are likely to be translatable.

A number of reviews have been conducted to attempt to assess the rates of return to golf following hip, knee or shoulder arthroplasty. One review was performed over five years previously, did not use PRISMA guidelines and presented their results in a narrative fashion with no pooling of the data. The other review looked specifically at shoulder arthroplasty and did not attempt to meta-analyse their data. Hip, knee and shoulder arthroplasty are often chosen as they are the most commonly performed arthroplasties performed globally.
In the UK there are approximately 175,000 hip and knee arthroplasties performed per annum.\textsuperscript{30}

The aim of the systematic review and meta-analysis was to report the rate and timing of people returning to golf and factors associated with these after hip, knee, or shoulder arthroplasty using the most up to date literature available. The objectives were to 1) critically appraise the relevant research 2) assess the studies for heterogeneity and 3) if possible, use sample size to weight studies and report pooled rates of returning to golf by each surgery type.

3.2.2 Methodology

The study was conducted in line with PRISMA guidelines. A search of PubMed/Medline was performed in March 2021 and was registered with PROSPERO. The flow diagram outlining the selection process of articles can be seen in figure 1 of the manuscript. The search terms and criteria for inclusion were:

Search terms were as follows: ‘(knee) OR (hip) OR (shoulder) AND (golf) OR (sport) AND (arthroplasty)’. The criterion for inclusion was any observational study on golfers returning to the sport after hip, knee, or shoulder arthroplasty. Studies were excluded if they did not examine golf, were review articles, or were not published in the English language. Two virtual meetings were conducted amongst the authors to agree on those variables which
would be extracted from each article. These comprised demographic data, clinical data and golfing performance variables. The primary objective was to report the rate of return to golf after joint arthroplasty. The secondary objectives included; presentation of the demographic data, comparisons of the time to return to golf and postoperative golfing outcomes.

The quality assessment tool used was Quality Assessment Tool for Observational Cohort and Cross-sectional Studies. The assessment tool has previously been recommended for analysing the risk of bias and risk in cohort or cross-sectional studies and it is the tool I am most familiar with for this.

Regarding the meta-analysing of the data, the heterogeneity among studies was tested with the preoperative parameters of age and sex using the I² index based on Cochran Q, with I² >50% deemed heterogeneous. Means were represented with standard deviations and 95% confidence intervals (CI) and weighted by sample size. Random-effects modelling was used to measure overall rates of returning to golf after arthroplasty, time to return to golf, and change in handicap. Tests for subgroup differences were employed to assess for differences in effect size among different types of arthroplasties.

3.2.3 Results
There were 23 studies included for final analysis with publication dates ranging from 1992 to 2021. All studies were retrospective cohort studies or case series. Four studies reported on total hip arthroplasty (THA), six on total knee arthroplasty (TKA) and 14 on shoulder arthroplasty (SA). The mean rate of returning to play was 80% (95% CI, 70 – 89.9) and the mean time to return was 4.4 months (95% CI, 3.2 - 6). Change in handicap was noted in 8 studies with a mean difference of -0.1 (95% CI, -2.4 - +2.2). The breakdown of each arthroplasty was as follows:

**Total hip arthroplasty**

The rate of patients returning to golf was 90% (95% CI, 82%-98%) with a mean time of 4.5 months (95% CI, 3.2 - 5.8). Three studies indicated an increase in golf handicap after THA (+2, +1.4, and +1.1).

**Total knee arthroplasty**

The rate of returning to golf was 70% (95% CI, 39% - 100%) with a mean time of 3.8 months (95% CI, 2.9 - 4.7). Change in handicap was noted by three studies: 2 with an increase (+1.4 and +1.9) and one with a decrease (–0.85).

**Shoulder arthroplasty**

The rate of return to golf after shoulder arthroplasty was 80% (95% CI, 68% - 92%). Rates of return by arthroplasty type were as follows: Total shoulder arthroplasty (TSA), 94.9% (95% CI, 85.7% - 100%); Reverse shoulder
arthroplasty (RSA), 70.5% (95% CI, 32.8% - 100%); and hemiarthroplasty, 52.4% (95% CI, 31.0% - 73.7%) (P = .001). The mean time to return to golf after shoulder arthroplasty was six months (95% CI, 3.7 - 8.4).

3.2.4 Conclusion
This was the first study to pool the data on rates of return to play following hip, knee and shoulder arthroplasty and meta-analyse the results. The study reports a high rate of returning to golf, which is highest after THA and fastest after TKA. However, it also highlights the paucity of prospective data on demographic, surgical, and golf-specific outcomes after arthroplasty. Future studies designed prospectively are required to eradicate response bias and accurately capture golf and patient-specific outcomes.

3.2.5 Contribution to knowledge
This study gives probabilities of returning to golf following the three most commonly performed joint replacement operations. Furthermore, the likely time taken to return to golf and the change in performance can also now be estimated. This gives researchers and clinicians data to both plan future studies and counsel patients in the clinic. Such percentages could be used as power calculations for randomised controlled trials.

This work was presented as a poster at the 2nd International Congress on Golf and Health (July 2022) and won best poster prize at the South-East Scotland Orthopaedic Registrar Research Day (April 2022).
3.2.6 Student contribution

My involvement in this study included the study idea, conception and undertaking the methods, data collection and analysis of the systematic review. I wrote the paper, revised it following co-author feedback, submitted it and revised the manuscript as per reviewers’ suggestions. The meta-analysis was primarily performed by Dr Tom Williamson using R Software. However, through this process I learned the principles of meta-analysis, in particular weighting averages of the pooled intervention effect (in our case by sample size), measuring heterogeneity (in our case by age and sex using the $I^2$ index with Cochran’s Q and manually observing the variation in results between sample sizes of each study) and using appropriate modelling to analyse the pooled data. Finally, using forest plots to demonstrate the summary effect size (for each joint replacement).
Rate and Timing of Return to Golf After Hip, Knee, or Shoulder Arthroplasty

A Systematic Review and Meta-analysis

Patrick G. Robinson,*1,2 MBChB, MSc(Res), Tom R. Williamson,1 MBChB, Andrew P. Creighton,3 DO, Jennifer Cheng,3 PhD, Andrew D. Murray,1,4 MBChB, Heidie Prather,5 DO, Joshua S. Dines,6 MD, Lawrence V. Guiotta,6 MD, Edwin P. Su,7 MD, Joel M. Press,8 MD, Roger Hawkes,9 MBChB, and Nick D. Clement,1 MBChB, PhD

Investigation performed at Edinburgh Orthopaedics, Royal Infirmary of Edinburgh, UK

Background: The physical and mental health benefits of golf are well recognized, and as a moderate-intensity activity, it is an ideal sport for patients after joint arthroplasty.

Purpose: To assess the rate and timing of returning to golf and the factors associated with these after hip, knee, or shoulder arthroplasty.

Study Design: Meta-analysis; Level of evidence, 4.

Methods: A search of PubMed and Medline was performed in March 2021 in line with the 2009 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement. Search terms included sport, golf, and arthroplasty. The criteria for inclusion was any published research article studying return to golf after arthroplasty. Random-effects modeling was used to measure rates of returning to golf for each type of arthroplasty.

Results: A total of 23 studies were included for review. All studies were retrospective in their methodology. The mean age of patients was 66.8 years (SD, 3.37). Four studies reported on hip arthroplasty, 6 on knee arthroplasty, and 13 on shoulder arthroplasty. Among 13 studies, the mean rate of returning to golf was 80% (95% CI, 70%-89.9%). Hip, knee, and shoulder arthroplasty had mean return rates of 80% (95% CI, 82%-88%), 70% (95% CI, 69%-71%), and 80% (95% CI, 68%-92%), respectively. Among 9 studies, the mean time to return to golf was 4.4 months (95% CI, 3.2-6). Change in handicap was reported in 8 studies (55%) with a mean change of −0.1 (95% CI, −2.4 to +2.2). There were no studies presenting factors associated with return to golf.

Conclusion: This is the first meta-analysis of returning to golf after joint arthroplasty. The study reports a high rate of returning to golf, which was greatest after hip arthroplasty. However, the study highlights the paucity of prospective data on demographic, surgical, and golf-specific outcomes after arthroplasty. Future prospective studies are required to eliminate response bias and accurately capture golf and patient-specific outcomes.

Keywords: shoulder replacement; hip replacement; golf; knee replacement; joint replacement in athletes

Golf is played by nearly 60 million people in 200 countries. In 2014, UK golfers spent £4.3 billion on their sport, accounting for 14% of all consumer spending on sport. The sport helps golfers meet the World Health Organization recommendations for physical activity, and the health benefits of golf were well described in a scoping review by Murray et al. with players indicating improved physical and mental well-being.

Joint arthroplasty (JA) is one of the most common and cost-effective operative procedures worldwide and an excellent intervention for patients who have end-stage arthritis. JA leads to reduced levels of pain and improved levels of function. Approximately 175,000 hip and knee arthroplasties are performed in England, Wales, and Scotland each year and about 1.8 million hip and knee arthroplasties in the United States per annum. Arthritis can have a significant effect on a patient's quality of life and prevent golfers from participating in their hobby. An estimated 20% of patients with JAs are golfers. Sorbie et al. studied the effect of golf course closure and opening during the COVID-19 pandemic on well-being and life satisfaction. They reported that belonging, enjoyment, and well-being were significantly associated with...
outdoor course activity and that a sense of belonging and satisfaction increases after golf course reopening. It is likely that these findings are applicable to golfers who are unable to play secondary to arthritis and subsequently return after JA.

This previous reviews analyzed the literature on returning to golf after arthroplasty surgery, however, to our knowledge there has been no meta-analysis of available data reporting factors associated with return and level of return to golf after JA. Swanson et al suggested recommendations from the literature regarding when patients can consider returning to play golf. Yet, this was based on a consensus statement by orthopaedic surgeons regarding sporting activities after arthroplasty and not on clinical studies. In addition, little is known regarding the predictors of returning to golf after arthroplasty. A retrospective study of returning to sport after unicompartamental knee arthroplasty (UKA) vs. total knee arthroplasty (TKA) showed 100% return to golf in those undergoing UKA as opposed to 30% after TKA.

The aims of this systematic review and meta-analysis were to assess the rate and timing of people returning to golf and factors associated with these after hip, knee, or shoulder arthroplasty.

METHODS

A search of PubMed and Medline was performed in March 2021 in line with the 2009 PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) statement. The study was registered in PROSPERO (CRD420 21244928).

Titles and abstracts identified were independently reviewed by 2 authors (P.G.R., T.R.W.), and those not meeting the inclusion criteria were excluded before full-text review. On occasion, when it was not clear from the abstract if studies were of relevance, the full text of the article was subsequently reviewed. Unanimous consensus was met on the inclusion of proposed studies for full-text review by the 2 authors. Full-text studies were evaluated against the inclusion and exclusion criteria. A search of the references was performed of the selected studies to ensure that no other relevant studies were missed.

Search Terms and Criteria for Inclusion

Search terms were as follows: (knee) OR (hip) OR (shoulder) AND (golf) OR (sport) AND (arthroplasty) (see Appendix 1, available in the online version of this article). The criterion for inclusion was any observational study on golfers returning to the sport after hip, knee, or shoulder arthroplasty. Studies were excluded if they did not examine golf, were review articles, or were not published in the English language.

Data Extraction

Consensus from experts in the fields of orthopaedic surgery, sports medicine, and rehabilitation methodology was achieved via 2 virtual meetings on the items that should be extracted from each study. The items for inclusion were as follows: the year of publication; type of study; patient age, sex, handedness, and side of operation; anatomical location, type, and method of joint replacement; surgical approach; primary or revision surgery; other JAs, and patients who were currently awaiting another JA or an orthopaedic consultation about another painful joint.

Postoperative golf-specific data included handicap, golfing ability, frequency of play, time passed since playing golf, golfing mobility, golfing satisfaction, and whether golfing activity was defined. Postoperative golf-specific data also included the number of patients returning to golf, the time to return to each stage of golf, and symptoms during and after golfing.

Outcome Measures

The primary objective was to report the rate to return to golf after JA. Secondary objectives included presenting the demographic data and comparing the time to and rate of return to golf among patients by type of JA. Postoperative golfing outcomes and change in outcomes were analyzed if possible.

Quality Assessment

All studies were quality assessed by 2 authors (P.G.R., T.R.W.) using the Quality Assessment Tool for

---

1 Address correspondence to Patrick G. Robinson, MBChB, MSc(Res), Edinburgh Orthopaedics, Royal Infirmary of Edinburgh, 16 Little France Crescent, Edinburgh, EH16 4SA, UK: email: patrick.robinson@hsc.nhs.uk; Twitter: @PGRobbins;
2 Edinburgh Orthopaedics, Royal Infirmary of Edinburgh, Edinburgh, UK;
3 Department of Physiatry, Hospital for Special Surgery, New York, New York, USA;
4 Public Health and Medical Department, The R&A, St Andrews, UK;
5 Department of Sports and Exercise/Physical Activity for Health, University of Edinburgh, Edinburgh, UK;
6 Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, New York, USA;
7 University College London, London, London, UK;
Submitted May 1, 2021; accepted September 14, 2021.

One or more of the authors has declared the following potential conflict of interest or source of funding: J.S.D. has received consulting fees from Afinex, Merck Sharp & Dohme, and Trice Medical and royalties from Arthrex and Con Med. J.S.D. is also on the board of VerteFix. L.V., D. has received royalties from Zimmer Biomet; consulting fees, speaking fees, and royalties from Exactech; consulting fees from Delphy Synthesis Products, Medical Device Business Services, and Zimmer Biomet; support for education from CROM surgical solutions; and speaking fees from Smith & Nephew. E.P.S. has received consulting fees from Smith & Nephew and United Orthopedics; royalties from Kycera Inc., United Orthopedics Inc., Smith & Nephew, and OrthAlign Inc.; and support for education from B Braun and Elite Orthopedics. E.P.S. also holds equity in Engage Ltd. ASCISIM has not conducted an independent investigation on the ODF and disclaims any liability or responsibility relating thereto.
Observational Cohort and Cross-sectional Studies (National Institutes of Health). The assessment tool comprised 14 questions to enable allocation of a score to each article, expressed as a percentage of yes responses. If there was disagreement regarding the scoring of a study, consensus was met after discussion among assessors and the senior author (N.D.C.).

Statistical Analysis

Statistical analysis was performed using SPSS 24 software (IBM) and R statistical software. Heterogeneity among studies was tested with the preoperative parameters of age and sex using the $F$ index based on Cochran Q, with $F > 60$% deemed heterogeneous. Means were represented with standard deviations and 95% CIs and weighted by sample size. Random-effects modeling was used to measure overall rates of return to golf after arthroplasty, time to return to golf, and change in handicap. Tests for subgroup differences were employed to assess for differences in effect size among types of arthroplasty.

RESULTS

There were 2120 articles identified in the initial search of databases and reference lists. After initial screening of titles and abstracts, 90 articles met the inclusion criteria for review. On full-text screening, 7 studies were removed (Figure 1). A list of studies that met the criteria and their publication years are illustrated in Table 1. The year of publication ranged from 1992 to 2021. All studies were retrospective cohort studies or case series. An assessment of each article’s quality is available in Appendix 2 (available online).

The mean age of patients was 66.8 years (SD, 3.37). Four studies reported on total hip arthroplasty (THA), 6 on knee arthroplasty, and 14 on shoulder replacements, of which 4 reported on hemiarthroplasties, 7 on total shoulder arthroplasties, and 4 on reverse shoulder arthroplasties (RSA). For return to golf, 13 studies indicated a mean rate of 86% (CI, 89–89.3) (Figure 2). Nine studies cited the mean length of time after surgery that players returned to golf, which was 4.4 months (95% CI, 3.2–6) (Table 2). Change in handicap was noted in 8 studies with a mean difference of $-0.1$ (95% CI, $-2.2$ to $+2.2$).

Outcomes

Total Hip Arthroplasty. There were 250 patients who had undergone THA. The rate of patients returning to golf was 96% (95% CI, 92–98%) (Figure 2). Of those who returned, the mean time after surgery was 4.5 months (95% CI, 3.2–5.8). Three studies indicated an increase in golf handicap after THA ($+2$, $+1.4$, and $+1.1$).

Total Knee Arthroplasty. There were 438 patients who underwent knee arthroplasty. The rate of returning to golf was 70% (95% CI, 39–100%) (Figure 2). Return to golf after TKA was achieved at a mean 3.8 months (95% CI, 2.9–4.7). Change in handicap was noted by 3 studies: 2 with an increase ($+1.4$ and $+1.9$) and 1 with a decrease ($-0.8$). One study compared TKA and UKA, citing a 90% rate of return to golf after TKA as opposed to 100% after UKA. If UKA cases were excluded, the mean rate of return to golf after TKA was 90.9% (95% CI, 17.8–100%).

Shoulder Arthroplasty. There were 331 patients undergoing shoulder arthroplasty (TSA). Of these, 130 underwent TSA (1 bilateral); 105, RSA; and 36, hemiarthroplasty. Arthroplasty type was not reported in 62 patients. The rate of return to golf after shoulder arthroplasty was 80% (95% CI, 68–92%) (Figure 2). Rates of return by arthroplasty type were as follows: TSA, 94.9% (95% CI, 85.7–100%); RSA, 70.5% (95% CI, 52.8–100%); and hemiarthroplasty, 52.4% (95% CI, 31–73.7%) ($P = .001$). One comparative study directly compared hemiarthroplasty with TSA and showed rates of return of 58% and 85%, respectively. The mean time to return to golf after shoulder arthroplasty was 6 months (95% CI, 2.7–8.4).

Papadakis et al. assessed golfing performance after press-fit RSA and showed that those receiving surgery on the dominant arm improved their handicap by 2.1, as compared with a 5.8 for the nondominant arm. They also showed that those receiving RSA in the dominant arm had a mean 13.6-yard improvement on their driving distance, as

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram outlining article selection process.
compared with 8.5 years for those receiving nondominant arm RSA. Changes in handicap were reported in 2 studies and reduced by 1.4 and 4.9 strokes. Two studies examined driving distance: 1 described an increase in distance by 12.2 yards and 1 an increase by 8.3 yards. There was a 10% to 20% rate of mild/fair pain or ache during golf after surgery and a 24% to 50% rate of mild/fair pain or ache after golf. Once study indicated the need for 14% of patients to take nonsteroidal anti-inflammatory drugs during or after golf for analgesia.

