International Journal of Golf Science, 2016, 5(Suppl.), S1-S77

http://dx.doi.org/10.1123/ijgs.2016-0015

International Journal of Golf Science

IJGS Vol 5, Supplement, 2016

Abstracts from the World Scientific Congress of Golf VII
St. Andrews, Scotland
July 18–22, 2016

TABLE OF CONTENTS

World Scientific Congress of Golf VII Abstracts

Keynote Abstracts

A Greener Game: Golf's Role in Wildlife Conservation

Matt Goode

Abstract
The role of golf courses in wildlife conservation has become increasingly important, especially where increased urbanization and agricultural development have resulted in loss of natural areas. Indeed, some golf courses have become biodiversity "hot-spots" in a sea of human-dominated landscapes. This is especially true in the built environment, where golf courses have the potential be an important part of green infrastructure, especially when designed around existing landscape structure. Unfortunately, the conservation value of golf courses has not been fully recognized, and many people view them as elitist and over consumptive. However, over the past two decades, the golf community has gradually realized that environmental impacts of poorly designed and managed golf courses can be substantial, thereby damaging the reputation of the industry. At the same time, the conservation community has started to recognize the potential importance of golf courses as wildlife habitat, and even a source of ecosystem goods and services. Furthermore, the golfing public values the intimate interaction of golf and the environment, providing increasingly rare opportunities for urban dwellers to observe wildlife in an outdoor setting. Clearly, golf can play an important role in wildlife conservation, but to maximize this role, the golf and conservation communities, and the golfing public, must join forces to protect our cherished wildlife resources. This is especially true, as we look for ways to make golf more sustainable in the so-called Anthropocene, an era where reconciliation ecology demands that we look for new and creative ways to preserve our environment, and the game itself.

Sustainability = Science + Learning Playing and Loving Golf for a Lifetime

Darwyn Linder

Abstract
This presentation is given as the Rafer Lutz Memorial Address at The World Scientific Congress of Golf VII.
There are a number of challenges to the sustainability of the game of golf and its associated industries, including reduced numbers of players, increasing greens fees, difficulty of learning the game, travel costs, availability of courses, climate change threats, and alternative forms of recreation. There are analogous challenges to the sustainability of snowsports (skiing, snowboarding). I have been a golfer for more than 50 years, but have never held a professional position as a teacher, club manager, greenskeeper or administrator. I have also been a skier for more than 50 years, with almost 35 years as a level 3 certified alpine instructor. In that position I have taught all levels of recreational skiing and trained instructors in teaching methods. For the past several years I have participated in the efforts of the Ski and Snowboard Schools of Aspen/Snowmass to develop more effective, science based, learning environments for our clients of all ages and levels of expertise. Our efforts have focused on the students, the terrain, and equipment and technology, analgous to the WSCG threefold focus on The Golfer, The Golf Course, and Equipment and Technology. I will describe our efforts and recommend that WSCG, and all of golf, search for innovations appropriate to golf's challenges that will enhance sustainability.

The Transformation of Golf Robotics from Research and Development to Teaching and Fitting

Gene Parente

Abstract
This presentation will focus on the history of robots in the golf industry and their evolution from research and development tools into the areas of equipment fitting and teaching. Golf Laboratories is an independent testing company that was founded in 1990. The company began its testing business with a machine that was powered by a garage door spring. Four years later it developed a computer controlled servomotor driven robot that has become the testing standard in the golf industry. The Golf Laboratories robot is used by all of the major manufacturers and governing bodies. Its integration into the research and development departments of the large golf manufacturers coincided with the largest growth in the history of the golf industry. It is capable of duplicating launch conditions of any player.

Two years ago Golf Laboratories began development of a mobile robot named LDRIC. This machine is powered by lithium ion batteries and can hit golf shots from tee to green, including putting. It has incorporated a proprietary biomechanical modeling system that is capable of duplicating any type of golf swing and launch conditions. It can be used for teaching and golf lessons. It also can reproduce the swings of individual golfers and be utilized for fitting golf equipment to the player's specific swing.

