

Institution: University of Bedfordshire		
Unit of Assessment: 24		
Title of case study: Enhancing golf performance through biomechanical analysis		
Period when the underpinning research was undertaken: 13 th January 2015 onwards		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Andrew Mitchell	Head of School: Sports Science & Physical Activity, Reader in Biomechanics	(01/09/2013) to date
Dr Laura Charalambous	Senior Lecturer in Biomechanics	(01/09/2013) to date
Dr Iain Fletcher	Principal Lecturer in Biomechanics	(11/04/2008) to date
Period when the claimed impact occurred: July 2016 to date		
Is this case study continued from a case study submitted in 2014? No		
<p>1. Summary of the impact</p> <p>Our research has established new assessment methods and physical profiling tests for clubhead velocity in golf and have been adopted by both the Professional Golfers' Association (PGA) European Tour Performance Institute (ETPI) and England Golf to profile their elite golfers. These tests now form the basis for the way in which elite and recreational golfers' training programmes are designed, delivered and evaluated. In order to carry out these tests, new coaches have been employed, new equipment has been purchased and provision of our assessment and physical profiling is now implemented by the ETPI in new facilities at 37 European Tour events across the world per year, in addition to the recent 2018 & 2019 Open Championships and the 2018 Ryder Cup.</p>		
<p>2. Underpinning research</p> <p>In 2015, the Sport Performance & Biomechanics Research Group (SPBRG) within the Institute for Sport and Physical Activity Research (ISPAR) at the University of Bedfordshire, began examining the testing, profiling and training modalities being used within elite golf to enhance driving distance. Driving distance (how far the ball travels from the tee) is negatively correlated with playing handicap (better golfers hit the ball further) and research suggests if a golfer can drive the ball 20 yards further, they are likely to gain 0.75 strokes per round, or 3 strokes over a four-day tournament. To put that into context, looking at the current scoring averages for the PGA, the top ranked golfer has a scoring average of 69.4 strokes per round. If we add 3 strokes to that, it falls to the golfer ranked 197th out of only 215 golfers on this tour.</p> <p>Data from 2018 shows that PGA golfers averaging between 310-320 yards in driving distance won an average of \$1,890,032 more than their counterparts that average between 300-310 yards. Whilst driving distance is a key performance parameter, it is affected by environmental conditions, limiting its ability to be reliably used to determine drive performance. Therefore, the most useful indicator of driving distance is clubhead velocity (CHV) at impact (how fast the club is moving when it strikes the ball).</p> <p>The SPBRG's initial research focussed on examining the relationships between CHV and vertical ground reaction force (vGRF) during bilateral strength and jumping based exercises in</p>		

highly skilled (handicap ≤ 5) golfers [3.1]. Previous literature had shown significant relationships between CHV and vertical jump height, however, these modalities do not measure vGRF, which is considered to be a critical aspect for increasing driving distance. Traditional approaches had focussed on using training modalities to develop rate of force development, which we found to be a less reliable method, compared to measuring impulse.

Our research indicated that exercises, similar in duration to the golf downswing, which aim to increase impulse and maximal force production have the greatest relationships with CHV [3.1]. Squat jump and countermovement jump positive impulse (CMJ PI) had the strongest correlations with CHV, whilst peak force was shown to significantly relate to peak CHV [3.1]. This was the first study to show that maximal explosive strength has an important relationship with golfers' drive distances.

As a result of this world leading research [3.1], the SPBRG collaborated with the European Tour in order to examine if CHV could be predicted by CMJ PI and isometric mid-thigh pull (IMTP) peak force in 31 European Challenge Tour (professional) golfers. This world-leading study was the first to examine the relationship between CHV and force generating capacity in elite golfers performing on the European Challenge Tour circuit [3.2]. The results showed that CMJ PI was a large significant positive predictor of Challenge Tour golfers' CHV. These findings offer significant practical insight, in that increasing CMJ PI by 46.85 N·s, should yield an increase in CHV of 1.69 m·s⁻¹. This provides clear guidance for strength and conditioning (S&C) coaches working with golfers to prescribe exercises and set goals to achieve this objective and increase CHV.