Variables

Demographic and Surgical Reporting. Six studies (36.1%) reported on the handedness of the player and 8 (53.8%) on the side of the operation. Fifteen studies (92.3%) indicated the type of joint replacement used, but no study described the method of surgery. One study (6.3%) described the surgical approach. Four studies (17.4%) included revision cases in their cohorts. Three studies (13%) stated whether patients were awaiting consultation regarding other joint surgical procedures or experiencing other joint pains that limited their golf, while 4 studies (17.4%) determined whether patients had previous JAs.

Golf-Related Reporting. Four studies (17.4%) reported on preoperative handicap, 6 (31.7%) on postoperative handicap, and 8 (39.1%) on change in handicap. The ability to play golf preoperatively was examined in 1 study (4.4%), preoperative golfing frequency in 4 (17.4%), and preoperative golfing ability in 2 (8.7%). Just 3 studies (13.5%) clearly defined criteria for “returning to golf.” One study described it as playing a full round, 1 as competing in handicap-qualifying events (i.e., competitions), and 1 detailed each aspect of returning to golf (putting, chipping, irons, etc.). Ten studies (43.5%) did not cite the rate of returning to golf after arthroplasty. No study noted when the patients played their last rounds before surgery or their levels of satisfaction while golfing preoperatively. Two studies (8.5%) reported on golfing satisfaction postoperatively. Five studies (21.7%) described postoperative performance-related statistics, such as driving distance. See Appendix 3 for description of all referenced studies.

DISCUSSION

This is the first meta-analysis analyzing the outcomes related to returning to golf after hip, knee, or shoulder arthroplasty. The key finding of this study was that the overall rate of returning to golf after arthroplasty was 89%, which was highest after TKA, followed by shoulder arthroplasty and TKA. The mean time to return to golf was 4.4 months and was fastest after knee arthroplasty.
and the mean postarthroplasty change in handicap was −0.1. Finally, there is an absence of prospective high-level evidence describing golfers’ return to play after arthroplasty, with many studies failing to report key surgical and golf-related variables.

Patients returned to golf most frequently after THA, with 90% of patients doing so, followed by 80% of patients after shoulder arthroplasty and 75% after knee arthroplasty. Patients who did return to golf after knee arthroplasty did so the fastest (mean, 3.8 months), followed by THA (4.5 months) and then shoulder arthroplasty (6 months). This prolonged time to return after shoulder arthroplasty may reflect greater restrictions in range of movement at the shoulder, which may take up to 6 months to reach maximum postoperative range.43 In addition, the complex demands of the joint with regard to range of movement are likely to be higher than in the lower limb.

When comparisons were made among types of shoulder arthroplasty, we found that return-to-golf rates were highest after TSA (84.9%), with lower rates seen after RSA (70.6%) and hemiarthroplasty (52.4%). This is in keeping with a meta-analysis by Liu et al.32 who reviewed rates of returning to sport after shoulder arthroplasty. The authors cited the highest rates after TSA and the lowest
TABLE 2
Golf-Specific Variables After Arthroplasty

<table>
<thead>
<tr>
<th>First Author</th>
<th>Return to Golf, %</th>
<th>Mean Time to Return to Golf, mo</th>
<th>Handicap Change</th>
<th>Symptoms, No. (%)</th>
<th>During Golf</th>
<th>After Golf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malinin19</td>
<td>NA</td>
<td>4</td>
<td>+1.1</td>
<td>13 (15.7), mild ache</td>
<td>29 (34.9), mild ache</td>
<td></td>
</tr>
<tr>
<td>Malinin19</td>
<td>NA</td>
<td>5</td>
<td>+1.9</td>
<td>13 (11.3), mild ache</td>
<td>3 (3.7), continuous pain</td>
<td></td>
</tr>
<tr>
<td>Jensen20</td>
<td>96</td>
<td>4.3</td>
<td>–4.9</td>
<td>2 (1.7), continuous pain</td>
<td>2 (1.7), continuous pain</td>
<td></td>
</tr>
<tr>
<td>Chatterji21</td>
<td>47</td>
<td>3.2</td>
<td></td>
<td>3 (1.2), mild ache</td>
<td>6 (34), mild ache</td>
<td></td>
</tr>
<tr>
<td>Arbustini1</td>
<td>87</td>
<td>5.4</td>
<td>+2</td>
<td>11 (17), some pain</td>
<td>24 (29), some pain</td>
<td></td>
</tr>
<tr>
<td>McCarthy1</td>
<td>77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hopper22</td>
<td>30, TKA 100, UKA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jackson13</td>
<td>NA</td>
<td>57% returned within 6 mo</td>
<td>69% improved; 10% no change</td>
<td>15 (17), some pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schuman14</td>
<td>190</td>
<td>8.4</td>
<td>–1.4</td>
<td>2.28, slight pain</td>
<td>4 (60), slight pain</td>
<td></td>
</tr>
<tr>
<td>Papadopoulos23</td>
<td>89</td>
<td>8.4</td>
<td>–1.4</td>
<td>5, NSAIDs “during or after”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garcia11</td>
<td>94</td>
<td></td>
<td></td>
<td>5, NSAIDs “during or after”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garcia15</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garcia16</td>
<td>98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Madczuk26</td>
<td>95</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piger27</td>
<td>99</td>
<td>3.7</td>
<td>–0.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gerbasty15</td>
<td>NA</td>
<td>2</td>
<td>+1.4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Blank cells indicate not recorded. NA, not applicable; NSAID, nonsteroidal anti-inflammatory drug; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

The following studies did not report data specific to the table: Zarakedes,15 Bullis,23 Simoni,24 Kurewitz,25 Mannova,26 and Wang,14

with hemiarthroplasty. TKA has been shown to give improved range of motion and functional outcomes in comparison with RSA and hemiarthroplasty, which may account for this finding.14,15 This is consistent with the general orthopaedic literature, which has found TKA to be superior to hemiarthroplasty in regard to pain relief and level of function.16

No studies examined the method of surgery (robotic vs computer navigated vs manual), and no lower limb study assessed the surgical approach used. Previous studies analyzing functional outcomes after lower limb arthroplasty have shown greater early improvement when robotically assisted surgery was performed.20,21 These findings may be transferable to golfers undergoing arthroplasty, and further studies should investigate this. In addition, early postoperative functional acuity has been reported with the anterior approach to the hip as compared with other approaches.18 This could have implications for golfers if analyzed. With regard to knee arthroplasty, a study showed markedly increased rates of returning to golf after TKA, and when UKA was removed from the analysis, there was a substantial reduction in the rate of returning to golf after TKA. This may be biased by the preoperative volume of arthritis suitable to warrant UKA as compared with TKA; nevertheless, this comparison may be worth exploring in future research.

The use of golf participant databases was introduced in 2020-2021 by 2 studies. Piger et al27 and Gerbasty et al28 used golf participant databases to extract data regarding players who had undergone arthroplasty. Piger et al collected data from a database of 54,461 golfers aged >50 years, achieving a response rate of 0.6%, while Gerbasty et al employed similar methodology and achieved a response rate of 3%. Undoubtedly, the majority of the people within these databases will not have had arthroplasty; therefore, the response rate is expectedly low. However, the prevalence of hip or knee arthroplasty in an age-matched group of the general population is between 7% and 11%.29 This suggests that the present studies suffer from a low response rate and potential response bias. Piger et al stated that 99% of respondents returned to golf, which is 5% higher than the best available literature.18 This number may be subject to overestimation of the true rate within the total cohort, given the mechanism for recruitment. Furthermore, it is possible that those who have had satisfactory outcomes after the surgery may be more likely to respond, as shown in previous arthroplasty studies.21,24 The return-to-golf rate is critical for managing patients’ expectations before and after arthroplasty, and clearly a multitude of factors will influence a golfer’s ability to return beyond the JA itself.

Interpretation of the lead or trail leg could be achieved in just 5 studies, which identified the side of the implant and the handedness of the player. The lead leg and trail leg undergo different forces during the golf swing.18 A
previous study revealed increased pain in the lead knee during the golf swing after TKA, and this correlates with higher tibial forces. It is unknown if these are differences in returning to golf after lead or trail knee, hip, or shoulder arthroplasty. Asymmetric functional differences may be present, and Di Caprio et al. found improved handicap and driving distance in patients undergoing dominant-shoulder arthroplasty as compared with nondominant.

The mean age of golfers in this study was 67 years. It is likely that one of the key factors associated with a satisfactory outcome after arthroplasty in this cohort is the ability and mobility to participate in the game. Previous studies have focused on handicap as a primary outcome measure when, in fact, the aforementioned features may be equal or more important to the patient. Only 2 studies cited the method by which participants mobilized around the golf course pre- or postoperatively. One of these studies showed that after TKA, the number of golfers using cart over 18 holes doubled. The energy expenditure of walking the golf course is almost double that of riding in a golf cart.

This is crucial and pertinent information to include in future studies to fully understand the effect of arthroplasty on recreational golfers.

It is not clear whether golfers are satisfied when they return to play, and assessing the level of return to golf after arthroplasty is poorly described. Participation can be interpreted in many ways, which require varying degrees of function and ability. For example, one person may interpret "return to golf" as putting at home, and another may believe it equates to walking 18 holes. In addition, predictors associated with return to golf and complications with the timing of return have not yet been reported in the arthroplasty literature, and further studies investigating this would be useful to help guide patient expectations before surgery. A specific questionnaire exploring a patient’s awareness of his or her joint replacement when returning to golf may be helpful in truly measuring golf-related postoperative function and satisfaction.

This study should be interpreted in light of its limitations. Overall, the level of evidence of the current literature is low and retrospective. The rates of returning to golf may therefore be underestimated because of the lack of response bias, and 10 of the 25 studies did not give sufficient data to determine rates of return. Future studies should focus on the accurate reporting of preoperative golfing function, surgical details, clear definitions of what constitutes "returning to golf," and postoperative outcomes (golf mobility, performance, and satisfaction).

CONCLUSION

This is the first meta-analysis of golfers returning to play after TKA. The study reports a high rate of returning to golf, which is highest after TKA. However, it also highlights the paucity of prospective data on demographic, surgical, and golf-specific outcomes after arthroplasty. Prospective studies are required to eliminate response bias and accurately capture golf- and patient-specific outcomes.

ORCID ID

Jennifer Cheng https://orcid.org/0000-0001-4958-610X

REFERENCES

3. Bresan BR, Naber O, Tiedeman A, Lindgren JU. Early gain in pain reduction and hip function, but more complications following the direct anterior minimally invasive approach for total hip arthroplasty: a randomized trial of 100 patients with 6 years of follow up. Acta Orthop. 2018;89(6):684-689.
3.3 Study 9: Letters to the Editor: Total Joint Arthroplasty and Golf Play: Analysis of Regional Golf Handicap Database


3.3.1 Aims and objectives

As my interest in research surrounding return to golf after joint arthroplasty began to evolve, I noticed a recently published article by Gorbaty et al studying the rate of returning to golf following hip or knee arthroplasty. I had a number of concerns regarding the methodology of the paper and felt it warranted a response to the authors in the form of a ‘letter to the editor’ to the Journal of the American Academy of Orthopaedic Surgeons.

The aim of this letter was to highlight some concerns regarding the interpretation of the results and conclusions made by the authors. The objectives were to 1) critically appraise the methods and interpretation of results from the study and 2) suggest potential, future research ideas in this field.

3.3.2 Methodology

The methods of this letter firstly involved recruiting a team of experts in the field of orthopaedics and golf medicine including: Mr. Nick Clement (Academic Orthopaedic Surgeon), Dr. Roger Hawkes (former DP World Tour Chief Medical Officer) and Prof. Andrew Murray (current DP World Tour Chief Medical Officer). Each colleague reviewed and critically appraised the
research article. We then had discussions regarding the key points we felt should be addressed prior to me writing a first draft of the letter.

3.3.3 Results
The critical appraisal yielded some key points that we made comment on. Firstly, the study cohort was 17,029 members from a golf association. They achieved a response rate of 3% and 0.3% were eligible for analysis. This alone is concerning for selection bias, in particular with sampling bias and volunteer bias. It is very possible that those who had poor outcomes may no longer play golf and are no longer a member of the association. In addition, those who returned and are enjoying golf again may be more likely to respond to the survey. With an age-matched population, you would expect those to have had a joint replacement to be 7 - 11% of the cohort. Therefore, the response rate of this study appears low. Secondly, the authors did not define ‘returning to golf’. There is a significant difference between hitting a few balls on the driving range and playing 18 holes. Finally, there was no reference to the mobility status of the players, i.e. walking vs pulling a trolley vs riding a cart. Clearly, following lower limb joint replacement, such variables are helpful to record.

3.3.4 Conclusion
Although we commended the authors for their interest in the field of golf medicine, we did feel it was important to raise the aforementioned points. We concluded by suggesting such sampling errors and biases could be at least partially overcome or reduced by prospectively conducting such research.
3.3.5 Contribution to knowledge base

Although this letter did not provide any new knowledge in the field of golf medicine, we do believe it demonstrated global engagement in this area and enthusiasm for further research. Disappointingly the authors of the index study did not respond to our letter. This letter demonstrates an eagerness to maintain up to date in the research in my field and critically appraising such work. I believe this makes me a more relevant and productive researcher in the field of golf medicine.

3.3.6 Student contribution

I identified the index article, suggested the letter, performed the initial critical appraisal, engaged my co-authors and chaired the discussions. I wrote the first draft of the letter and edited further versions before submitting the journal.
Letters to the Editor

Letters to the Editor: Total Joint Arthroplasty and Golf Play: Analysis of Regional Golf Handicap Database

To the Editor: We read with interest the study by Gorbaty et al. evaluating the performance-related golfing outcomes after hip and knee arthroplasty. We commend the authors on pursuing evidence-based information applicable to golfers undergoing total joint arthroplasty (TJA). The physical and mental health benefits of golf are well-recognized, and as a moderate-intensity activity, it is an ideal sport for patients after TJA. However, the methodology used by Gorbaty et al. to assess the rate of return and the level of play may have limitations, and interpretation of their results should recognize these when offering a patient advice.

One of the main goals of the authors was to identify the "rate of return" to golf, but it could be argued that they only assessed the time to return to golf for those who were able to do so, in view of their continued membership of the golf association, after TJA, whereas patients not returning to golf after TJA may no longer be a member of the golf association, and this raises the concerns of sampling and response bias. Data were requested from 17,029 members of a golf association, achieving a response rate of 3% (n = 539), of which only 118 (0.7%) were eligible for analysis. Undoubtedly, most of the people within this database will not have had TJA, and therefore, the response rate will be expectantly low. However, the prevalence of hip or knee arthroplasty in an age-matched group of the general population in the United States has been reported to be 7% to 11%.

The authors reported that the average time to return to golf after TJA was 2 months, which is at least 1 month (and up to 3.4 months) faster than any of the previous best available literature. It is not clear what constituted "return to golf," and the authors do not specify this. Clearly, returning to chipping and pitching is likely to be achieved much faster than playing an entire round of 18 holes, and it is likely that the recipients of this survey will have had varying interpretations of this question.

The authors did not report the method by which participants mobilized around the golf course preoperatively or postoperatively. The energy expenditure of walking the golf course is almost double that of riding in a golf cart, and in their discussion, the authors have acknowledged the previous literature on the decreased frequency of patients walking the golf course after surgery, yet they do not report these data themselves. Patient advice surrounding mobility on the golf course is crucial to manage patients' postoperative expectations when returning to golf, and these will be more complex than simply whether one's handicap increases or decreases.

TJA is undoubtedly an excellent intervention for hip and knee arthritis; however, we would recommend caution in the interpretation of this study.
secondary to its possible overestimation of rate of returning to golf, underestimation of the time to return to golf, and lack of reporting of the methods of golfers’ mobility on the course. Prospective research would be best suited to overcome the issues that have been highlighted.

Patrick G. Robinson, MRCS, MSc(Res)®
Edinburgh, UK
Nick D. Clement, PhD, FRCS(Orth)
Edinburgh, UK
Roger Hawkes, Dip. SEM, FFSEM
London, England
Andrew D. Murray, FRCP, FFSEM
Edinburgh, UK

References
References printed in bold type are those published within the past 5 years.
3.4 Study 10: Golfers have greater preoperative and equal postoperative function when undergoing total knee arthroplasty compared to non-golfers

Robinson PG, Kay R, MacDonald D, Murray AD, Clement ND. Golfers have greater preoperative and equal postoperative function when undergoing total knee arthroplasty compared to non-golfers. Eur J Orthop Surg Traumatol. 2022. Apr 1;1,7. PMID: 35362779

3.4.1 Aims and objectives
Edinburgh Orthopaedics at the Royal Infirmary of Edinburgh regularly collect demographic, subjective and objective clinical data on patients following hip and knee arthroplasty surgery. There is therefore a wealth of data on the arthroplasty research database. I decided to explore whether it would be possible to identify golfers from this database who had undergone total knee arthroplasty (TKA) and assess their clinical outcomes. Therefore, the primary aim of this study was to assess if golfers undergoing total knee arthroplasty had an equal improvement in their outcomes compared to non-golfers pre- and postoperatively. The objectives were to assess (1) preoperative and postoperative differences in demographics, symptoms and function between golfers and non-golfers (2) differences in health-related quality of life (HRQoL), (3) the rates of return to golf at one- and five-years following surgery, and (4) to assess the influence of golf on motivation and rehabilitation following TKA.

3.4.2 Methodology
Golfers were identified retrospectively from a prospectively collected database from a single year of surgery with a minimum of five years of follow up. This retrospective design suffers from the unmatched nature of the demographics in each cohort. Particular independent variables affected were sex and the unknown activity levels of the non-golfing cohort. All patients had undergone the same primary knee arthroplasty (Triathlon, Stryker). Inclusion criteria was restricted to a single sided, primary arthroplasty performed for osteoarthritis to ensure homogeneity of the surgical procedure. Each patient from the chosen year of operating was contacted to assess whether they were a golfer at the time of their surgery.

Clinical outcome measures were the Oxford Knee Score (OKS), EuroQoL five dimension (EQ5D), pain score and satisfaction (measured on a Likert scale ranging from very dissatisfied to very satisfied). Each outcome measure had previously been validated. We then asked a number of golf specific questions including whether golf was a motivation for why patients underwent surgery, if golf was beneficial to their recovery and finally their overall satisfaction in the game of golf. We felt these types of questions may extract meaningful data regarding the patient’s overall recovery and take a more holistic approach to the patient’s postoperative journey.