The presentation will discuss the following subjects:

- History of golf robots and Golf Laboratories
- Development of independent robotic testing standards for the industry
- Description of the capabilities of the Golf Laboratories robot and its mechanics
- Development of LDRIC and its potential for teaching and equipment fitting
- Details of the biomechanical modeling system and its application to golf

Tutorial Abstracts

Golfer's Cramp: A Task-Specific Movement Disorder?

Charles Adler

Abstract
This presentation will focus on the possible neurologic cause of golfer's cramp or the yips. The yips have long been consider to be caused by performance anxiety, however, similar to other task-specific movement disorders, such as writer's cramp and musician's cramp, it is likely that some golfers have a neurologic cause for the yips. This presentation will discuss the following:

- What are task-specific movement disorders and how are they diagnosed?
- Do task-specific movement disorders occur in athletes?
- In studies of golfers with and without the yips what data suggests that some of the golfers have a task-specific movement disorder?
- Videos of individuals with task-specific movement disorders will be used to demonstrate these points.
- Can task-specific movement disorders, including golfer's cramp, be treated?
- How does treatment for golfer's cramp differ from the treatment of performance anxiety?

At the end of the presentation attendees should have a good understanding of the neurologic phenomenon of task-specific movement disorders and be able to apply this understanding to evaluation of golfers with the yips.

Kinematic Sequence in Golf: Form, Function or Fallacy?

Jeff Broker & Phil Cheetham

Abstract
This presentation focuses on Kinematic Sequencing in Golf, an oft-cited expression of proximal-to-distal sequencing (PDS) in human movement. Fundamentally, the kinematic sequence represents a product of motion capture and analysis that provides a simple, golf-adapted portrait of pelvis-torso-arms-club coordination. Qualitative and quantitative examinations of this sequence appear to provide strong support for PDS in expert level golfers, yet subtle differences in sequencing, even among professional golfers, exist. The extent to which the kinematic sequence exposes cause and effect interactions between segments, muscle roles in influencing these interactions, as well as transfers of energy and "rotational speed gains" across segments is debatable.
This tutorial will explore the kinematic sequence in golf by stepping through the following questions:

- What measures are used to develop the kinematic sequence?
- What basic qualitative and quantitative differences in the kinematic sequence are seen between amateur and professional golfers?
- What subtle differences in the kinematic sequence emerge when professionals are compared against each other, and what do these differences say about the robustness of PDS?
- Can the kinematic sequence expose fundamental movement strategies common in non-golfers, aimed at the generation of high end-segment velocities, applicable to golf?
- Can the kinematic sequence really be used as feedback in the teaching environment?
- What are the challenges to the interpretation of kinematic sequencing in golf?

The answers to each of these questions are developed from studies conducted using amateur and professional golfers. Concepts developed from the discoveries described will have broad application to golf analysis, teaching and learning.

Technique Change in Experienced Golfers: Coaching Considerations for Maximizing Long-Term Permanence ***and*** Pressure Resistance

Howie Carson, **Dave Collins & Bob Christina**

Purpose
Coaching interventions are often designed to impact on a golfer's skill with a variety of intended outcomes. Primarily, these have concerned the acquisition of a *new* skill (e.g., Dail & Christina, 2004), and the optimal execution of an already acquired skill (usually under conditions of competitive pressure; Bell & Hardy, 2009). However, recent study suggests that coaches are challenged when refining/tweaking a golfer's suboptimum but already well-learned skill (Carson, Collins & MacNamara, 2013). Here, it is usually imperative that the new version skill possesses both long-term permanence (i.e., does not regress) and resistance against negative anxiety effects (i.e., is pressure-proof). Considering the importance of successful skill refinement to a coach's armory, it is surprising that these outcomes remain under-addressed by sport science/coaching researchers, despite Christina (1987) highlighting the issue over three decades ago. Accordingly, this symposium is targeted at assisting coaches working with *experienced* players, whether seasoned 15-handicappers or PGA Tour professionals. Specifically, it aims to offer a review and critique of key issues to provide sound building blocks towards achieving successful skill refinement, offering guidelines to fellow professionals on how to do it better.
Method
A progressive approach will be taken towards the delivery of three presentations. Firstly, we present an argument that high-performing environments require the coach to cater for both main effects and interactions between biological, psychological, and sociological factors. Secondly, dependent factors for successful refinement, mechanistic underpinnings, and essential precursors to making refinements will be presented. Thirdly, and finally, an interdisciplinary five-stage process (Carson & Collins, 2011) will be presented that operationalizes these considerations with the aims of long-term permanence and pressure resistance. Data will be presented to demonstrate support for the precepts of this model.
Analysis/Results