The SPBRG extended the evidence base further by compiling an asymmetry profile for highly skilled golfers across a range of bilateral strength and jumping based exercises in order to examine if there was a relationship between vGRF asymmetry and CHV [3.3]. Whilst golf is an inherently asymmetrical sport, there is conflicting evidence within the literature as to the association between asymmetry and increased risk of injury and reduced performance. The standardised assessment and physical profiling used within this [3.3] and previous studies [3.1, 3.2] can be used to reliably identify asymmetries in countermovement jump, squat jumps, drop jumps and IMTP in highly skilled golfers. Whilst asymmetries were found to have no significant relationship with CHV in this study, it lays important groundwork, to enable the group to prospectively examine the relationship between vGRF asymmetry and injury within highly skilled golfers. In the meantime, S&C coaches should focus on prescribing exercises to maximise force production rather than matching symmetry.

3. References to the research

- 3.1: Wells, J.E.T., Mitchell, A.C.S., Charalambous, L.H., Fletcher, I.M. (2018). Relationships between highly skilled golfers' clubhead velocity and force producing capabilities in vertical jumps & an isometric mid-thigh pull. *Journal of Sports Sciences*, 36(16), 1847-1851.
- 3.2: Wells, J.E.T., Charalambous, L.H., Mitchell, A.C.S., Coughlan, D., Brearley, S.L., Hawkes, R.A., Murray, A.D., Hillman, R.G., Fletcher, I.M. (2019). Relationships between Challenge Tour Golfers' clubhead velocity and force producing capabilities during a countermovement jump and isometric mid-thigh pull. *Journal of Sports Sciences*, 37(12), 1381-1386.
- 3.3: Wells, J.E.T., Mitchell, A.C.S., Charalambous, L.H., Fletcher, I.M. (2020). Relationships between highly skilled golfers' clubhead velocity and vertical ground reaction force asymmetry during vertical jumps & an isometric mid-thigh pull. *Journal of Strength & Conditioning Research*, 34(10), 2824-2831.

4. Details of the impact

Changes to assessment methods used by the PGA European Tour & England Golf

Our research findings were presented by Dr Jack Wells to the Chief Medical Officer of the European Tour [5.1]. These findings showed a strong relationship between vGRF variables and CHV [3.1] and showed the importance of IMTP peak force and CMJ PI for CHV and in turn golf

driving distance. This highlights that the more force generated during a vertical jump, the faster the swing of the golf club and the further the ball will travel. At the time, this was the first study to examine these vGRF variables in highly skilled golfers. Based on this research [3.1] and the presentation to the Chief Medical Officer, the ETPI moved away from their traditional method of evaluating explosive strength in their golfers [5.1]. They changed their approach to assessment in professional golf, from using vertical jump height, to looking at IMTP peak force and CMJ impulse saying *“As a consequence of our discussions with you and your research team and on the basis of the evidence in your work, we began to investigate the use of peak force and impulse measures of strength and explosive strength”* [5.1].

The ETPI, subsequently contacted all 650 PGA European Tour, Challenge Tour and Senior Tour players, offering them the new standardised assessment and physical profiling we identified [3.1 & 3.2] and confirmed the impact of this new approach, stating: *“For the first time at the ETPI, we implemented a standardised approach to physical profiling; previously we had no such assessment players could use”* [5.1]. England Golf also adopted the standardised assessments and profiling we identified to improve performance [3.1 & 3.2] and these are now carried out with England Golf’s male and female national and regional squads, totalling 208 golfers [5.2].

Collaboration with the PGA European Tour & England Golf to gain insight and enhance provision for their golfers

Working in collaboration with the ETPI, recommendations from our research [3.1] were tested in a cohort of 31 elite golfers on the PGA European Tour, which resulted in a world-leading study on elite golfers [3.2]. Subsequently, the ETPI implemented our recommended approach to physically profiling its golfers [5.3] based on our assessment methods [3.1 & 3.2]. This revolutionised and standardised their current practices, where previously there had been no consistent and reliable approach [5.1]. In order to do this, the ETPI purchased two PASCO Scientific Force Plates, so they could replicate our recommended assessment methods [5.1]. All 650 PGA European Tour, Challenge Tour and Senior Tour players were contacted and offered S&C training support based on the results of the assessment [5.1]. Following the lead of the ETPI, England Golf [5.2] purchased two PASCO Scientific Force Plates, so their S&C coaches at the National Performance Centre could replicate the standardised profiling assessments we recommended based on findings from our research [3.1 & 3.2], with their elite squads. England Golf highlighted the impact of using our research in practice, stating: *“This research has been of great value to England Golf, as it allows us to objectively track the progress of our players as well as informing the strength and conditioning delivery, which sets us apart from other NGB programmes”* [5.2].