Regarding the statistical analysis of the paper, we used tests for normality, and analysed the normally distributed data with parametric testing. Continuous variables were analysed with unpaired t tests or one way analysis of variance
(ANOVA) if >2 cohorts. Chi squared tests were used for binary variables while Fisher’s exact test was applied to groups <5. Linear regression analysis was performed to assess if golfing status would be an independent predictive variable for postoperative continuous outcomes while binary logistic regression was applied to assess if golfing status predicted satisfaction. Dichotomising the satisfaction outcome variable made binary, logistic regression analysis possible. This is a common application of this outcome measure in my institution however, I appreciate the researcher loses the granularity of satisfaction on a Likert scale. Therefore, future work may consider the statistical tests required for ordinal data or simply to collect satisfaction as a binary outcome variable for the beginning. A post-hoc power calculation based on the OKS minimally clinical important difference of 4.3 and an alpha of 0.05 was performed to give 81% power.

An important learning point from the statistical analysis of study 10 was to determine the small but significant differences around nomenclature in regression modelling. For instance, the difference between ‘multi-variable’ and ‘multi-variate’. The regression model in this study had a single independent variable ‘golfing status’ and multiple outcome measures (i.e. the functional outcome scores). Therefore, this was described as ‘multi-variate’. However, if there had been multiple independent variables and and a single outcome measure then the analysis could have been considered ‘multi-variable’. Further, there were a large number of statistical tests performed, as seen in table 1. This increases the risk of significant tests by chance alone.
with a significance level set at $p=0.1$ for the inclusion in the regression modelling. Considerations of a Bonferroni correction or a smaller threshold for the $p$ value may have been helpful in reducing this risk.

3.4.3 Results

There were a total of 514 participants. The golfing and non-golfing cohorts were well matched for demographics and comorbidities except for female distribution which was higher in the non-golfing cohort. Golfers had statistically higher EQ5D VAS, and OKS preoperatively. The rate of returning to golf was 89.6% at a mean follow up of one year and 65% of those were still playing five years postoperatively. Most players were satisfied with their involvement in the game of golf postoperatively (88.4%).

3.4.4 Conclusion

We found golfers to have better knee specific function prior to TKA compared to non-golfers. Postoperative functional outcomes were equal between both groups. The majority of golfers had returned to play by one year postoperatively and were typically satisfied with their involvement in the game however, this is not in keeping with rates of return in the previous meta-analysis discussed in this thesis which showed a pooled mean return to golf following TKA of 70%.107

3.4.5 Contribution to knowledge base
This study has added further data to the field of golf medicine regarding rates of returning to golf following TKA. This study was the first to explore satisfaction in golf postoperatively which is arguably the most important outcome measure for golfers who wish to return to play. We have shown that golfers have typically superior preoperative knee function and greater quality of life metrics than a non-golfing cohort. Further research is required to explore why this might be and if it is true in other arthroplasty surgeries such as THA.

3.4.6 Student contribution

I contributed to the research idea, data collection, data analysis, and led the writing of the manuscript. In particular, I identified the appropriate database within the Edinburgh Orthopaedic research department and cleaned the spreadsheets appropriately for analysis. I then devised additional golf specific questions to add to the data collection and proceeded to contact all potential potentials to identify those who were golfers and collected the aforementioned golf data. Mr. Nick Clement and I performed the data analysis and I wrote the primary manuscript and revised revisions based on co-author and reviewers’ suggestions.
3.4.7 Publication

Golfers have greater preoperative and equal postoperative function when undergoing total knee arthroplasty compared to non-golfers

P. G. Robinson1,2, R. S. Kay3•D. MacDonald1 • A. D. Murray1•5 • N. D. Clement1

Received: 3 December 2021 / Accepted: 15 March 2022 © The Author(s) 2022

Abstract

Background Approximately 10% to 20% of patients with joint arthroplasties are golfers. The aim of this study was to assess if being a golfer is associated with functional outcomes, satisfaction or improvement in quality of life (QoL) compared to non-golfers following total knee arthroplasty.

Methods All patients undergoing primary total knee arthroplasty (TKA) over a one-year period at a single institution were included with one-year postoperative outcomes. Patients were retrospectively followed up to assess if they had been golfers at the time of their surgery. Multivariate linear regression analysis was performed to assess the independent association of preoperative golf status on postoperative function and health-related outcomes.

Results The study cohort consisted of a total of 514 patients undergoing TKA. This included 223 (43.3%) male patients and 291 (56.7%) female patients, with an overall mean age of 70 (SD 9.3) years. The preoperative Oxford Knee Score (OKS) was significantly higher in golfers when adjusting for confounders (Diff 3.4 [95% CI 1 to 5.8], p = 0.006). There was no difference in postoperative outcomes between golfers and non-golfers. There was however a trend towards a higher Forgotten Joint Score (FJS) in the golfers (difference 9.3, 95% CI —0.2 to 18.8, p = 0.056). Of the 48 patients who reported being golfers at the time of their surgery, 43 (89.6%) returned to golf and 88.4% of those were satisfied with their involvement in golf following surgery.

Conclusions Golfers had better preoperative and equal postoperative knee specific function compared to non-golfers. The majority of golfers returned to golf by one year and were satisfied with their involvement in the game.

Level of evidence III.

Keywords Golf • Knee • Arthroplasty • Outcomes • Recovery

Introduction

Total knee arthroplasty (TKA) is one of the most cost-effective operative procedures worldwide and is an good intervention for patients suffering from end stage arthritis [28, 29]. Joint arthroplasty (JA) leads to reduce levels of pain and improved levels of function [12, 27]. There are approximately 175,000 hip and knee arthroplasties performed in England, Wales and Scotland each year [11, 17], while there are approximately 1.88 million hip and knee arthroplasties performed in the USA per annum [8]. It has been reported that up to 14% of patients with JA are golfers [14]. Arthritis can have a significant impact on a patients’ quality of life and can prevent golfers from participating in their favoured recreation [19]. Sorbie et al. studied the impact of golf course closure and opening during the COVID-19 pandemic on wellbeing and life satisfaction. They reported that
belonging, enjoyment and wellbeing were significantly associated with outdoor course activity and a sense of belonging and satisfaction increased following golf course reopening [21]. It is likely that these findings are applicable to golfers who are unable to play secondary to their arthritis and subsequently return following IA.

TKA in the golfing population has been investigated by Trainer et al., who demonstrated that component type (cruciate-retaining versus posterior-stabilised) has no impact upon pain, performance or stability in those who return to play golf [25]. What is not known, is if being a golfer has any influence on the outcomes compared to other patients undergoing TKA, as their expectations may be different and this has been shown to influence outcome [16, 30]. Furthermore, there is little knowledge of the golfers’ motivation to return to golf following TKA.

The primary aim of this study was to assess if golfers had an equal improvement in their knee specific outcome compared to non-golfers one year following surgery. The secondary aims were to assess (1) preoperative differences in demographics, symptoms and function (2) differences in health-related quality of life (HRQoL), (3) the rates of return to golf at one and five years following surgery, and (4) to assess the influence of golf on motivation and rehabilitation following TKA.

Patients and methods

Patients were identified from a prospectively compiled arthroplasty database. One year of patients undergoing primary total knee arthroplasty for osteoarthritis were included. All patients received a cruciate-retaining Triathlon® prosthesis. Inclusion criteria were given as: primary TKR, unilateral surgery, preoperative diagnosis of osteoarthritis, and prospective, preoperative and one-year postoperative outcome measures. Exclusion criteria included those not consenting to follow-up or revision surgery. Demographic and co-morbidity data were collected prospectively. Patients were retrospectively followed up to assess if they had been golfers at the time of their surgery and questions regarding their involvement and expectations regarding golf postoperatively.

Surgical protocol

All patients underwent TKA using either a general or spinal anaesthetic. The use of a regional block was at the discretion of the anesthetist. All surgeries were performed with tourniquets and tranexamic acid was not routinely used. A medial parapatellar approach was used, and intramedullary referencing for the femur and extramedullary referencing for the tibia were employed. Balancing techniques were at the discretion of the surgeon. Knees were performed using mechanical alignment, and the patella was not routinely resurfaced. All patients were mobilised with physiotherapy on day one postoperatively with no restrictions.

Outcomes measured

The Oxford Knee Score (OKS) [1] was the primary outcome measure and was recorded preoperatively and at 12-month postoperatively. The OKS consists of twelve questions assessed on a Likert scale with values from 0 to 4. A summative score is then calculated where 0 is the worst possible score (least symptomatic) and 4 is the worst possible score (most symptomatic). The minimally clinically important difference (MCID) for the OKS is 4.3 points (function) and is thought to represent a clinical difference between two groups of patients [2].

The forgotten joint score (FJS) consists of 12 questions and assesses the awareness of your affected joint during a variety of activities of daily living [36]. Each is scored on a Likert scale ranging from 0 to 4. The total sum of the scores is converted into a scale ranging from 0 to 100, where higher scores reflect less joint awareness during activities of daily living.

The EuroQol (EQ) general health questionnaire evaluates five domains (5D: assesses mobility, self-care, usual activities, pain/discomfort and anxiety/depression) and was recorded preoperatively and at 12-month postoperatively [8]. The 3L version of the EQ questionnaire was used, with the responses to the five domains being recorded at three levels of severity (no problems, some problems or unable/extreme problems) with 243 possible health states. This index is on a scale of −0.594 to 1, where 1 represents perfect health, and 0 represents death. Negative values represent a state perceived as worse than death [19]. The second page of the EQ questionnaire consists of a standard vertical 20 cm visual analogue scale (EQ VAS) which is transformed to a scale of 0 (poor health) to 100 (best health) with current health-related quality of life.

The pain visual analogue scale (VAS) is a 15 cm horizontal scale from 0 to 10 where 0 is no pain and 10 is pain as bad as it could be.

Patient satisfaction was assessed by asking the question “How satisfied are you with your operated knee?” The response was recorded using a five-point Likert scale: very satisfied, satisfied, neither satisfied nor dissatisfied simplified to neutral for the rest of manuscript, dissatisfied and very dissatisfied. Satisfaction was dichotomised into ‘satisfied’ and ‘dissatisfied’. Satisfied was considered ‘satisfied’ and ‘very satisfied’ and dissatisfied was considered ‘neutral’, ‘dissatisfied’ and ‘very dissatisfied’. Five further questions were asked specifically to those who reported being a golfer at the time of the surgery.
Golf-related outcomes

Golfers were asked if they returned to golf postoperatively and if they were still playing currently. They were also asked if returning to golf was a motivator for undergoing TKA, if they believed golf was beneficial to their recovery and if it improved their overall well-being. Of those patients that returned to golf, they were asked to define how satisfied they were with their involvement in the game of golf since TKA on a five-point Likert scale: very satisfied, satisfied, neutral, dissatisfied and very dissatisfied.

Statistical analysis

Statistical Package for Social Sciences version 17.0 (SPSS Inc., Chicago, IL, USA) was used for all data analysis. Data were assessed for normality and parametric tests where appropriate. Scalar variables were assessed using either unpaired Student’s t test, or one-way analysis of variance (ANOVA). A Chi square test was used to assess gender, comorbidity and satisfaction differences between groups. Fisher’s exact test was used for groups < 5. Significance was set as a p value of < 0.05. Multivariate linear regression analysis was performed to assess for golfing status as a preoperative independent variable when adjusted for preoperative confounders. Binary logistic regression was also performed to assess if golfing status predicted postoperative satisfaction when adjusting for confounders.

A power calculation was performed using the MCON for the OKS (primary outcome measure) of 4.3, a standard deviation of 10 points (effect size 0.43), with an alpha of 0.05 and two tailed analysis with 48 in the golfing group and 466 in the non-golfing group achieved 81% power.

Ethics

Ethical approval was obtained from the regional ethics committee (Research Ethics Committee, South East Scotland Research Ethics Service, Scotland [16/SS/0026]) for analysis and publication of the presented data. The data collection was carried out in accordance with the GMC guidelines for good clinical practice and the Declaration of Helsinki.

Results

Study cohort characteristics

The study cohort consisted of a total of 514 patients undergoing TKR with complete preoperative and one-year postoperative data that met the inclusion criteria. This included 223 (43.3%) male patients and 291 (56.7%) female patients, with an overall mean age of 70 (SD 9.5) years and a mean BMI of 30.1 (SD 5.9). Two hundred and seventy-six TKA were left (53.7%), and 218 (46.3%) were right sided. Thirty-six patients had died at the time of golfing status assessment (i.e. five years postoperatively). All identified golfers played right-handed. Preoperative demographic comparisons between the golfer cohort (n = 48) and the non-golfer cohort (n = 466) can be seen in Table 1.

Functional and health-related outcomes

There was no difference in postoperative functional or health-related outcomes between golfers and non-golfers (Table 2) which persisted when adjusting for preoperative confounders (Table 3). Preoperative OKS was significantly higher in golfers compared to non-golfers and when adjusted for sex differences between the groups golfing status was independently associated with greater preoperative OKS score (difference 3.4 [95% CI 1 to 5.8], p = 0.006). HRQoL was also greater in golfers which was significant for EQ5D VAS with a trend towards significance in EQ5D Index. There was also a trend towards significance (p = 0.056) for golfers to be less aware (FIS) of their knee joint postoperatively compared to non-golfers (Table 2).

At one-year follow-up, there were 35 golfers (74.5%) who were satisfied and 12 (25.5%) who were dissatisfied, compared to 367 non-golfers (80.8%) who were satisfied and 87 (19.2%) who were dissatisfied (p = 0.297). Following binary regression analysis adjusting for preoperative confounders, there was no difference in satisfaction between golfers and non-golfers (p = 0.22).

Returning to golf following TKA

Of the 48 patients who actively participated in golf at the time of their surgery, 43 (89.6%) returned to golf within 1 year and 31 (65%) were still playing five years postoperatively. Of those that were no longer playing, two patients associated this with problems related to their TKA. Thirty patients (62.5%) reported golf as being an important reason for undergoing surgery. Thirty-two patients (66.7%) reported that they felt golf helped with their rehabilitation and 39 (81.3%) felt returning to golf improved their overall well-being. Of those that returned to golf, thirty-eight patients (88.4%) were deemed to be satisfied overall with their involvement in golf following surgery. There was no difference in health-related or functional outcomes in golfers when comparing left and right-sided surgery at one year (p > 0.41). There were no surgical complications in the golfer cohort.
Table 1 Proportional demographics and functional outcomes between gaiters and non-gaiters

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Gaiters (n=514)</th>
<th>No (n=466)</th>
<th>Yes (n=88)</th>
<th>Difference/odds ratio (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>223 (43.3)</td>
<td>181 (37.2)</td>
<td>42 (47.5)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Female</td>
<td>291 (56.7)</td>
<td>285 (62.8)</td>
<td>6 (12.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Side (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>276 (53.7)</td>
<td>252 (54.1)</td>
<td>24 (50)</td>
<td></td>
<td>0.59</td>
</tr>
<tr>
<td>Right</td>
<td>238 (46.3)</td>
<td>214 (45.9)</td>
<td>24 (50)</td>
<td>OR 1.2 (0.8 to 2.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Mean age (years, SD)</strong></td>
<td>70 (9.5)</td>
<td>70.2 (8.6)</td>
<td>68.5 (8.2)</td>
<td>Diff -1.7 (-4.5 to 1.2)</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>30.1 (5.9)</td>
<td>30.6 (5.9)</td>
<td>29.3 (5.9)</td>
<td>Diff -0.9 (-2.6 to 0.9)</td>
<td>0.33</td>
</tr>
<tr>
<td><strong>Co-morbidities (n, %)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HbD</td>
<td>25</td>
<td>22</td>
<td>3</td>
<td>OR 1.4 (0.4 to 4.7)</td>
<td>0.64</td>
</tr>
<tr>
<td>COPD</td>
<td>19</td>
<td>18</td>
<td>1</td>
<td>OR 0.5 (0.1 to 4)</td>
<td>0.446</td>
</tr>
<tr>
<td>Vascular disease</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>OR 0.7 (0.4 to 1.3)</td>
<td>0.81</td>
</tr>
<tr>
<td>Diabetes</td>
<td>57</td>
<td>50</td>
<td>7</td>
<td>OR 1.4 (0.8 to 3.1)</td>
<td>0.64</td>
</tr>
<tr>
<td>Gastrointestinal disorder</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>OR 1 (1 to 1)</td>
<td>0.72</td>
</tr>
<tr>
<td>Kidney disease</td>
<td>9</td>
<td>8</td>
<td>1</td>
<td>OR 1.2 (0.2 to 9.7)</td>
<td>0.74</td>
</tr>
<tr>
<td>Liver disease</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>OR 1 (1 to 1)</td>
<td>0.92</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>16</td>
<td>14</td>
<td>2</td>
<td>OR 2.7 (0.3 to 5.8)</td>
<td>0.98</td>
</tr>
<tr>
<td>Preoperative EQ5D VAS</td>
<td>70.8 (18.8)</td>
<td>70.1 (19.1)</td>
<td>71.1 (14.7)</td>
<td>Diff 0.7 (1.5 to 12.6)</td>
<td>0.01</td>
</tr>
<tr>
<td>Preoperative EQ5D Index</td>
<td>0.422 (0.31)</td>
<td>0.414 (0.31)</td>
<td>0.449 (0.218)</td>
<td>Diff 0.084 (-0.096 to 0.177)</td>
<td>0.37</td>
</tr>
<tr>
<td>Preoperative Pain VAS</td>
<td>51.6 (21.8)</td>
<td>51.3 (21.6)</td>
<td>55.1 (25.5)</td>
<td>Diff 3.8 (2.7 to 10.3)</td>
<td>0.25</td>
</tr>
<tr>
<td>Preoperative OKS</td>
<td>20.9 (8.8)</td>
<td>20.4 (7.9)</td>
<td>25.3 (7.8)</td>
<td>Diff 4.9 (2.5 to 7.2)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

BMI Body mass index, SD Standard deviation, HbD Ischaemic heart disease, COPD Chronic obstructive pulmonary disease, EQ5D EuroQol 5 dimension, VAS Visual analogue scale, OKS Oxford knee score