Presentation 1. Optimizing the impact of these interactive factors is crucial. Accordingly, there is a need to employ a Professional Judgment and Decision Making (PJDM; Martindale & Collins, 2005) approach *if* we are to be truly working in the interests of *each* golfer. Practically, this means that coaching decisions are derived from a process of generating alternative courses of action, then weighing up the pros and cons of each against the intended outcome and presenting context. The impact is then carefully monitored, with adjustments made as necessary. The approach necessitates moving away from a "one size fits all" approach and understanding *why* an action should and another should not be taken. In short, the practitioner as creative chef rather than recipe following order cook!

Presentation 2. In determining whether or not to implement technical refinement, coaches must consider a multitude of factors. From a motoric perspective, what is the influence of the athlete's existing technique and how complex are the changes that are required? Psychologically, is the golfer capable of making a change and are they motivated to do so? Sociologically, is there a need to provide a team of experts and, if so, how will they be organized to best support, and ensure essential trust with, the golfer? Once these questions can be answered the golfer and coach must understand that the cognitive mechanism involved requires the motor program to be modified by a return to conscious control; a process that can be very dispiriting for many golfers. Finally, as a precursor to initiating this process the coach might consider the following practices with their player.

Presentation 3. Technical refinement must proceed through stages of Analysis, Awareness, Adjustment, (Re)Automation, and Assurance; the Five-A Model. There are several risky periods during this process that may compromise success. Notably, and building on the previous presentations, coaching techniques such as contrast drills, shaping, use of holistic cues (e.g., rhythm), and combination training (physical exertion and high level technical challenge) can positively facilitate the process. Finally, data from empirical case studies reveal that changes in intra-individual movement co-variability across various components of technique (either targeted or not targeted for refinement) can be employed as a useful indicator of a golfer's level of conscious control applied and, therefore, progression through the Five-A Model.

Conclusions

Skill refinement holds relevance to any experienced golfer (not just elites) attempting to change their already existing and well-established movement pattern. Notably, the process is distinct from skill acquisition and performance. Moreover, effective use of a PJDM approach enables the coach to operationalize the nonlinear Five-A Model to best suit each golfer and their presenting needs. Coach education services should make these distinctions, the underpinning evidence-base, and support for a PJDM approach clear.

Keywords: Five-A Model; Interdisciplinary approach; Movement Variability; Skill Refinement

References

Bell, J. J., & Hardy, J. (2009). Effects of attentional focus on skilled performance in golf. *Journal of Applied Sport Psychology*, *21*, 163–177. doi:10.1080/10413200902795323

Carson, H. J., & Collins, D. (2011). Refining and regaining skills in fixation/diversification stage performers: The Five-A Model. *International Review of Sport and Exercise Psychology*, *4*, 146–167. doi:10.1080/1750984x.2011.613682

Carson, H. J., Collins, D., & MacNamara, Á. (2013). Systems for technical refinement in experienced performers: The case from expert-level golf. *International Journal of Golf Science*, *2*, 65–85.

Christina, R. W. (1987). Motor learning: Future lines of research. In M. J. Safrit & H. M. Eckert (Eds.), *The cutting edge in physical education and exercise science research* (pp. 26–41). Champaign, IL: Human Kinetics.

Dail, T. K., & Christina, R. W. (2004). Distribution of practice and metacognition in learning and long-term retention of a discrete motor task. *Research Quarterly for Exercise and Sport*, *75*, 148–155. doi:10.1080/02701367.2004.10609146

Martindale, A., & Collins, D. (2005). Professional judgment and decision making: The role of intention for impact. *The Sport Psychologist*, *19*, 303–317.

Aim Small, Miss Small: To What Extent Does it Work?