The standardised Physical Profile Report & Physical Profiling Decision Tree used by the ETPI [5.3] has been developed from our research findings [3.1 & 3.2]. Used in conjunction, they enable a series of standardised tests to be carried out, providing an evidence-based assessment leading to specific training modalities that can then be prescribed based on the results of the tests. Tailored assessments can facilitate optimal performance of the golfer, taking key factors related to performance into account. For example, if IMTP peak force is low, strength training at 80-100%1RM would be prescribed, however, if it is high and CMJ PI is low, prescription would focus on exercises that elicit increases in impulse, such as weighted jumps [5.3]. Using these novel assessment methods not only offers ways to improve performance, but also enables audit, feedback and monitoring of the players’ progress. This in turn highlights the positive impact the S&C training is having on their physical profile and in turn their CHV. Based on the results of the Challenge Tour research [3.2] the ETPI now use a scoring system from 1-10, which provides benchmarking for players undertaking our profiling [5.3]. Our research [3.3] has also laid the foundation for a prospective asymmetry epidemiology study in this cohort of highly skilled golfers.

Employment of additional strength & conditioning coaches by the PGA European Tour

Our research has created additional roles for S&C coaches within the golf arena. In order to deliver the standardised assessment and physical profiling across its tournaments worldwide, the ETPI employed four additional S&C staff to carry out the testing, interpret the data and design bespoke S&C programmes for golfers based on the results of their profiling assessment [5.1]. Our group were responsible for training the newly appointed staff [5.1]. As of February 2020, just prior to the global COVID-19 pandemic, 25% of the 650 European Tour golfers had taken up the profiling and subsequent training programmes, with the majority reporting meaningful improvements in driving distance and 12 players winning tournaments attributed to the tailored programming and subsequent S&C coaching, delivered based on our research [5.1].

Provision of coaches and facilities at global golf tournaments by the PGA European Tour and R&A

Our research [3.1 & 3.2] has led to significant changes in provision of support and facilities at PGA European Tour golf tournaments across the world. The ETPI are now funding the delivery of the standardised profiling assessment, at 37 golf tournaments per year across Europe and in Qatar, Saudi Arabia, UAE, South Africa and Kenya, with approximately 25% of participants in each tournament benefiting from the assessment [5.1]. In addition, the research has influenced the provision of enhanced facilities by the ETPI, at events such as the 2018 & 2019 Open Championships, and 2018 Ryder Cup and both the PGA European Tour and The Royal & Ancient Golf Club of St Andrews (R&A) who have confirmed their intention to continue to provide this support in the future [5.1]. These enhanced facilities include the two PASCO Scientific Force Plates (to measure IMTP peak force and CMJ impulse) that were purchased in order to carry out our assessments and profiling, in addition to specialist strength training equipment that is housed in the European Tour Performance Unit, which travels across the world to each tournament.

Re-defining the way strength & conditioning coaches design programmes for elite golfers