Table 2 Comparison of postoperative variables between gaiters and non-gaiters

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Gaiters (n=514)</th>
<th>No (n=466)</th>
<th>Yes (n=88)</th>
<th>Difference/odds ratio (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ5D VAS 1 year</td>
<td>77.6 (1.8)</td>
<td>81.5 (7.7)</td>
<td>77.6 (77.6)</td>
<td>3.8 (-1.6 to 9.4)</td>
<td>0.166</td>
</tr>
<tr>
<td>Change 1 year</td>
<td>7.4 (19.6)</td>
<td>4.4 (17.6)</td>
<td>-3.1 (-8.9 to 2.7)</td>
<td>0.298</td>
<td></td>
</tr>
<tr>
<td>EQ5D Index 1 year</td>
<td>0.74 (0.268)</td>
<td>0.723 (0.262)</td>
<td>0.03 (-0.025 to 0.1)</td>
<td>0.498</td>
<td></td>
</tr>
<tr>
<td>Change 1 year</td>
<td>0.525 (0.354)</td>
<td>0.274 (0.346)</td>
<td>-0.051 (-0.151 to 0.49)</td>
<td>0.314</td>
<td></td>
</tr>
<tr>
<td>Pain VAS 1 year</td>
<td>72.9 (26.9)</td>
<td>74.8 (28.4)</td>
<td>4.1 (-6.2 to 9.9)</td>
<td>0.657</td>
<td></td>
</tr>
<tr>
<td>Change 1 year</td>
<td>21.5 (31.3)</td>
<td>19.7 (35.8)</td>
<td>4.8 (-11.2 to 7.7)</td>
<td>0.715</td>
<td></td>
</tr>
<tr>
<td>OKS 1 year</td>
<td>35.5 (10)</td>
<td>38.1 (10.6)</td>
<td>2.6 (-0.4 to 5.6)</td>
<td>0.089</td>
<td></td>
</tr>
<tr>
<td>Change 1 year</td>
<td>15 (8.8)</td>
<td>12.7 (11.4)</td>
<td>-2.4 (-5.4 to 1.1)</td>
<td>0.118</td>
<td></td>
</tr>
<tr>
<td>FIS 1 year</td>
<td>50.1 (31.8)</td>
<td>59.4 (33.1)</td>
<td>9.3 (-0.2 to 18.8)</td>
<td>0.056</td>
<td></td>
</tr>
</tbody>
</table>

EQ5D EuroQol 5 dimension, VAS Visual analogue scale, OKS Oxford knee score, FIS Forgotten joint score
Table 3 Multivariate linear regression analysis of golfing status postoperatively as an independent predictor when adjusting for significant preoperative variables (p<0.1) in the model (Gender, preoperative EQ-5D index, preoperative OKS)

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>B</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ-5D index (r=0.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>−0.01</td>
<td>−0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Pan VAS (r=0.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>−0.4</td>
<td>−8.7</td>
<td>7.9</td>
</tr>
<tr>
<td>OKS (r=−0.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>0.95</td>
<td>−2.9</td>
<td>3</td>
</tr>
<tr>
<td>FIS (r=0.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>2.7</td>
<td>−7</td>
<td>12.3</td>
</tr>
</tbody>
</table>

Discussion

This study has shown that golfers had an outcome that was equal to non-golfers according to knee-specific function, HRQoL, and satisfaction. However, they did have higher preoperative knee-specific function and HRQoL scores.

The rate of return of golfers was high with ninety percent of golfers returning at one year postoperatively, with a self-reported satisfactory involvement in the game of golf achieved by 88% of golfers undergoing TKA.

Golf can provide moderate intensity physical activity (with a reported general metabolic equivalents [MET] of 4.8/9), while one ‘round’ of 18 holes can burn approximately 1200kcal and players will perform 11,000 to 16,000 steps over a distance of 4–8 miles [7, 23]. Some of these health benefits may explain why golfers were found to have superior functional preoperative scores compared to the rest of a population undergoing TKA. However, it was interesting to note that there was no difference in BMI between the two cohorts. Golfers also reported higher HRQoL compared to non-golfers. A previous Swedish study of 300.818 golfers and non-golfers reported a 40% lower mortality rate in the golfing cohort, which correlated to a 5-year increase in life expectancy regardless of gender, age or socioeconomic status [4].

The overall prevalence of golfers was 9%, which increased to 23% for male patients. This may be unique to the demographics of the population assessed; however, a previous UK study has reported approximately 14% of hip arthroplasty patients were golfers in their cohort [14]. In the current study, 89.6% of the golfers returned to golf following TKA surgery. A recent meta-analysis has reported a 70% rate of returning to golf after TKA [13]. Motivation for returning to golf after TKA and patients’ satisfaction with their golfing involvement has not previously been investigated. Golfers in this study reported that getting back to playing sport contributed to their reason for undergoing joint replacement in 63% of cases. Clinicians should be aware of this when counselling patients regarding TKA and the likelihood of being able to return. It was reassuring to report that of those that returned, 88% were satisfied with their involvement in the game of golf after surgery. Arguably, these data are more important than exploring postoperative performance related metrics such as changes in handicap or driving distance, which are influenced by other factors such as increasing age [22]. The process of playing golf requires significant balance [26], muscular function [10] and strength [20] and returning to the sport may be a surrogate marker for patients coping with their new joint replacement.

The physical and mental health benefits of golf were reported by our cohort of golfers with two thirds believing golf contributed to their rehabilitation and 81% believing returning to the game improved their overall well-being. This is in keeping with a previous study during the COVID-19 pandemic which showed that sense of belonging, enjoyment and well-being were significantly associated with returning to play golf after activity restrictions were lifted following lockdown [21]. Despite golfers having superior preoperative scores compared to non-golfers, there was no difference in functional outcomes between the two groups postoperatively. Although we cannot conclude why this is, it may be that golfers who have lower thresholds were undergoing TKA due to arthritis limiting their hobby or that they have greater expectations postoperatively compared to non-golfers.

Limitations

This study must be interpreted in light of its limitations. There was a predominance of males in the golfing cohort. This is however reflective of the overall golfing community, and previous studies have shown no influence on gender following TKA [3, 13, 24]. Furthermore, we did adjust for gender during the regression analysis. The severity or pattern of osteoarthritis within the knee prior to surgery was not assessed, and this may contribute to attaining satisfaction and acceptable patient outcomes postoperatively although there is limited evidence to support this [18]. In addition, this is a UK-based study where golf is a popular sport. The results therefore may not be applicable in other countries where golf is less prevalent.
Conclusion

Golfers have better knee-specific function prior to TKA compared to non-golfers. Postoperative functional outcomes are equal between both groups. The majority of golfers will return to golf by one year and be satisfied with their involvement in the game.

Authors' contributions
PGR contributed to research idea, data collection, data analysis, and writing manuscript. RK contributed to data collection. DM, involved in writing manuscript. AM involved in writing manuscript. NDC contributed to research idea and writing manuscript. All authors read and approved the final manuscript.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Code availability
Statistical Package for Social Sciences (SPSS) software (IBM, Inc., Armonk, New York, United States) v24.

Declarations
Conflict of interest
None.

Open Access
This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References
14. Robins PM, Khan S, MacDonald D, Murray H, Macpherson GJ, Clement ND (2021) Golfers have a greater improvement in their hip specific functions compared to non-golfers after total hip arthroplasty, but less than three-quarters returned to golf. Bone Jt Open 3:145–151

Springer

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.
3.5 Study 11: Golfers have a greater improvement in their hip specific function compared to non-golfers after total hip arthroplasty but less than three-quarters returned to golf

Robinson PG, Khan ST, MacDonald D, Murray AD, Clement ND. Golfers have a greater improvement in their hip specific function compared to non-golfers after total hip arthroplasty but less than three-quarters returned to golf. Bone Jt Open. 2022 Feb;3(2):145-151. PMID: 35172585

3.5.1 Aims and objectives

Following the successful publication of Robinson et al. studying return to golf following knee arthroplasty108, I decided to conduct a similar study using the Edinburgh Orthopaedics arthroplasty research database and analyse the rate of return to golf was following total hip arthroplasty (THA). Compared to TKA, THA is known to be less painful perioperatively and during postoperative activities, patients have greater satisfaction and a greater change in pre- to postoperative functional outcome scores.109 The primary aim of this study was to assess if golfers had greater improvement in outcomes compared to non-golfers following THA. The objectives were to assess preoperative and postoperative differences in demographics, symptoms, and function; postoperative differences in health-related quality of life (HRQoL); the rates of return to golf following surgery and factors that influence this; and the influence of golf on motivation and recovery following THA.

3.5.2 Methodology

Similar methodology to the previous study was applied and suffered the shortcomings previously mentioned. However, this retrospective methodology
allowed us to utilise a wealth of data that had not been leveraged for this type
of research and avoided the time commitments associated with beginning the
study prospectively. Further, we added a qualitative element to the golf-related
questions which had not previously been performed. Given the unmatched
nature of golfing and non-golfing cohorts, future work I perform may consider
propensity matching to minimise convenience sampling and selection bias and
produce better comparative groups. This included; one years’ worth of patients
form the Royal Infirmary of Edinburgh arthroplasty database. The time period
was chosen to allow at least 5 years’ worth of potential follow up. Patients were
included if they had had a primary, unilateral THA for osteoarthritis and had
returned functional outcome measures at one year postoperatively. Golf
related questions included whether they were a golfer at the time of their
surgery, what their current involvement was and what were their expectations
regarding playing golf postoperatively.

Outcome measures included the Oxford hip score (OHS), forgotten joint score
(FJS), the EQ5D, pain scores, and satisfaction. In terms of the statistical
analysis, we used tests for normality, and analysed the normally distributed
data with parametric testing. Continuous variables were analysed with
unpaired t tests or one way analysis of variance (ANOVA) if >2 cohorts. Chi
squared tests were used for binary variables while Fisher’s exact test was
applied to groups <5. Linear regression analysis was performed to assess if
golfing status would be an independent predictive variable for postoperative
continuous outcomes while binary logistic regression was applied to assess if
golfing status predicted satisfaction. A post-hoc power calculation based on the OHS minimally clinical important difference of 5 and an alpha of 0.05 was performed to give 93% power.

As previously discussed in the study 10, there were a large number of statistical tests performed, as seen in table 1. Similar adjustments previously proposed may have reduced the risk of some ‘significant’ p values occurring simply through chance alone.

3.5.3 Results

There were 308 patients included in the study. The non-golfing cohort had a statistically higher proportion of females and a lower preoperative OHS. Postoperatively, golfers had higher EQ5D VAS scores and OHS. When adjusting for preoperative confounders, regression analysis showed golfing status to be an independent predictor for change in OHS.

When comparing preoperative variables amongst those who did and did not return to golf, we found those who returned had superior EQ5D (VAS and Index) scores and greater OHS. Postoperatively, there were no functional differences between the groups. The rate of returning to play was 72.7%, of which 81% were still playing five years postoperatively. Of those who did not return to play, only 16.7% related this to issues with their hip or mobility. The most common reasons for not returning were losing the habit of playing, time
restraints, back pain and other surgeries. Of those that did return, 84.4% were satisfied with their involvement in the game of golf.

3.5.4 Conclusion

Golfers have a greater improvement in their hip-specific function (OHS) compared to non-golfers after THA. However, less than three-quarters of patients will return to golf, with male sex and those who have greater preoperative QoL or hip-related function were more likely to return. Of those who did not return, 83.3% gave a reason unrelated to their hip surgery.

3.5.5 Contribution to knowledge

This study has provided further data on the rates of returning to golf after THA. We have shown that preoperative health outcomes as well as hip function can predict the likelihood of returning to play. Interestingly, despite worse overall clinical outcomes seen globally with TKA (compared to THA), the rate of returning to play golf following THA was lower than that of TKA. However, knowing the reasons for not returning is helpful in unpicking the true reasons for being unable to play. This cohort also reported the number of golfers undergoing THA in our orthopaedic unit. We showed an overall prevalence of golfers to be 14% (which was 32% for males).

This study did have limitations which included its 70% response rate and male dominance in the demographics, however this is representative of the playing population in Scotland. Further studies should be performed in a prospective
manner to reduce selection bias and provide more accurate and detailed longitudinal data for such patients. In addition, future studies should explore greater numbers of female players and the unique experiences they have.

3.5.6 Student contribution

My contribution to this study was very similar to the previous study in this thesis on knee arthroplasty. I led the research idea, data collection, data analysis, and the writing/revising of the manuscript. In particular, I cleaned the spreadsheets appropriately for analysis and applied the additional golf specific questions to the data collection. Mr Nick Clement and I performed the data analysis and I wrote the primary manuscript and revised revisions based on co-author and reviewers’ suggestions.
Golfers have a greater improvement in their hip specific function compared to non-golfers after total hip arthroplasty, but less than three-quarters returned to golf

**Aims**
Golf is a popular pursuit among those requiring total hip arthroplasty (THA). The aim of this study was to determine if participating in golf is associated with greater functional outcomes, satisfaction, or improvement in quality of life (QoL) compared to non-golfers.

**Methods**
All patients undergoing primary THA over a one-year period at a single institution were included with one-year postoperative outcomes. Patients were retrospectively followed up to assess if they had been golfers at the time of their surgery. Multivariate linear regression analysis was performed to assess the independent association of preoperative golfing status on outcomes.

**Results**
The study cohort consisted of a total of 300 patients undergoing THA, of whom 44 were golfers (14%). This included 120 male patients (39%) and 180 female patients (61%), with an overall mean age of 67.8 years (SD 11.2). Golfers had a greater mean postoperative Oxford Hip Score (OHS) (3.7 (95% confidence interval (CI) 1.9 to 5.5); p = 0.039) and EuroQol visual analogue scale (5.3 (95% CI 0.1 to 11.9); p = 0.039). However, there were no differences in EuroQol five-dimension score (p = 0.124), pain visual analogue scale (p = 0.305), or Forergus Joint Score (p = 0.215). When adjusting for confounders, golfers had a greater improvement in their Oxford Hip Score (2.7 (95% CI 0.2 to 5.3); p < 0.001) compared to non-golfers. Of the 44 patients who reported being golfers at the time of their surgery, 32 (72.7%) returned to golf and 84.4% of those were satisfied with their involvement in golf following surgery. Those who returned to golf were more likely to be male (p = 0.039) and had higher (better) preoperative health-related QoL (p = 0.046) and hip-related functional scores (p = 0.026).

**Conclusion**
Golfers had a greater improvement in their hip-specific function compared to non-golfers after THA. However, less than three-quarters of patients returned to golf, with male patients and those who had greater preoperative QoL or hip-related function being more likely to return to play.

**Cite this article:** Bone Jt Open 2022;3-2:145–151.

**Keywords:** Golf, Hip Arthroplasty, Outcomes, Recovery

**Introduction**
Total hip arthroplasty (THA) is an effective treatment for hip arthritis that can return patients to a pain-free and functional state. There are over 175,000 hip and knee arthroplasties performed in England, Wales, and Scotland each year, while 1.88 million hip and knee arthroplasties performed are in the USA, and the volume is predicted to continue to grow. When patients are...
physically active prior to their THA, they are more likely to return to being “back to normal” compared to inactive patients.11 It has been reported that up to 20% of patients who undergo lower limb arthroplasties are golfers.12 Therefore, the impact of arthritis on golfers’ quality of life (QoL) can be significant if it prevents them from participating in their favoured recreational activities.13 A previous study has shown that restrictions to golf during the COVID-19 pandemic had a negative effect on well-being and life satisfaction, and that the reopening of golf courses improved a sense of belonging and enjoyment.14 Similar impacts may occur when golfers who suffer from arthritis are unable to play the game and can no longer enjoy the social and health benefits of playing.

Playing golf can contribute to meeting the World Health Organization (WHO) recommendations for physical activity.15 A previous study reported that golfers live, on average, five years longer than a matched non-golfer cohort.16 However, it is unclear whether being a golfer has any influence on the functional outcomes following THA compared to non-golfers. It is possible that their expectations may be different, and this has previously been shown to influence outcomes.17,18 In addition, there is a paucity of knowledge regarding golfers’ motivation to return to golf following THA, and whether there are factors that influence the rate of return to golf.

The primary aim of this study was to assess if golfers had greater improvement in their hip-specific outcomes compared to non-golfers one year following surgery. The secondary aims were to assess preoperative differences in demographics, symptoms, and function; postoperative differences in health-related quality of life (HRQoL); the rates of return to golf following surgery and factors that influence this; and the influence of golf on motivation and recovery following THA.

### Methods

Patients were identified from a prospectively compiled arthroplasty database. One year (2016) of patients undergoing primary THA for osteoarthritis (OA) were included (n = 439). All patients received the Exeter polished taper V40 cemented femur (Stryker, USA) and either a Trident acetabulum (Stryker) or cemented Contemporary cup (Stryker). Inclusion criteria were: primary THA, no previous surgery, preoperative diagnosis of OA, and preoperative and one-year postoperative outcome measures. Exclusion criteria included those not consenting to follow-up, or revision surgery. Demographic and convexity data were collected preoperatively. Patients were retrospectively followed up to assess if they had been golfers at the time of their surgery. They were also asked questions

### Table I: Preoperative demographics and functional outcomes between both golfers and non-golfers.

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Study cohort (n = 514)</th>
<th>Non (n = 264)</th>
<th>Yes (n = 44)</th>
<th>Difference/CI (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>212 (413)</td>
<td>82</td>
<td>30</td>
<td>OR 0.8 (0.5 to 1.2)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Female</td>
<td>202 (587)</td>
<td>182</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>182 (354)</td>
<td>159</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>220 (650)</td>
<td>105</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean age (yrs SD)</td>
<td>62.8 (11.4)</td>
<td>58.2 (12.2)</td>
<td>65.3 (11.3)</td>
<td>OR 1.2 (1.7 to 2.6)</td>
<td>0.150*</td>
</tr>
<tr>
<td>Mean BMI (kg/m^2) SD</td>
<td>27.3 (5.3)</td>
<td>28 (3)</td>
<td>27.3 (5.3)</td>
<td>OR 0.8 (0.3 to 0.8)</td>
<td>0.910*</td>
</tr>
<tr>
<td>Comorbidities, n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>30</td>
<td>26</td>
<td>4</td>
<td>OR 0.9 (0.3 to 2.8)</td>
<td>0.686*</td>
</tr>
<tr>
<td>COPD</td>
<td>28</td>
<td>27</td>
<td>1</td>
<td>OR 0.2 (0.01 to 1.4)</td>
<td>0.666*</td>
</tr>
<tr>
<td>Vascular</td>
<td>20</td>
<td>29</td>
<td>1</td>
<td>OR 0.2 (0.01 to 1.4)</td>
<td>0.696*</td>
</tr>
<tr>
<td>Diabetes</td>
<td>45</td>
<td>37</td>
<td>4</td>
<td>OR 0.6 (0.2 to 1.9)</td>
<td>0.477*</td>
</tr>
<tr>
<td>Gout</td>
<td>24</td>
<td>22</td>
<td>2</td>
<td>OR 0.9 (0.5 to 2.3)</td>
<td>0.949*</td>
</tr>
<tr>
<td>Kidney disease</td>
<td>25</td>
<td>23</td>
<td>2</td>
<td>OR 0.8 (0.5 to 2.2)</td>
<td>0.654*</td>
</tr>
<tr>
<td>Liver disease</td>
<td>24</td>
<td>22</td>
<td>4</td>
<td>OR 1.1 (0.3 to 1.4)</td>
<td>0.770*</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>22</td>
<td>21</td>
<td>1</td>
<td>OR 0.9 (0.04 to 2.1)</td>
<td>0.137*</td>
</tr>
<tr>
<td>Mean preoperative EQ-5D VAS (SD)</td>
<td>70.4 (10.7)</td>
<td>69.9 (11.1)</td>
<td>74.4 (8.5)</td>
<td>OR 0.8 (1.8 to 1.4)</td>
<td>0.539*</td>
</tr>
<tr>
<td>Mean preoperative EQ-5D Index (SD)</td>
<td>0.437 (0.18)</td>
<td>0.434 (0.169)</td>
<td>0.447 (0.185)</td>
<td>OR 0.1 (0.2 to 0.62)</td>
<td>0.108*</td>
</tr>
<tr>
<td>Mean preoperative pain VAS (SD)</td>
<td>52.2 (21.9)</td>
<td>52.1 (21.9)</td>
<td>52.4 (21.9)</td>
<td>OR 0.4 (0.5 to 0.4)</td>
<td>0.231*</td>
</tr>
<tr>
<td>Mean preoperative OHS (SD)</td>
<td>30.4 (9.2)</td>
<td>30.0 (9.2)</td>
<td>30.5 (8.4)</td>
<td>OR 0.2 (1.3 to 4.9)</td>
<td>0.044*</td>
</tr>
</tbody>
</table>

*p* = chi-squared test.
*CI* = confidence interval.
COPD: chronic obstructive pulmonary disease.
EQ-5D: EuroQol five-dimensional questionnaire.
HLD: haemorrhagic diabetic.
OHS: Oxford Hip Score.
VAS: visual analog scale.
regarding their involvement and expectations regarding golf postoperatively.

**Outcomes measurements.** The primary outcome measure was the Oxford Hip Score (OHS),13,14 which was recorded preoperatively and at one year postoperatively. The OHS comprises 12 questions assessed on a Likert scale with values from 0 to 4. A summative score is then calculated where 48 is the best possible score (least symptomatic) and 0 is the worst possible score (most symptomatic). The minimal clinically important difference (MCID) for the OHS is five points, and is thought to represent a clinical difference between two groups of patients.15

The Forgotten Joint Score (FJS) consists of 12 questions and evaluates the awareness of the affected joint during an array of activities of daily living. Each question is scored on a Likert scale ranging from 0 to 4. The total sum of the scores is converted into a scale ranging from 0 to 100, where higher scores reflect less joint awareness.

The EuroQol (EQ) general health questionnaire evaluates five domains (SD: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression) and was recorded preoperatively and at one year postoperatively.16 The three-level (3L) version of the EQ questionnaire was used, with the responses to the five domains being recorded at three levels of severity (no problems, some problems, or unable/extreme problems). This index is on a scale of -0.594 to 1, where 1 represents perfect health, 0 represents death, and negative values represent a state perceived as worse than death.16 The second page of the EQ questionnaire consists of a standard vertical 20 cm visual analogue scale (EQ-VAS) which is transformed to a scale of 0 (poor health) to 100 (best health) with current HRQoL.

A VAS was also used to assess subjective pain using a 15 cm horizontal scale from 0 to 100, where 100 is no pain and 0 is pain as bad as it could be.

Patient satisfaction was assessed by asking the question, “How satisfied are you with your operated hip?”. The response was recorded using a five-point Likert scale: very satisfied, satisfied, neither satisfied nor dissatisfied (simplified to neutral for the rest of the article), dissatisfied, and very dissatisfied. Satisfaction was dichotomized into ‘satisfied’ and ‘dissatisfied’. Satisfied was considered ‘satisfied’ and ‘very satisfied’, and dissatisfied was considered ‘neutral’, ‘dissatisfied’, and ‘very dissatisfied’. Five further questions were posed specifically to those who reported being a golfer at the time of the surgery.

**Golf-related outcomes.** All patients were contacted and asked whether they were a golfer prior to their THA. A golfer was defined as someone who considered golf as a hobby prior to surgery and played on a golf course. Golfers were asked if they returned to golf postoperatively and if they were still playing currently. They were also asked if returning to golf was a motivator for undergoing THA, if they believed golf was beneficial to their recovery, and if it improved their overall wellbeing. Of those patients who returned to golf, they were asked to define how satisfied they were with their involvement in the game of golf since THA on a five-point Likert scale: very satisfied, satisfied, neutral, dissatisfied, and very dissatisfied.

**Patients.** The study cohort consisted of a total of 308 patients undergoing THA with complete pre- and postoperative data that met the inclusion criteria. This included 120 male patients (39%) and 188 female patients (61%), with an overall mean age of 67.8 years (standard deviation (SD) 11.6) and a mean BMI of 28 kg/m² (SD 3.5). All golfers were right-handed. A total of 182 THAs were performed on the left side (59%) and 126 on the right side (41%). Preoperative demographic comparisons between the golfer cohort (n = 264) and the non-golfer cohort (n = 44) can be seen in Table I.

**Statistical analysis.** SPSS v. 17.0 (SPSS, USA) was used for all data analysis. Data were assessed for normality and parametric tests conducted where appropriate. Scalar variables were assessed using either an independent-samples t-test, or one-way analysis of variance (ANOVA). A chi-squared test was used to assess sex, comorbidity, and satisfaction differences between groups. Fisher’s exact test was used for groups of less than five. Significance was set as a p-value of < 0.05. Multivariate linear regression analysis was performed to assess golfing status as a preoperative independent variable when adjusted for preoperative confounders. Binary logistic regression was also performed to assess if golfing status predicted postoperative satisfaction when adjusting for confounders.

A post-hoc power calculation was performed using the MCID for the OHS (primary outcome measure) of 5,
Table III. Multivariate linear regression analysis of golfer status as an independent predictor for change in scores when adjusting for confounders.

<table>
<thead>
<tr>
<th>Variable</th>
<th>B (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ-SD Index ($z &lt; -0.1$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>0.04 (0.01 to 0.07)</td>
<td>0.269</td>
</tr>
<tr>
<td>EQ VAS ($z = 0.04$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>-4.8 (-3.2 to 1.1)</td>
<td>0.012</td>
</tr>
<tr>
<td>Pain VAS ($z = 0.01$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>3.2 (1.7 to 4.7)</td>
<td>0.054</td>
</tr>
<tr>
<td>OHS ($z = 0.1$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>2.7 (0.2 to 5.2)</td>
<td>0.057</td>
</tr>
<tr>
<td>SF ($z = 0.03$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-golfer</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Golfer</td>
<td>3.9 (1.9 to 6.0)</td>
<td>0.014</td>
</tr>
</tbody>
</table>

CI, confidence interval; EQ-SD, EuroQol five-dimension questionnaire; OHS, Oxford Hip Score; VAS, visual analogue scale.

Results

Functional and health-related outcomes. There was no difference in preoperative health-related measures between golfers and non-golfers ($p = 0.109$, independent-samples $t$-test) (Table I). However, golfers had significantly higher preoperative hip-specific function measured by the OHS (20.0 (SD 8.0)) vs 23.9 (SD 8.4); $p = 0.004$, independent-samples $t$-test) (Table I), which remained so postoperatively (19.5 (SD 7.7) vs 43.1 (SD 5.2); $p = 0.001$, independent-samples $t$-test) (Table II). Golfers had greater perceived postoperative health status measured by the EQ VAS ($p = 0.033$, independent-samples $t$-test); however, there was no difference in EQ-SD index ($p = 0.124$, independent-samples $t$-test) or pain VAS ($p = 0.505$, independent-samples $t$-test). Golfers were not more aware of their joint compared to non-golfers according to the FJS ($p = 0.215$, independent-samples $t$-test) (Table II).

When adjusting for confounders, golfers had a significantly greater improvement in their OHS of 2.7 points ($p = 0.037$) when compared to non-golfers, however there were no other significant differences in the change in outcomes measures between the groups (Table III).

At one-year follow-up, there were 39 golfers (88.6%) who were satisfied and five (11.4%) who were dissatisfied, compared to 238 non-golfers (90.2%) who were satisfied and 26 (9.8%) who were dissatisfied ($p = 0.75$, Fisher’s exact test; Table IV). Following binary regression analysis adjusting for preoperative variables, there was no difference in satisfaction between golfers and non-golfers ($p = 0.934$).

Comparison of postoperative satisfaction at one year between golfers and non-golfers.

<table>
<thead>
<tr>
<th>Golfer</th>
<th>Satisfaction</th>
<th>No</th>
<th>Yes</th>
<th>OR (95% CI)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfied</td>
<td>238</td>
<td>39</td>
<td>1.4 (0.6 to 2)</td>
<td>0.257</td>
<td></td>
</tr>
<tr>
<td>Dissatisfied</td>
<td>39</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Fisher’s exact test.

CI, confidence interval; OR, odds ratio.

Table IV. Reasons for golfers not returning to play following total hip arthroplasty.

<table>
<thead>
<tr>
<th>Reason for not returning</th>
<th>Patients, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lost the habit of playing</td>
<td>2</td>
</tr>
<tr>
<td>Time restrictions</td>
<td>2</td>
</tr>
<tr>
<td>Pain in hip</td>
<td>1</td>
</tr>
<tr>
<td>Fear mobility</td>
<td>1</td>
</tr>
<tr>
<td>Other medical reasons</td>
<td>1</td>
</tr>
<tr>
<td>Back pain</td>
<td>2</td>
</tr>
<tr>
<td>Other symptoms</td>
<td>2</td>
</tr>
<tr>
<td>Head and chest injuries</td>
<td>1</td>
</tr>
<tr>
<td>Femoral injury</td>
<td>1</td>
</tr>
</tbody>
</table>

Discussion

The most important finding of this study was that golfers had greater pre- and postoperative hip-specific function, and when adjusting for confounding, significantly greater improvement in the hip-specific function compared to non-golfers following THA. The rate of returning to golf following surgery was only 72.7% (n
Table VI. Comparison of demographic and functional outcomes of golfers who returned and those who did not.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Return to golf</th>
<th>Did not return to golf</th>
<th>Difference/DR (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
<td>2</td>
<td>OR 0.1 (0.02 to 0.9)</td>
<td>0.039*</td>
</tr>
<tr>
<td>Injury, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>8</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>4</td>
<td>17</td>
<td>OR 2.3 (0.6 to 9.1)</td>
<td>0.210</td>
</tr>
<tr>
<td>Mean BMI, kg/m² (SD)</td>
<td>28.5 (5.6)</td>
<td>27.1 (3.5)</td>
<td>DHR 1.5 (1.4 to 1.6)</td>
<td>0.301</td>
</tr>
<tr>
<td>Comorbidities, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart disease</td>
<td>1</td>
<td>3</td>
<td>OR 1.1 (0.1 to 12.1)</td>
<td>0.915</td>
</tr>
<tr>
<td>COPD</td>
<td>0</td>
<td>1</td>
<td>OR 1.1 (1 to 13)</td>
<td>0.536*</td>
</tr>
<tr>
<td>Vascular disease</td>
<td>0</td>
<td>1</td>
<td>OR 1.1 (1 to 13)</td>
<td>0.536*</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1</td>
<td>3</td>
<td>OR 1.3 (0.1 to 12.1)</td>
<td>0.915</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>2</td>
<td>OR 1.1 (1 to 13)</td>
<td>0.536*</td>
</tr>
<tr>
<td>Liver disease</td>
<td>1</td>
<td>3</td>
<td>OR 1.1 (0.1 to 12.1)</td>
<td>0.915</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>0</td>
<td>3</td>
<td>OR 1.1 (1 to 13)</td>
<td>0.536*</td>
</tr>
<tr>
<td>Preoperative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean EQ-5D VAS (SD)</td>
<td>64.3 (23.8)</td>
<td>78.7 (44.7)</td>
<td>DHR 14.4 (1.1 to 103.3)</td>
<td>0.018</td>
</tr>
<tr>
<td>Mean EQ-5D Index (SD)</td>
<td>0.291 (0.261)</td>
<td>0.147 (0.27)</td>
<td>DHR 1.3 (0.3 to 0.5)</td>
<td>0.040*</td>
</tr>
<tr>
<td>Mean pain VAS (SD)</td>
<td>47.8 (22.8)</td>
<td>54.2 (22.4)</td>
<td>DHR 6.1 (0.7 to 21.2)</td>
<td>0.299</td>
</tr>
<tr>
<td>Mean OHI (SD)</td>
<td>19.5 (9.1)</td>
<td>25.0 (9.3)</td>
<td>DHR 3.2 (1 to 11.4)</td>
<td>0.026*</td>
</tr>
<tr>
<td>Postoperative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean EQ-5D VAS (SD)</td>
<td>81.8 (18.7)</td>
<td>81.1 (10.7)</td>
<td>DHR 0.2 (1.2 to 17.7)</td>
<td>0.819</td>
</tr>
<tr>
<td>Mean EQ-5D Index (SD)</td>
<td>0.837 (0.231)</td>
<td>0.830 (0.204)</td>
<td>DHR 0.62 (0.3 to 0.62)</td>
<td>0.814</td>
</tr>
<tr>
<td>Mean pain VAS (SD)</td>
<td>80.9 (10.7)</td>
<td>77.7 (11.8)</td>
<td>DHR 3.2 (24.7 to 142.2)</td>
<td>0.781</td>
</tr>
<tr>
<td>Mean OHI (SD)</td>
<td>62.7 (18.6)</td>
<td>41.3 (24.6)</td>
<td>DHR 3.2 (1.2 to 0.2)</td>
<td>0.716</td>
</tr>
<tr>
<td>Mean HO (SD)</td>
<td>61.6 (26.4)</td>
<td>61.5 (28.2)</td>
<td>DHR 0.7 (0.3 to 1.8)</td>
<td>0.526</td>
</tr>
<tr>
<td>Satisfaction, n (%)</td>
<td>12</td>
<td>28</td>
<td>OR 1.5 (0.2 to 0.9)</td>
<td>0.720</td>
</tr>
</tbody>
</table>

*Fisher’s exact test
**Independent-samples t-test, CI, confidence interval; COPD, chronic obstructive pulmonary disease; EQ-5D, EuroQol five-dimension questionnaire; FJS, Forgotten (joint) Score; HO, heart; HOH, Oxford Hip Score; OR, odds ratio; SD, standard deviation; VAS, visual analogue scales.

= 32) at one year postoperatively, and a self-reported satisfactory involvement in the game was achieved by 84.4% (n = 27).

Golf is known to be an activity which can provide moderate physical activity, given its requirement to walk significant distances during a round.13,14 This exercise may contribute to the superior preoperative functional scores observed in golfers. The same may be true for the greater postoperative function and golf’s ability to aid with recovery. In addition, it would also be consistent with preoperative function being a significant predictor of postoperative outcomes following joint arthroplasty.15 Golfers in our study had pre- and postoperative OHIs four points greater than non-golfers, which is more than the suggested lower threshold for the minimal clinically important difference of three points.16 Golfers also reported perceived greater health status, according to the EQ-VAS, postoperatively compared to non-golfers. Returning to golf may contribute to the perception that patients are back to a healthier state with improved wellbeing.12

Although golfers reported greater functional outcomes postoperatively, there was no difference in joint awareness measured by the FJS. Golf is a physically demanding sport for an elderly population, requiring both strength and balance to swing the golf club,13 and endurance to walk the golf course.22 Despite these demands, golfers reported an equivalent level of joint awareness in their joint compared to a general population. However, the activity levels of the comparative cohort have not been explored in this study.

The overall prevalence of golfers was 14%, which increased to 32% for male patients. The demographics of this study are unique to the UK; however, they are similar to a European study which reported a prevalence of 20% in a cohort undergoing lower limb arthroplasty.16

---
More than 70% of the golfers returned to golf following surgery. Previous rates of returning to golf after THA have been higher in the literature, ranging from 87% to 95%. Despite a high percentage of golfers reporting golf as a primary motivator for undergoing surgery, satisfaction rates were not different between the golf and non-golf cohorts. The motivation for returning to golf after hip arthroplasty has not previously been explored. In the present study, golfers reported that getting back to playing sport contributed to their reason for undergoing joint arthroplasty in 43.2% of cases ($n=19$). Awareness of this by the operating clinician may be an important part of preoperative counselling.

The physical and mental health benefits of golf were reported by our cohort of golfers, with 45.4% ($n=20$) believing golf contributed to their rehabilitation and nearly 59% of golfers ($n=26$) believing that returning to the game improved their overall wellbeing. Preoperative factors may be able to predict the ability to return to golf. Those who returned had higher HRQoL scores and hip-related functional scores compared to those who did not. Although the study was not powered to detect these differences, it may suggest that preoperative rehabilitation strategies and health improvements could be beneficial to golfers who are keen to return to their sport. Further prospective research is needed to assess predictors of returning to golf.

This study must be interpreted considering its limitations. The overall response rate was 70%, which may expose the results to selection bias. The golfing cohort consisted predominantly of males. However, this is reflective of the overall golfing demographic and previous studies have shown no influence on sex following THA. Furthermore, adjustment was made for sex during the regression analysis which did not change the significance of the findings. The severity or pattern of OA within the hip prior to surgery was not assessed, nor were symptomatic degenerative joint diseases elsewhere in the body. In addition, activity levels in the non-golfing cohort were not explored, however, the study did not aim to explore this, instead simply assessing the outcomes of golfers following THA compared to all other THA patients, and therefore allowing for generic, pragmatic guidance for clinicians at the time of preoperative counselling and postoperative review.