Our new guidelines for physical profiling [5.3] [3.1 & 3.2] is widely cited by S&C coaches supporting professional golfers. *“At the ETPI, we typically measure explosive strength using CMJ net positive impulse and strength using IMTP peak force”* and *“Explosive strength is of great importance in golf. Players are required to generate large forces through the ground, then through the body and into the clubhead to generate speed”* [5.4a]. *“We built a programme which targeted the development of muscle groups which are primarily responsible for ground reaction force generation in the golf swing”* [3.2] and *“He did make reasonable improvements in explosive strength (as indicated by the countermovement jump impulse), likely attributable to the squat jumps”* [5.4b]. In addition, we see our research referred to when the ETPI discuss how the best golfers in the world are using S&C to elevate their performance, saying *“There is substantial evidence showing positive relationships between various strength and power measures and clubhead speed”* [3.2] and *“Due to his increases in body mass, Bryson DeChambeau’s vertical jump height may well be lower (or similar) than when he first began his training programme, but his momentum at take-off will almost certainly be higher (he is more powerful, but not relative to body mass) and it is this which relates more strongly to CHV”* [5.5]. Practitioners providing physiotherapy and S&C support to European Tour and US PGA Tour golfers have confirmed that implementing our training guidelines has increased the CHV of a number of their clients [5.6 & 5.7]. Coaches confirmed they are “now able to objectively monitor fatigue levels of the athletes closer and enhance robustness of the player, thus reducing the risk of injury” and see “how an individual’s strength and conditioning programme is influencing their peak force and their ability to express higher forces within the swing [5.7].

Re-defining the way strength & conditioning coaches design programmes for amateur golfers

The Titleist Performance Institute cited our work [5.8] saying *“The two primary tests linked in the research to elite golf performance are the IMTP and CMJ. Enhanced performance in these tests have been correlated to an increase in clubhead speed, which is likely to improve driving distances. Consequently, these 2 tests have been used to benchmark players.”* In addition Golf & Health [5.9] state *“As with most striking, hitting or throwing sports, the lower body is the engine (force generation) for the motion of the golf swing. This is why leg strength is a priority. This is now supported by research indicating significant relationships between lower body strength, explosive strength and CHV”* [3.1 & 3.2]. Coaches working with recreational golfers have also confirmed that they have changed their approach to S&C programme prescription as a result of our research. Orbiss Fitness confirm *“The research has been beneficial to us and has enhanced the way we train our golfers. After reviewing your research, we changed our approach around preparing golfers, by improving their overall strength followed by improving their ability to produce club head velocity”* [5.10]. Golf coaches have also confirmed that our research is changing their practice: *“Utilising some of the research by your team, we as golf coaches can make more informed decisions for changes in technique, or development of S&C programmes for golfers”* [5.11].

Finally, we were pleased to get feedback on our research from the ETPI saying, *“Your work resulted in organisational level change and practitioner level change in practice regarding profiling and training for players”* [5.1].

5. Sources to corroborate the impact

- 5.1: Impact statement: Dr Dan Coughlan, Head of Strength & Conditioning at the European Tour Performance Institute, 24/02/2020
- 5.2: Impact Statement: Stephen Burnett, Performance Manager at England Golf, 19/02/2021
- 5.3: ETPI Physical Profile Report & Physical Profiling Decision Tree
- 5.4: Articles on European Tour website: (a) “Training the Modern Golfer: Andrea Pavan” <https://www.europeantour.com/european-tour/news/articles/detail/training-the-modern-golfer-andrea-pavan/> and (b) “Training the Modern Golfer: Jazz Janewattananond” <https://www.europeantour.com/european-tour/news/articles/detail/training-the-modern-golfer-jazz-janewattananond/>
- 5.5: Blog on British Journal of Sports Medicine website on “How the best golfers in the world are using Strength & Conditioning to elevate their performance” <https://blogs.bmj.com/bjism/2020/08/12/how-the-best-golfers-in-the-world-are-using-strength-conditioning-to-elevate-their-performance/>
- 5.6: Impact statement: Rob Hobkinson, Director at Peak Golf Performance, 10/03/2021
- 5.7: Impact statement: Sam Vickers, Coach at National Performance Centre, 10/02/2021
- 5.8: Article on US based Titleist Performance Institute website on “Understanding strength qualities in golf and how to develop them” https://www.mytpi.com/articles/fitness/understanding_strength_qualities_in_golf_and_how_to_develop_them?search=Jordan%20Spieth
- 5.9: Article on Golf & Health website on “What should golfers do in the gym?” <https://www.golfandhealth.org/benefits/what-should-golfers-do-in-the-gym/>
- 5.10: Impact statement: Russ Brinklow, Director & Head Coach at Orbiss Fitness, 17/03/2021
- 5.11: Impact statement: Lewis Clarke, Golf Biomechanist & Performance Coach at Peter Field Golf, Norwich Family Golf Centre, 18/03/2021