In conclusion, golfers have a greater improvement in their hip-specific function (OHS) compared to non-golfers after THA. However, less than three-quarters of patients will return to golf, with male sex and those who have greater preoperative QoL or hip-related function more likely to return.

**Take home message**
- Golfers have a greater improvement in their hip-specific function compared to non-golfers after total hip arthroplasty (THA).
- Male sex and preoperative quality of life and hip function can predict those who will return to golf following THA.

**References**
178
3.6 Study 12: Infographic: Total hip arthroplasty in golfers


3.6.1 Aims and objectives

Dissemination of research messages is vital for impact in both scientific and clinical environments. One such method is using information graphics aka infographics. Infographics has have been shown to be most effective when limited to <400 words and a combination of data visualisations and illustrations are included. The British Journal of Sports Medicine and the Bone and Joint Journals have successfully introduced these via the leadership of colleagues who are co-authors on the golf and arthroplasty publications. Recognising this, I looked to improve our dissemination and engagement with an infographic. Previous publications have provided a helpful guide on aspects to consider when designing an infographic which were applied to the construction of this present publication. Having seen the utility of the infographic included in the first study in this thesis, I was pleased to be able to lead this work for the present study. The aim of this infographic was to provide a visual representation of the published study to increase the dissemination of this work. The objectives were to use key take home points from the paper and represent them using brief statistics, graphs and images to enable rapid and easy reader consumption.

3.6.2 Methodology
Mr Shujaa Khan and myself summarised the key findings of this study. We discussed a variety of visual variables including the colour scheme, graphics, layout and overall message we hoped to achieve by the infographic. Mr Khan then began designing the infographic with regular meetings with myself to review and adapt the versions.

3.6.3 Results
We prioritised a portrait layout to accommodate the Bone Joint Open's journal structures. A green colour scheme was added to represent the grass that golf is played on. We used the Canva.com website for access to the design features including the graphics. Key graphics we wanted to include were 1) golf related images i.e. the golf ball and players as well as 2) anatomical graphics i.e. the pelvis with the illustration of a total hip replacement in place. We kept the volume of text to a minimum and represented key data with bar charts, pie charts and figures. Finally, we designed the infographic to flow from the top of the page naturally down to the bottom to finish with the conclusion and key message which was the rate of returning to golf.

3.6.4 Conclusion
This was the first infographic I have been involved in creating. It was a helpful learning experience to 1) appreciate the role and impact of infographics in general and 2) understand the expectations and style journals are looking for.

3.6.5 Contribution to knowledge
This infographic has since been shared independently by users on Instagram, LinkedIn and Twitter which demonstrates its engagement. It has been integrated into PowerPoint presentations for national and international presentations.

3.6.6 Student contribution

My contribution to this was the idea and conceptualisation of using an infographic for this study. I suggested the layout, colour scheme and key messages to include. This design process went through an iterative process with input from all co-authors. I helped our colleague Mr. Khan through the design process using canva.com, a website I am very familiar with which allows users to design many different graphics for research and business purposes, including infographics.
Total hip arthroplasty (THA) is a clinically beneficial and cost-effective treatment for patients with end-stage hip arthritis. Among patients undergoing lower limb arthroplasty, golf is a popular pursuit. Hip arthritis can limit patients’ ability to play golf, and this can adversely affect quality of life (QoL). However, the effect of being a golfer on functional outcomes and QoL following THA versus a non-golfer are unclear. Furthermore, there is a paucity of studies exploring factors associated with return to golf following THA.

Robinson et al set out to assess the hip-specific functional outcomes, satisfaction, and improvements in QoL following THA in golfers versus non-golfers. Additionally, the study aimed to determine the rate of return to golf and influencing factors. Overall, 328 patients undergoing primary THA over a one-year period at a single institute were included. Of these, 120 patients (39%) were male and 188 (61%) were female, with an overall mean age of 62.8 years (standard deviation (SD) 11.6). There were 44 golfers (14%) within this group.

This study found that golfers had significantly higher hip function than non-golfers at one year following surgery (Oxford Hip Score of 43.1 (SD 5.2) vs 39.5 (SD 7.7); p < 0.001, independent-samples t-test). In addition, golfers had a significantly greater EuroQol visual analogue scale score (82.6 (SD 15.2) vs 77.1 (SD 20.4); p = 0.039, independent-samples t-test) indicating a higher perceived QoL following surgery. Of the 44 golfers, 32 (72.7%) returned to golf, and within this group, 27 (84.4%) were satisfied with their involvement in golf since returning from their surgery. Finally, this study found that male sex (p = 0.001, chi-squared test), those with greater preoperative QoL (p = 0.039, independent-samples t-test) or greater preoperative hip function (p = 0.026, independent-samples t-test) were more likely to return to golf. These findings can assist surgeons and patients in shared decision-making for THA.

References
6. Robinson PS, Khan SF, Macdonald R, Murray IR, MacDermid J, Clement ND. Golfer have a greater improvement in their hip-specific function compared to non-golfers after total hip arthroplasty but less than three-quarters returned to golf. Bone Joint J 2012;94-B(1):141–145.
TOTAL HIP ARTHROPLASTY IN GOLFERS

AIM
Assess 1 year post-op outcomes of golfers vs non-golfers undergoing THA

STUDY DESIGN
- 308 Patients
- Mean age = 67.8
- 120 golfers, 188 non-golfers

HIP FUNCTION

QUALITY OF LIFE

RETURN TO GOLF
- 72.7% returned
- 84.4% satisfied with their golf

Rate of return if:
- Male gender
- Pre-op ODI
- Pre-op hip function

REFERENCES:
3.7 Study 13: Golfing after Orthopaedic surgery: a Longitudinal Follow up project (GOLF): A prospective study protocol


3.7.1 Aims and objectives

The purpose of this protocol study was to present the aims and methodology of a prospective, longitudinal follow up study of the outcomes of golfers following hip, knee, ankle or shoulder arthroplasty. To date, no study has prospectively assessed returning to golf after arthroplasty. Therefore, there has been a paucity of reliable evidence in this field. In addition, retrospective studies have previously failed to closely report the progressive recovery from surgery and therefore, the time points by which golfers return to different aspects of the game. From the previous meta-analysis in this thesis, the hypothesis was that total hip arthroplasty will have the highest rate of return followed by shoulder and then knee arthroplasty. However, knee arthroplasty patients would return fastest, followed by hip and then shoulder arthroplasties. Little data was known regarding the outcomes of ankle arthroplasty prior to commencing this study.

This study will fill the holes of several gaps in the literature regarding returning to golf after arthroplasty. The data will help guide clinicians in managing a safe
recovery back to the sport for patients but also manage expectations on the
likelihood of returning based on demographic and surgical factors.

The surgical procedures being undertaken will be primary total hip
arthroplasty, revision total hip arthroplasty, primary hip resurfacing, total knee
arthroplasty, revision knee arthroplasty, unicompartmental knee arthroplasty,
total shoulder arthroplasty, total and revision ankle arthroplasty, reverse
shoulder arthroplasty and hemiarthroplasties. The benefits of these surgeries
are well documented, as are the physical activity benefits of golf.

The primary aim was to include the rate of returning to golf. Secondary aims
included determining the timing of return to golf, changes in ability, handicap,
and mobility, and assessing joint-specific and health-related outcomes
following surgery. The objectives were to follow patients closely at four time
points to measure the nature of their return to golf. Golf specific questionnaires
and patient reported outcome measures will be used to measure the
functionality of each participant.

3.7.2 Methodology
This is a multi-centre, prospective, longitudinal study between the Hospital
for Special Surgery (HSS), New York City and Edinburgh Orthopaedics,
Royal Infirmary of Edinburgh. This prospective study design should achieve
superior evidence compared to what was produced in study 10 and 11. I will
have a more controlled inclusion criteria and exclude (or account for)
potential variables that could confound the data. By publishing the protocol methods, I hope to be transparent in what I and the co-authors have set out to do and what results we have stated we would report on. Further, the peer-reviewed process has enhanced the scientific quality of the overall protocol. All patients who meet the inclusion criteria for the study and who are scheduled for hip, knee, ankle and shoulder arthroplasty at each centre will be asked if they consider themselves a golfer. Patients will be enrolled preoperatively and followed for one year postoperatively.

Outcome measures collected will be golf-specific data in the ‘Golfing after orthopaedic surgery: a longitudinal follow up (GOLF) questionnaire’ (Appendix 1). This has been specifically created for this study. Patient-reported outcome measures will include the Golf After Arthroplasty Surgery Score (GAAS) (Appendix 2), Hip Disability and Osteoarthritis Outcome Score – Joint Replacement (HOOS-JR), Knee Injury and Osteoarthritis Outcome Score – Joint Replacement (KOOS-JR), American Shoulder and Elbow Score (ASES), the Manchester-Oxford Foot Questionnaire (MOXFQ) and PROMIS Global Health Survey. Time points for follow up are as follows: GOLF Questionnaire collected preoperatively, 6 weeks, 3 months, 6 months and 12 months. HOOS-JR, KOOS-JR, ASES, MOXFQ collected preoperatively and at 6 and 12 months. The GAAS Questionnaire collected at 6 and 12 months. The GOLF questionnaire is qualitative in design and has not been validated. These questions were devised by a group of experts in the field of golf medicine, orthopaedic surgery, physical activity and research
methods. In contrast, the GAAS questionnaire has been designed to be quantitative. Preliminary, unpublished data has already been recorded from a retrospective cohort of patients in an effort to begin the validation of the questionnaire. Following the data captured from this prospective study, we will complete the final components of the validation including test re-test reliability, internal consistency and construct validity.

The sample size calculation for this descriptive study is based on the estimated numbers of patients who undergo hip, knee, ankle or shoulder arthroplasty per year and meet the eligibility criteria. We estimate that 75, 20, 35, and 30 golfers will undergo hip, knee, shoulder, or ankle arthroplasty, respectively, per year at HSS. Edinburgh estimates that 45, 45, 10, and 10 golfers will undergo hip, knee, shoulder, or ankle arthroplasty per year. Across both sites, the yearly estimates are 120, 65, 45, and 40 golfers who undergo hip, knee, shoulder, and ankle arthroplasty, respectively. This study protocol is also accessible via clinicaltrials.gov (Study ID: NCT05675618).

3.7.3 Results
The results of this prospective study will be produced once the sample sizes at each site have been achieved. On completion of data collection, both data sets from each site will be merged and analysed at the Royal Infirmary of Edinburgh site. Data will be analysed using SPSS Statistics v. 24.0 software (IBM, USA).
3.7.4 Conclusion

We hope this study will produce the most comprehensive data on returning to golf after arthroplasty in the present literature. This will provide clinicians with information to counsel and consent golfers prior to orthopaedic surgery. In addition, the study will produce data which could be used to statistically power future studies accurately.

3.7.5 Contribution to knowledge base

This study will build on the previous retrospectively conducted research analysing the functional outcomes of golfers following hip and knee arthroplasty. It will also be the first study to use collaborative working to present a multicentre, prospective approach to epidemiological research related to golf and arthroplasty.

3.7.6 Student contribution

Senior author Dr. Roger Hawkes had voiced an interest in collaborating with international colleagues at the HSS to assess outcomes of golfers following orthopaedic surgery. One informal chat led to my suggestion to Dr. Hawkes for me to lead this study and build on the retrospective work already underway at the University of Edinburgh. Dr. Hawkes made the introductions with the team at HSS and this was met with enthusiasm and allowed planning to begin. During a virtual meeting we discussed key stakeholders who should be involved in the study including orthopaedic surgeons, sports medicine physicians, physiatrists, and research managers.
Following a basic outline of what we were trying to achieve in the study, I drafted a protocol. This underwent numerous revisions with input from all co-authors to ensure what we were designing was both achievable and methodological sound. I submitted the protocol to IRAS and our local research and development ethics committee. Both were approved. More recent discussions at the beginning of 2023 lead to an enthusiasm to include total ankle arthroplasty. There was therefore an amendment to the methods and ethics, drafted by myself and approved. The study began recruiting patients in January 2023.
3.7.7 Publication

ARthroplasty

Golfing after Orthopaedic Surgery: A longitudinal follow-up (GOLF) study protocol


From Edinburgh Orthopaedics, Royal Infirmary of Edinburgh, UK and Hospital for Special Surgery, New York City, New York, USA

Aims
The primary aim of this prospective, multicentre study is to describe the rates of returning to golf following hip, knee, ankle, and shoulder arthroplasty in an active golfing population. Secondary aims will include determining the timing of return to golf, changes in ability, handicap, and mobility, and assessing joint-specific and health-related outcomes following surgery.

Methods
This is a multicentre, prospective, longitudinal study between the Hospital for Special Surgery, (New York City, New York, USA) and Edinburgh Orthopaedics, Royal Infirmary of Edinburgh, (Edinburgh, UK). Both centres are high-volume arthroplasty centres, specializing in upper and lower limb arthroplasty. Patients undergoing hip, knee, ankle, or shoulder arthroplasty at either centre, and who report being golfers prior to arthroplasty, will be included. Patient-reported outcome measures will be obtained at six weeks, three months, six months, and 12 months. A two-year period of recruitment will be undertaken of arthroplasty patients at both sites.

Conclusion
The results of this prospective study will provide clinicians with accurate data to deliver to patients with regard to the likelihood of return to golf and timing of when they can expect to return to golf following their hip, knee, ankle, or shoulder arthroplasty, as well as their joint-specific functional outcomes. This will help patients to manage their postoperative expectations and plan their postoperative recovery pathway.

Cite this article: Bone Jt Open 2023;4(7):490–495.

Keywords: Golf, Arthroplasty, Hip, Knee, Shoulder

Introduction
Golf is played by over 66 million people in 206 countries.

In 2019, UK golfers spent £5.1 billion on their sport, which reflects a 20% increase in consumer spending since 2014. The sport helps golfers meet the World Health Organization (WHO) recommendations for physical activity, and the health benefits of golf have been well presented in a scoping review by Murray et al., with players describing improved physical and mental wellbeing.

Joint arthroplasty is one of the most common and cost-effective operative procedures worldwide and is an excellent intervention for patients suffering from end-stage arthritis. Joint arthroplasty leads to reduced levels of pain and improved levels of function. There are approximately 175,000 hip and knee arthroplasties performed in England, Wales, and Scotland each year, while there are approximately 1.88 million hip and knee arthroplasties performed in the USA per annum. Arthritis can have a significant impact on a patient’s quality of life and can prevent golfers from participating in their hobby (or livelihood). It is estimated that up to 20% of patients with joint arthroplasties are golfers. Sorbie et al. studied the impact of golf course closure during the COVID-19 pandemic on wellbeing and life satisfaction. They reported that belonging,
enjoyment, and wellbeing were significantly associated with outdoor course activity, and a sense of belonging and satisfaction increased following the reopening of golf courses. It is likely that these findings are applicable to golfers who are unable to play secondary to their arthritis prior to arthroplasty.

A previous review analyzed the literature assessing return to golf after arthroplasty surgery; however, to the authors' knowledge, there has been no prospective study describing the rate of return or predictive factors associated with returning to golf following arthroplasty. Swanson et al. suggested recommendations based on the literature regarding when patients can consider returning to play golf. However, this was based only on a consensus statement by orthopaedic surgeons regarding sporting activities following arthroplasty. A retrospective study of returning to sport following unicompartamental knee arthroplasty (UKA) compared to total knee arthroplasty (TKA) showed a 100% return to golf if in those undergoing UKA, compared to only 30% following TKA. However, where this difference is observed prospectively is not clear, or whether other arthroplasty options such as resurfacing versus standard THA can influence return to golf. This protocol aims to outline the methodology that will be employed for a prospective study of golfers undergoing hip, knee, ankle, or shoulder arthroplasty. These were chosen as they are the most commonly performed arthroplasty procedures.

**Aims.** The primary aim of this prospective, multicentre study is to describe the rates of returning to golf following hip, knee, ankle, and shoulder arthroplasty in an active golfing population. Secondary aims will include determining the timing of returning, changes in ability, handicap and mobility, and functional/health-related outcomes. In addition, outcome comparisons will be made between arthroplasty type.

**Methods**

**Study setting and design.** This is a multicentre, prospective, longitudinal study between the Hospital for Special Surgery, New York City and Edinburgh Orthopaedics, Royal Infirmary of Edinburgh. Both centres are tertiary referral centres, specializing in upper and lower limb arthroplasty.

**Recruitment.** Patients scheduled for hip, knee, ankle, and shoulder arthroplasty at each centre will be asked if they consider themselves a golfer. Potential patients will include those undergoing hip, knee, ankle, or shoulder arthroplasty at the two medical centres. Patients will be enrolled preoperatively and followed for one year postoperatively.

**Eligibility criteria.** Inclusion and exclusion criteria will be applied. Patients included in this study will not have any alterations to their treatment, nor will their treatment be affected if they are excluded or decline participation. Reasons for exclusion will be recorded.

Inclusion criteria are as follows: 1) age ≥ 18 years; 2) a self-reported golfer; 3) able to consent to treatment; and 4) assessed and listed for one of the following surgical procedures: total hip arthroplasty, hip resurfacing, revision hip arthroplasty, total knee arthroplasty, unicompartmental knee arthroplasty, revision knee arthroplasty, primary ankle arthroplasty, revision ankle arthroplasty, total shoulder arthroplasty, reverse shoulder arthroplasty, shoulder hemiarthroplasty, and revision shoulder arthroplasty. Exclusion criteria are as follows: 1) patients unable to comply with postoperative data gathering, including completing questionnaires; 2) patients declining operative management; 3) no desire to return to golf postoperatively; and 4) medical comorbidities that affect the patient's ability to play golf, that will ultimately not allow the patient to return to golf postoperatively.

**Data collection and management.** Patients undergoing arthroplasty will be identified from outpatient clinics and pre-assessment clinics. At the pre-assessment clinic, approximately two to four weeks prior to surgery, appropriate patients will be offered information regarding the study from the treating surgeon or research assistant. Patients will also be identified, enrolled, and consented electronically on the day of surgery if they are not identified at the pre-assessment. As the study is low-risk, additional patient interaction is minimal and does not impact their treatment. Consent will be performed by a member of the research team. In the UK, this will be a Good Medical Practice trained individual, and in the USA it will be a research assistant. On recruitment to the study, the patients' details (including name, age, and contact details) and hospital identification number will be logged into a secure database at the respective hospital site. Each database will be identical and allow for merging at the end of the study period, to allow for ease of data analysis.

Demographic and surgical data are routinely collected by both medical centres and accessible via electronic medical records (Table 1). Golf-specific data collected in the ‘Golfing after orthopaedic surgery: a longitudinal follow-up (GOLF) Questionnaire’ (Supplementary Material) will be gathered via Research Electronic Data Capture (REDCap; Vanderbilt University, USA) at the Hospital for Special Surgery, and via the use of Formic forms (Formic, UK) at the Royal Infirmary of Edinburgh. Questionnaires will be collected electronically pre- and postoperatively.

**The GOLF questionnaire.** The questionnaire has been designed by multinational experts in orthopaedic surgery, sports medicine, physiatry, research, and public lay members who were active golfers and who had previously undergone arthroplasty. It is designed to be qualitative and applicable in the pre- and postoperative setting. The questionnaire can be seen in the Supplementary Material.
Data reporting. The response rate of golfers undergoing arthroplasty will be reported as a percentage of the total eligible cohort of golfers. The demographic details of those who declined follow-up or were lost to follow-up will be reported.

Primary outcome measures. The primary outcome will be to report the rates of return to golf following hip, knee, ankle, and shoulder arthroplasty. "Returning to golf" will be defined as a golfer returning to their desired maximal level of involvement. Levels of involvement will include putting, chipping, iron shots, driver shots, and playing nine holes and 18 holes.

Secondary outcome measures. Secondary outcomes will include the timing of return, changes in the frequency of golfing, changes in mobility on the golf course, changes in handicap, joint pain during and after golf, and satisfaction with their involvement in golf. Other variables that will be reported include: if patients’ golf is affected by any other joint problems, if patients have other existing joint arthroplasties or are awaiting consultation/surgery on other joints, and the type of golf course they play on. Patient-reported outcome measures will include the Golf After Arthroplasty Surgery score (GAAS) (Supplementary Material 2). Knee injury and Osteoarthritis Outcome Score—Joint Replacement (HOOS-JR). Knee Injury and Osteoarthritis Outcome Score—Joint Replacement (KOOS-JR). American Shoulder and Elbow Surgeons score (ASES). The Manchester-Oxford Foot Questionnaire (MOXFQ). The Manchester-Oxford Foot Questionnaire (MOXFQ) is a 16-item questionnaire scored on a five-point Likert scale (each item is scored from 0 to 4, with 4 signifying 'most severe'). There are three underlying domains: walking/standing problems (seven items), foot pain (five items), and social interactions (four items). Raw scores are converted to a scale from 0 to 100, where 100 represents the most severe. The three domain scales (walking/standing, pain, and social interaction) have been shown to have excellent psychometric properties in terms of reliability, validity, and responsiveness.

HOOS-JR. The HOOS-JR was constructed from the longer, original version of the Hip disability and Osteoarthritis Outcome Score (HOOS). The HOOS-JR contains six items from the original HOOS survey. Items are scored from 0 to 4, none to extreme, respectively. HOOS-JR is calculated by summing the raw response (range 0 to 24) and then converting it to an interval score. The interval score ranges from 0 to 100, where 0 represents total hip disability and 100 represents complete hip health.

KOOS-JR. The KOOS-JR was developed from the original version of the Knee Injury and Osteoarthritis Outcome Score (KOOS). The KOOS-JR comprises seven items from the original KOOS survey. Items are coded from 0 to 4, none to extreme, respectively. KOOS-JR is scored by summing the raw response (range 0 to 28) and then converting it to an interval score. The interval score ranges from 0 to 100, where 0 represents total knee disability and 100 represents perfect knee health.

ASES. The ASES is a mixed outcome reporting measure for use in a variety of shoulder pathologies. The ASES score can be viewed as a 100-point scale that evaluates two dimensions of shoulder function: pain and performance in activities of daily living. Each of the two domains make up for 50 of the 100 points.

MOXFQ. The Manchester-Oxford Foot Questionnaire (MOXFQ) is a 16-item questionnaire scored on a five-point Likert scale (each item is scored from 0 to 4, with 4 signifying 'most severe'). There are three underlying domains: walking/standing problems (seven items), foot pain (five items), and social interactions (four items). Raw scores are converted to a scale from 0 to 100, where 100 represents the most severe. The three domain scales (walking/standing, pain, and social interaction) have been shown to have excellent psychometric properties in terms of reliability, validity, and responsiveness.

PROMIS Global-10. The PROMIS Global-10 is a publicly available global health assessment tool that...
allows measurements of symptoms, functioning, and healthcare-related quality of life for a variety of chronic diseases. It consists of ten items that assess general domains of health and functioning, including overall physical health, mental health, social health, pain, fatigue, and overall perceived quality of life.

**Participant timeline.** Patients will be assessed preoperatively and then again at six weeks, three months, six months, and 12 months postoperatively by completing the questionnaires. Follow-up will be done using email and/or phone consultation for non-responders. Data collection at each timepoint can be seen in Table II.

**Strengths and limitations.** The strengths and limitations of this prospective study can be viewed in Table III.

**Sample size and statistics.** There are no published data reporting the proportion of patients undergoing arthroplasty who are active golfers. However, one study suggested this might be as high as 20%.[1] The sample size calculation is based on the estimated numbers of patients who undergo hip, knee, ankle, or shoulder arthroplasty per year and meet the eligibility criteria. We estimate that 75, 20, 35, and 30 golfers will undergo hip, knee, shoulder, or ankle arthroplasty, respectively, per year at HSS. Edinburgh estimates that 45, 45, 10, and 10 golfers will undergo hip, knee, shoulder, or ankle arthroplasty per year, respectively. Across both sites, the yearly estimates are 120, 65, 45, and 40 golfers who undergo hip, knee, shoulder, and ankle arthroplasty, respectively. For procedure breakdowns, we estimate the following: 1) for hips, 65% will be primary total hip arthroplasties, 30% will be resurfacings, and 5% will be revisions; 2) for knees, 75% will be primary total knee arthroplasties, 15% will be unicompartimental knee arthroplasties, and 10% will be revisions; 3) for shoulders, 40% will be primary total shoulder arthroplasties, 50% will be reverse total shoulder arthroplasties, 7% will be revisions, and 3% will be resurfacings; and 4) for ankles, 80% will be primary total ankle arthroplasties, and 20% will be revisions.

We plan to collect data over a two-year period, which results in a total of 540 patients (240 hips, 130 knees, 90 shoulders, 80 ankles). From these, we expect 80% to agree to participate in the study, leading to final numbers of 192 hips, 104 knees, 72 shoulders, and 64 ankles (total = 432).

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>First prospective study assessing return to golf following joint arthroplasty</td>
<td>Surgeons may influence patients’ decision on when or if to return to golf</td>
</tr>
<tr>
<td>Multicentre study</td>
<td>Selection bias of patients willing to be recruited</td>
</tr>
<tr>
<td>Accurately defining “return to golf”</td>
<td>Potential for loss to follow-up</td>
</tr>
<tr>
<td>Characterizing timing of returning to golf-specific activities (putting, chipping, etc.)</td>
<td></td>
</tr>
<tr>
<td>First study to use a globally applied standardized handicap system</td>
<td></td>
</tr>
</tbody>
</table>

On completion of data collection, both datasets will be merged and analyzed by the Royal Infirmary of Edinburgh site. Data will be analyzed using SPSS Statistics v. 24.0 (IBM, USA), with continuous variables analyzed using range and standard measures of central tendency (mean and standard deviation (SD) or median and interquartile range (IQR) depending on the normality, which will be assessed using Shapiro-Wilk testing). Any comparison between study groups will use the chi-squared test (categorical variables) and paired t-test or non-parametric Mann-Whitney U test (continuous variables) as appropriate. Analysis of variance (ANOVA) testing will be used to compare the four main cohorts of arthroplasty. Statistical significance will be set at p < 0.05.

**Data management.** Data collected during the study will be handled and stored in line with the 1998 Data Protection Act, which states data should be de-identified as soon as it is practical to do so. Hard-copy data collection forms will be stored in locked filing cabinets at each respective site, and accessible only by research team members. Any hard-copy data and participant information will be converted to electronic spreadsheets stored securely on hospital servers only accessible by research team members on password-protected computers. Quality control procedures will be in the form of regular inspections of each master file at each site, and research will be in compliance with the protocol agreed by the ethics committee and Good Medical Practice. Access to the final dataset will be limited to the co-authors and research assistants involved in the study.

**Protocol amendments.** Any changes in research activity – except those necessary to remove an apparent, immediate hazard to the participant in the case of an urgent safety measure – must be reviewed and approved by the Principal Investigator at each Investigator Site. Amendments will be submitted to a sponsor representative for review and authorization, before being submitted in writing to the appropriate research ethics committee (REC) and local research and development (R&D) committees for approval prior to participants being enrolled into an amended protocol.

**Data monitoring.** The data steering and monitoring committee, which is composed of research personnel at both sites, will undertake regular checks to ensure data.
collection and management is appropriate. In addition, they will ensure the feasibility of the study to continue.

The Principal Investigator is responsible for the quality of the data recorded in the study database at each Investigator Site. Investigators and institutions involved in the study will permit trial-related monitoring and audits on behalf of the sponsor, REC review, and regulatory inspection(s). In the event of audit or monitoring, the Investigator agrees to allow the representatives of the sponsor to have access to all study records and source documentation. In the event of regulatory inspection, the Investigator agrees to allow inspectors direct access to all study records and source documentation.

Data protection. All Investigators and staff involved with this study will comply with the requirements of the appropriate data protection legislation (including the General Data Protection Regulation and Data Protection Act) with regard to the collection, storage, processing, and disclosure of personal information. Computers used to collate the data will have limited access measures via usernames and passwords. Published results will not contain any personal data or identifiable information, and will prevent re-identification from taking place.

Patient confidentiality. All records will be kept in a secure storage area with limited access. Clinical information will not be released without the written permission of the patient. The Investigator and study staff involved with this study may not disclose (or use for any purpose other than performance of the study) any data, record, or other unpublished information which is confidential or identifiable to those individuals for the purpose of the study. Prior written agreement from the sponsor must be obtained for the disclosure of any said confidential information to other parties.

Ethics. The protocol was reviewed by the South East Scotland Research Ethics Service, and a letter of approval was provided on 10 November 2021 for the Royal Infirmary of Edinburgh site (21/SC/0380). The study also received ethical approval from the Hospital for Special Surgery (IRB 2021-0437). The study was registered with clinicaltrials.gov (NCT05675618 version 1.2). Access to the SPIRIT checklist for this study is available in Supplementary Material 3.

Dissemination. The results of this prospective study will be disseminated to the orthopaedic and sports medicine/physiatry communities via presentations at national and international meetings. A manuscript for a peer-reviewed journal will be prepared and submitted.

Discussion

This research aims to be the first prospective study to report the rates and timings of returning to golf following hip, knee, ankle, or shoulder arthroplasty. Currently, available evidence-based advice regarding returning to golf following joint arthroplasty is outdated.20 A recent meta-analysis of all studies analyzing return to golf following hip, knee, or shoulder arthroplasty identified only retrospective studies. The authors reported pooled rates of returning to golf of 90%, 70%, and 80% for the hip, knee, and shoulder, respectively. Timings were reported to be 4.5 months for hip arthroplasty, 3.8 months for knee arthroplasty, and 6 months for shoulder arthroplasty.23 The influence of joint prosthesis design on rates of returning to golf following knee arthroplasty has also recently been studied, but no difference was shown in posterior-stabilizing and cruciate-retaining implants.24 Two retrospective studies analyzing the satisfaction levels of golfers when returning after hip or knee arthroplasty reported rates of 84% or 88%, respectively.2,25 This study aims to prospectively follow patients through their arthroplasty journey and accurately describe key milestones in their return to golf. In addition to standard outcome measures, this study will facilitate the validity of a newly designed outcome questionnaire. The GAAS questionnaire aims to highlight detailed experiences of golfers’ perceptions of their joint arthroplasty during a variety of golf-specific activities. This outcome measure, and the overall study, will help to give accurate golf-specific expectations to patients awaiting surgery and during the consent process for surgery.

Supplementary material

Pre- and postoperative GOLF questionnaires, Golfing After Arthroplasty Surgery Score, and SPIRIT checklist

References


25. Robinson PG, Khan S, MacDonald D, Murray IR, Macpherson GJ, Clement ND. Golfers have a greater improvement in their hip specific function compared to non-golfers after total knee arthroplasty, but less than those younger returned to golf. Bone Jt Open 2021;2(3):145-151.

Author information:
1. PG Robinson, FRCS, FRCS (Orth), Consultant Orthopaedic Surgeon, Edinburgh Orthopaedic, Royal Infirmary of Edinburgh, Edinburgh, UK, European Tour Performance Institute, Virginia Water, UK.
3. E Cheng, RN, Research Manager.
5. E P Su, MD, Attending Orthopaedic Surgeon.
7. D Padvad, MD, Attending Orthopaedic Surgeon.
8. C Dennehy, PhD, NET, Attending Orthopaedic Surgeon.
11. Hospital for Special Surgery, New York City, New York, USA.

Author contributions:
1. PG Robinson: Conceptualization, Methodology, Writing – original draft, Writing – review & editing.
2. A Gough: Conceptualization, Methodology, Writing – original draft, Writing – review & editing.
3. E Cheng: Conceptualization, Methodology, Writing – original draft, Writing – review & editing.
4. E Sines: Methodology, Writing – review & editing.
5. E V Gallina: Methodology, Writing – review & editing.
6. E P Su: Methodology, Writing – review & editing.
7. D Padvad: Methodology, Writing – review & editing.
8. C Dennehy: Methodology, Writing – review & editing.
9. H Parther: Methodology, Writing – review & editing.
11. R Hampel: Conceptualization, Methodology, Writing – review & editing.
12. N D Clement: Conceptualization, Methodology, Writing – review & editing.

Funding statement:
1. This study was independently funded by each participating institution.

ICMJE COI statement:
1. RG Clement is on the editorial board for Bone & Joint Research and The Bone & Joint Journal. C Dennehy reports payments from Wolters Kluwer Health, IP royalties from Elsevier and InBios, and consulting fees from Elsevier, InBios, Mindray, and 1ST Surgical; speaker payments from Extravas, all of which are unrelated to this article. C Dennehy is also a board member of the American Orthopaedic Foot and Ankle Society. J Duhne reports royalties from ArtFix and OrthoMentor, research support payments from ArtFix, publishing royalties from Thieme and Wolters Kluwer, all of which are unrelated to this article. E V Gallina reports royalties from Zimmer Biomet and Exactech, and consulting fees, speaker payments, support for attending meetings and travel (from Exactech); all of which are unrelated to this article. E P Su: Each of the following companies pays Remedi, a technology company. None of these companies pay or have paid for any portion of the research related to this manuscript. E Sines reports royalties from DIO Global, and holds shares in St. Francis Hospital, unrelated to this article. E Sines reports a research support grant from the American Orthopaedic Foot and Ankle Society. R Hampel reports a research grant from IndoChina Physical Therapy, unrelated to this article, and is Senior Editor of Arthroplasty, Section Chief of NASS, and Chair of the USRA-LIB committee. E Cheng received honoraria from Kyocera, United Orthopedics, Smith and Nephew, and Orthologics; consulting fees from Smith & Nephew and United Orthopaedics, and stock or stock options in Overture Orthopedics, all of which are unrelated to this article.

Acknowledgements:
1. We would like to thank the teams at HSS and Edinburgh Orthopaedics in making this collaboration possible.

Ethical review statement:
1. The protocol was reviewed by the South East Scotland Research Ethics Service and a letter of approval was provided on 15 November 2021 for the Royal Infirmary of Edinb urgh site (20/SC/0038). The study also received ethical approval from the hospital for special surgery (IRB # 2021-04-07).

© 2023 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution NonCommercial No Derivatives (CC BY-NC-ND 4.0) licence, which permits the copying and dissemination of the work only, and provides that the original author and source are cited. See https://creativecommons.org/licenses/by-nc-nd/4.0/
Appendix 1. Pre and postoperative GOLF Questionnaires

**Preoperative Golf Questionnaire**

1. Do you play golf?
   a. Yes
   b. No

2. How long have you been playing golf?
   a. State no. of years

3. Do you have a desire to return to golf after surgery?
   a. Yes
   b. No

4. What is your handicap index?
   a. Enter number ----
   b. Do not have an official handicap
      i. Please give estimate

5. Do you play golf right or left handed? Please tick
   a. Left
   b. Right

6. What was your typical involvement in golf prior to joint problems related to your arthritis?
   a. Driving range only
   b. 9 holes (max)
   c. 18 holes

7. How often did you play golf prior to the onset of joint problems related to your arthritis?
   a. More than twice a week
   b. Twice a week
   c. Weekly
   d. Monthly
   e. Yearly

8. Which of the following are you currently able to do? Please select the most you can do.
   a. Putt
   b. Chip/pitching
   c. Hitting irons
   d. Hitting woods
   e. Play 9 holes
   f. Play 18 holes
   g. None of the above
9. If still playing, how often do you currently play golf?
   a. More than twice a week
   b. Twice a week
   c. Weekly
   d. Monthly
   e. Yearly

10. Please state the slope rating and yardage of the course you play most frequently. If unknown, please name golf club
   a. Slope rating
   b. Yardage
   c. Not applicable

11. When was the last time you played golf on the course?
   a. Last week
   b. Last month
   c. 1-6 months ago
   d. 6-12 months ago
   e. >1 year ago
   f. Not applicable

12. What is the form of mobility you use around the course during a typical round? (choose one of the following)
   a. Walking with caddie
   b. Walking and carrying one’s bag
   c. Walking and with trolley
   d. Cart
   e. Not applicable

13. Please characterize your frequency of pain during golf?
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. Always

14. Please describe the severity of your pain during golf?
   a. None
   b. Mild
   c. Moderate
   d. Severe

15. Please characterize your frequency of pain after golf?
   a. Never
   b. Rarely
   c. Sometimes
d. Often
e. Always

16. Please describe the severity of your pain after golf?
   a. None
   b. Mild
   c. Moderate
   d. Severe

17. Have you undergone any other joint replacement surgery before? Please select and subsequently indicate which side.
   a. Hip replacement
   b. Knee replacement
   c. Shoulder replacement
   d. Not applicable

18. Are you awaiting additional orthopaedic review/surgery on another joint which affects your ability to play golf?
   a. Yes
   b. No

19. Are you awaiting additional assessment advice/treatment on your back or neck which affects your ability to play golf?
   a. Yes
   b. No

20. Please characterize your level of satisfaction with your involvement in the game of golf due to your joint problem currently. Please select one of the following.
   a. Very dissatisfied
   b. Dissatisfied
   c. Neither satisfied nor dissatisfied
   d. Satisfied
   e. Very satisfied

21. How important is the social aspect of playing golf to you?
   a. Not at all important
   b. Slightly important
   c. Moderately important
   d. Very important
   e. Extremely important

22. What are your expectations for your frequency of golfing after surgery?
   a. Not expecting to return
   b. Expect to play less than preoperatively
   c. Expect to play the same as preoperatively
d. Expect to play more than preoperatively

23. Did your doctor advise you on when you could return to golf?
   a. Yes
      i. Please specify
   b. No

24. Did your physical therapist advise you on when you could return to golf?
   a. Yes
      i. Please specify
   b. No

25. Are you undertaking any golf-specific rehabilitation?
   a. Yes
      i. Please specify
   b. No
Postoperative Golf Questionnaire

1. Have you returned to golf?
   a. Yes
   b. No

2. If not, why?
   a. Please state

3. Do you have a desire to return to golf after surgery?
   a. Yes
   b. No

4. What is your handicap index?
   a. Enter number ----
   b. Do not have an official handicap
      i. Please give estimate

5. Which of the following are you currently able to do? Please select the most you can do.
   a. Putt
   b. Chip/pitching
   c. Hitting irons
   d. Hitting woods
   e. Play 9 holes
   f. Play 18 holes
   g. None of the above

6. How often do you currently play golf?
   a. More than twice a week
   b. Twice a week
   c. Weekly
   d. Monthly
   e. Yearly

7. What is the form of mobility you are currently using around the course during a typical round? (choose one of the following)
   a. Walking with caddie
   b. Walking and carrying one’s bag
   c. Walking and with trolley
   d. Cart
   e. Not applicable (not returned yet)

8. Please characterize your frequency of pain during golf?
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
9. Please describe the severity of your pain during golf?
   a. None
   b. Mild
   c. Moderate
   d. Severe
   e. Not applicable (not returned yet)

10. Please characterize your frequency of pain after golf?
    a. Never
    b. Rarely
    c. Sometimes
    d. Often
    e. Always
    f. Not applicable (not returned yet)

11. Please describe the severity of your pain after golf?
    a. None
    b. Mild
    c. Moderate
    d. Severe
    e. Not applicable (not returned yet)

12. Are you awaiting additional orthopaedic review/surgery on another joint which affects your ability to play golf?
    a. Yes
    b. No

13. Are you awaiting additional assessment advice /treatment on your back or neck which affects your ability to play golf?
    a. Yes
    b. No

14. Please characterize your level of satisfaction with your involvement in the game of golf due to your joint problem currently. Please select one of the following.
    a. Very dissatisfied
    b. Dissatisfied
    c. Neither satisfied nor dissatisfied
    d. Satisfied
    e. Very satisfied

15. Did your doctor advise you on when you could return to golf?
    a. Yes
       i. Please specify
    b. No
16. Did your physical therapist advise you on when you could return to golf?
   a. Yes
      i. Please specify
   b. No

17. Are you undertaking any golf-specific rehabilitation?
   a. Yes
      i. Please specify
   b. No
Appendix 2. Golf After Arthroplasty Surgery (GAAS) Score

Please answer the following questions on a scale of:

Never-almost never-seldom-sometimes-mostly

How aware are you of your joint replacement when:

1. Walking on the course on the flat
2. Walking on the course up hills
3. Walking on the course down hills
4. Walking in the rough
5. Hitting driver
6. Hitting irons
7. Hitting wedges
8. Putting
9. Hitting sand shots
10. Getting out of the bunker
11. Picking your ball out of the hole
12. Teeing the ball up
13. Picking up your tee
14. During the front 9
15. During the back 9
16. Sitting in the clubhouse after your round
17. Driving home
18. During the rest of the day following your round
19. In bed/overnight following your round
20. The following day
3.8 Summary of theme 2

The body of work covering the topic of return to golf after joint replacement surgery was systemically constructed following early discussions with myself, Prof. Andrew Murray, Dr. Roger Hawkes and Dr. Joel Press. The eventual goal was always to conduct a prospective study following players progressively through their golf journey from arthritis to joint replacement and returning to play. Similar to the structure of theme 1, I needed to better understand the literature in this area. A basic knowledge of it meant it was obvious there were no prospective studies that had been conducted. We began with a systematic review of all studies performed to the present date. However, unlike the systematic review of professional golf injuries, there was a satisfactory amount of homogeneity amongst studies to allow us to perform a meta-analysis of the data. This subsequently provided the most reliable data to date for returning to golf after hip, knee or shoulder arthroplasty. At that time I better understood the literature in the field and was keeping a close eye on new research being published. This was ultimately how I identified the study critiqued in study 9. Given the journey of research I was undertaking, I felt it was pertinent to formally appraise the study performed by Gobarty et al. and highlight some of my concerns with the study. Although we did not get a response, it was a useful process to undertake and reassured me that there was value in conducting a prospective study in the future which resolved a number of the flaws.
Study 10 and 11 demonstrated that golfers undergoing hip or knee arthroplasty are not necessarily representative of the entire patient population. It was interesting to note that golfers had greater joint specific functional scores compared to non-golfers. Although retrospective research had been performed in this area previously, much of which was included in the meta-analysis, I did think there was merit in performing a study on both hip and knee arthroplasty for the following reasons. Firstly, there were no studies using golf as an independent variable for outcomes after surgery. Nor had studies explored the functionality of golfers compared to non-golfers. Such data would give both patients and surgeons more relevant expectations postoperatively. In addition, no study had explored many of the personal and social factors of undergoing joint replacement as a golfer both pre and postoperatively. Data exploring golf as a motivator for surgery and also the holistic question of ‘how satisfied are you with your involvement in the game of golf?’ was captured and it was informative to see that a substantial proportion of golfers were satisfied. This question perhaps captures more than simply performative data postoperatively such as handicap change, which had typically been the focus of previous studies in the literature. In addition, we were the first to collect longer term golf-related outcomes at a minimum of 5 years.

The prospective study protocol drew on lessons learned from the previous literature and my previously performed studies. In particular, the GOLF questionnaire covers key golf-specific topics at key time-points which I believe will be truly helpful to both patients for guiding their expectations but also
doctors and physiotherapists to help manage patients through their recovery and return to play by giving accurate, evidence-based advice. For example, we chose our time points to be 6 weeks, 3 months, 6 months and 12 months. We felt an early time point would capture those who returned to simple shots such as putting and chipping and which require less physical demands. Anecdotally, myself and orthopaedic colleagues were in agreement that common questions from patients postoperatively concern when they can go back to chipping and putting. A timepoint at 3 months and 6 months will hopefully capture the majority of the patients who turn to playing golf in full. These estimations are backed by the results of the meta-analysis data in study 8. Finally, a 12 month time point is a typical waypoint for orthopaedic surgery and therefore this will give us comparative patient reported outcome which could be compared to other patients who do not golf.

We also plan to capture data on players expectations of 1) if they return and 2) if their quantity of golf increases or decreases. In addition, we explore confounding variables for returning such as having undergone previous joint replacements or other musculoskeletal spinal pains requiring clinical review. Myself and the co-authors have created a new, quantifiable questionnaire which explores patients’ awareness of their joint during the game of golf. This will hopefully provide clinicians with more understanding of the patients’ experiences during their journey and help with consultations regarding what patients can expect when they return to play. This questionnaire is not yet validated however, we hope to do that with the data collected in this study.
This study will be the most granular, detailed study performed in the field of returning to golf after orthopaedic surgery and we hope it becomes the landmark paper to managing patients’ expectations.
Chapter 4 Impact of the research and future perspectives

4.1 Introduction

As someone who has worked in government policy as well as clinical practice, I have been acutely aware of the need not only to publish, but also to look to support research uptake, use and impact. Barton et al, and Murray et al describe processes to publish research, and develop tools such as infographics to support dissemination.\textsuperscript{113,114} Utilising social media and wider platforms to engage with relevant stakeholders can generate uptake and use. There is a dedicated goal from our research group in Edinburgh to drive golf medicine research from a centre which recognises the health benefits of golf and has the desire to explore how we can better understand injury and illness in golf and ultimately implement evidence-based strategies which prevent such occurrences.

Golf medicine research has historically lagged behind other sports in terms of output but also funding. This is despite golf having a similar number of participants as football and cricket in Great Britain and Ireland over the past 7 years.\textsuperscript{115} It became a sport which thrived during the COVID-19 pandemic as it could be played outdoors where social distancing was possible.\textsuperscript{85} The numbers of golfers have grown significantly during this time and so too has the academic interest. Since 2010, the number of research articles published in relation to golf has grown by 94%.\textsuperscript{116} This bibliometric trend represents an overall acknowledgment of the opportunity and importance of golf medicine
and some indication for the future potential in this field. By assessing the knowledge gaps, and working with established researchers, industry experts and policy makers, I was able to conduct research that has grown the knowledge base in priority areas for these stakeholders.

4.2 Impact of this work on policy and practice

The research contained in this thesis is a progression of the foundational work of the Golf and Health project founded by the World Golf Foundation, and Dr. Roger Hawkes. Dr. Hawkes and Prof. Murray have worked systematically with golfing organisations such as the International Golf Federation and the R&A to identify knowledge gaps and conduct research in these areas. The systematic review on injuries in professional golf has been presented to the medical and scientific departments of the major golf leagues and organisations who host professional events. The consensus statement on reporting of injury and illness in golf involved the first author of the overall IOC consensus for sport, and is becoming the standard blueprint for conducting injury epidemiology research in golf. This will then allow future studies to include pertinent findings, correctly report incidence (or prevalence) and enable future comparisons and meta-analytics to be performed. This is a significant enhancement, noting the heterogeneity of previous data, and the expressed intent of the International Golf Federation to assist with the development of more consistent injury reporting.
The narrative review of golf during the COVID-19 pandemic provided scientific evidence to the UK government, but was also shared with ministers and officials in Scotland, Ireland, Wales, Australia and Canada, amongst other countries. This helped countries decide whether to restrict golf, and what mitigations could be put in place. This report was cited during conversations with World Health Organisation officials. Overall, this study encouraged policy makers to enable golf to be played during the pandemic due to its safety and health benefits with appropriate mitigations.

The research conducted on rates of SARS-CoV-2 on elite golfers was instrumental in developing risk assessment and risk mitigation strategies, and evaluating them. This approach was articulated to the health authorities in each of the countries the DP World Tour visited, which significantly informed the approach to sporting events in Europe, and the Middle East. The Chief Executive of the DP World Tour has described the research as being essential in keeping the DP World Tour functioning, limiting any risk in the countries tournaments were being hosted, and supporting important collaborations with governments and health authorities. It is estimated that three events would have been cancelled during the 2021 season if it had not been for the risk-assessed and risk-mitigating approaches used from our research. Each subsequent study provided scientific evidence that the medical team and executives on the tour could present to policy makers and public health officials in the many countries that the organisation delivered events at. An example of this, was the tour medical and research team presenting the evidence to the
UK Government, Public Health England, and local authorities regarding daily testing as opposed to standard isolation. An agreement to run tour protocols as a research study in the United Kingdom (incorporated into wider golf studies in the 2021 season) allowed the UK specific event to proceed. The evidence from this study, and from a similar workplace study with Jaguar Land Rover was presented to these parties. Following this, the United Kingdom/ England moved to a policy of permitting daily testing as an alternative to standard isolation. Event organisers were thinking hard about moving their events from the UK at this time and the research from this thesis contributed to the evidence to allow these events to proceed.

Similarly, our work in golf enabled conversations with authorities in countries such as South Africa, England and Scotland to put in place risk assessments and control measures to permit persons with COVID-19 to play, if isolated at other times. This enabled all competitors who were well enough to play, to participate. Elements of this approach were discussed with the World Health Organisation, and the medical teams for other international organisations including football, rugby, tennis, sailing, motorsport and basketball. Each of these organisations were generous with their knowledge, and worked with golf and each other on shared protocols and pathways.

The research which formed the essence of theme two in this thesis has already had an impact on clinicians and patients by enhancing the patient experience of undergoing joint replacement. In particular, the meta-analysis of returning
to golf following hip, knee and shoulder arthroplasty has provided clear, concise probabilities of returning to golf following each surgery and mean time frames. The infographic published on returning to golf following hip arthroplasty is used in our local hospital (Royal Infirmary of Edinburgh) to help consent patients for surgery and manage expectations. It has also been shared by interested clinicians and researchers on social media.

Much of the research included in this thesis was included and influential in a successful application to the International Olympic Committee (IOC) for a recognised centre of research awarded to the University of Edinburgh and University of Bath. This IOC centre is known as the UK Collaborative Centre for Injury and Illness Prevention in Sport.

4.3 Directions for future research

This is an exciting time for golf medicine research. Leading universities and golf institutions are largely working collaboratively across key themes. These include:

1. The health benefits and disbenefits of golf
2. Illness and injury prevention and treatment in golf
3. Increasing inclusion and diversity
4. Improving the performance of golfers
5. Building a health legacy from golf events
I have returned to my further training in orthopaedic surgery, and I am mostly now involved in injury prevention and the treatment of injuries/ musculoskeletal complaints. This includes the G.O.L.F. study which is currently underway. This study will be the first to prospectively follow patients after surgery and hopefully guide patients through some of the nuances of returning to golf such as when it is safe to return to chipping or full shots on the golf course. This study will address the methods of mobility when returning to golf which are important variables to include when considering the health benefits of playing. In addition, research in injury epidemiology in recreational golfers is underway using the golf specific IGF recommendations on reporting of injury and illness.

The summation of the thesis has not been explicit in exploring the role of sex as a confounding or effect modifier in the findings of golf related outcomes. Future work should explore this in more detail. Studies included in the systematic review in study 1 were heavily biased towards male golfers. However, one included study by Gosheger et al. did analyse sex and reported no statistical difference between the number, anatomical distribution or severity of golf injuries.\cite{Gosheger2008} That was, however, not the focus of the study and efforts should go towards exploring some of the unique differences surrounding potential risk factors for injuries and functional outcomes in women’s golf compared to men’s. Some more recent studies have studied female golfers in isolation in the elite game\cite{Ueda2016} and I believe these efforts would be warranted in the recreational sport also. With regards to the role of sex in theme 2, studies have shown superior functional outcomes for male compared
to female patients following THA\textsuperscript{118}, TKA\textsuperscript{119} and shoulder arthroplasty.\textsuperscript{120} We discuss sex in study 10 and 11 as confounders of the independent variable (i.e. golfing status) but on reflection, it is likely that it would have been more useful to report sex as an effect modifier (i.e. differentiation of the outcome based on the variable as opposed to distortion of the association). Performing a stratification analysis to assess the associations of male and female golfers separately with regards to outcomes may have yielded more meaningful data.

The internal validity of some studies in this thesis may have been compromised by selection bias and confounders. For example, the increasing rate of vaccination status during study 6 may have confounded the effects of the risk mitigating efforts of other aspects of the protocol. In addition, the athletic levels of non-golfers in study 10 and 11 were not recorded. The uncertainty of such activity levels make the comparison between the two groups and the conclusions of the study, somewhat uncertain. Such levels, if known, could have been accounted for as independent variables in the regression analysis performed. In theme 2, the qualitative data such as motivation and satisfaction for players continuing to play golf five years following hip or knee arthroplasty is likely to suffer from selection bias as those who are no longer playing did not answer these questions. The external validity of the data in this thesis in reference to is generalisability is likely to be questionable for female golfers given the significant distribution of participants in favour of men. Further, such biases with regards to gender distribution amongst the included papers in this thesis may affect the external validity of
such studies. Hence, generalisability of the results to all golfers may be questioned.

Injury burden is an interesting epidemiological concept which considers injury severity alongside injury incidence rates. There are currently no large prospective studies analysing the incidence and burden of injuries in non-professional nor professional golfers using the golf-specific consensus framework. Previous expert opinion has described the benefits of reporting injury burden in addition to incidence and time-loss. The two concepts can be combined in a risk matrix to give the relative importance of each injury. Future work in golf should consider applying this concept which has been useful in describing injury in other sports.

My long term research goal in the field of golf medicine is to work with colleagues in Edinburgh and globally to better understand golf, it’s health benefits and the injuries and illnesses associated with it. This will allow me to continue to contribute to the knowledge base, and inform golfers, health practitioners, the academic community and policy makers to improve health outcomes for golfers.
References


3. Golf & Health Scientific Meeting. The International Congress for Golf and Health.; 2018 17/10/18; London.


51. European Tour Player A to Z Europeantour.com: The PGA European Tour 1997 - 2017; [Available from:


85. R&A. Participation growth in Great Britain and Ireland 2023 [16/04/23].
   Available from: https://www.randa.org/en/articles/participation-growth-in-
great-britain-and-ireland.

86. Perrault A, Charpignon M, Gruber J, et al. Designing Efficient Contact Tracing

   transmission in international professional golf. Unpublished Work 2021

   [Available from: https://www.who.int/publications/i/item/contact-tracing-in-
   the-context-of-covid-19 accessed 21/05/21.


90. Mina MJ, Andersen KG. COVID-19 testing: One size does not fit all. Science

    enhanced protocols regarding contacts at an international professional golf
    event. BMJ Open Sport Exerc Med 2021;13(7)

92. Murray AM, A. Pluim, BM. Calder, J. Falvey, E. Contact tracing for

93. Office for national statistics. Coronavirus (COVID-19) Infection Survey, UK:
    Office for National Statistics; [Available from:
    https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/
    /conditionsanddiseases.

95. Veneti L, Bøås H, Bråthen Kristoffersen A, et al. Reduced risk of hospitalisation among reported COVID-19 cases infected with the SARS-CoV-2 Omicron BA.1 variant compared with the Delta variant, Norway, December 2021 to January 2022. Euro Surveill 2022;27(4)

96. Lauring AS, Tenforde MW, Chappell JD, et al. Clinical Severity and mRNA Vaccine Effectiveness for Omicron, Delta, and Alpha SARS-CoV-2 Variants in the United States: A Prospective Observational Study. medRxiv 2022


102. Robinson PG, Khan S, MacDonald D, et al. Golfers have a greater improvement in their hip specific function compared to non-golfers after total hip arthroplasty, but less than three-quarters returned to golf. *Bone Jt Open* 2022;3(2):145-51.