Bob Christina & Eric Alpenfels

Purpose

"Aim small, miss small" is an intuitively appealing strategy that is often used in playing, teaching and coaching golf shots. It appears to have had its origin in the shooting sports (e.g., rifle, archery) and was made even more popular in the 2000 movie titled "The Patriot" (http://www.ThePatriot(2000)-Trivia-IMBd) The strategy holds that the amount of shot error is positively related to the size of the target at which one aims. Hence, the smaller the target, the smaller the error and vice versa. Despite considerable testimonial evidence (e.g., see http://www references) claiming support for the strategy's effectiveness for playing golf shots, research evidence emanating from direct tests of its effectiveness was not found. Moreover, this testimonial evidence is inconsistent with evidence from action-perception research (e.g., Proffitt & Linkenauger, 2013; Witt et al., 2008; 2012; Wood et al., 2013; Woodman & Hardy, 2003) that found that visually perceiving a target as bigger makes people feel more confident, which improves motor performance. Thus, the purpose of this research was to provide a direct test of the extent to which the "Aim Small, Miss Small" strategy was effective for minimizing shot error for drives, irons, pitching, chipping and putting.

Method

In the following three studies, participants were (a) instructed not to use intermediate targets and play shots like it was a tournament round, and (b) randomly assigned to testing conditions; the order of which was counter-balanced.

Study 1: Thirty-two males volunteered (ages 17 – 84 years; *M*

= 65; *SD* = 14.55; handicaps 1 – 30; *M* = 12.84; *SD* = 7.83). Driving accuracy and distance was studied as a function of Target Size (small = middle fairway; large = 29.26 m wide fairway) aimed at and Club (driver; three metal) in a 2 X 2 (Target Size X Club) within-subjects design. Targets were located at a distance down the 14th fairway of Pinehurst #2 where each participant estimated the ball would land on a well-struck drive.
Study 2: Thirty males volunteered (ages 16 – 81 years; *M* = 50; *SD* = 21.78; handicaps +1 – 30; *M* = 12.40; *SD* = 8.04). Iron shot accuracy was studied as a function of Target Size (small = middle of the green; large = 13.72 m wide green) aimed at and Club (six and nine iron) in a 2 X 2 (Target Size X Club) within-subjects design.
Study 3: Thirty males volunteered (ages 16 – 78 years; *M* = 65; *SD* = 14.83; handicaps 0 – 27; *M* = 13.94; *SD* = 6.23). The accuracy of short putts (1.22, 1.83, 2.44 m), long putts (7.32, 8.53, 9.75 m), chip shots (7.32, 8.53, 9.75 m), and pitch shots (14.63, 18.29, 21.95 m) was studied as a function of Target Size (short putts - small = .64 cm , large = 1 cm diameter; long putts – small = 10.80 cm diameter, large = 182.88 cm diameter; chips – small = 10.80 cm diameter, large = 182.88 cm diameter; pitches = small 10.80 cm diameter, large = 365.76 cm diameter) aimed at in a within-subjects design.

Analysis/Results

Variance analyses revealed that aiming at the large target (LT) as opposed to the small target (ST) produced significantly longer average total driving distance (LT *M* = 210.33 m vs ST *M* = 204.69 m; $p < .01$, $\eta_p^2 = .36$) for the driver with less average error (LT *M* = 12.68 m vs ST *M* = 14.11 m; $p = .079$, $\eta_p^2 = .10$). Significantly less average error (LT *M* = 35.60 m vs ST *M* = 44.78 m; $p = .03$, $\eta_p^2 = .17$) was found for the 26 participants whose handicaps ranged from 1 to 21. Chi Square analyses indicated that aiming at the LT yielded a significantly ($p < .05$) higher percentage of drives (a) with less average error (60% of 96), and (b) hitting the fairway (60% of 96). Also, the LT produced significantly ($p < .035$) less average error than the small target on long putts. No other appreciable ($p > .05$) shot accuracy differences were found, but significantly ($p < .01$) longer average carry distance resulted with the nine and six iron by aiming at the LT.

Conclusions

No evidence was found supporting the superior effectiveness of the "Aim Small, Miss Small" strategy for minimizing shot error. In fact, the driver and long putt accuracy findings support the opposite strategy, which indicates that (a) the widely accepted "Aim Small" strategy is not for everyone, and (b) the best target size to use is the one that provides the most shot accuracy.

Keywords: Aim Small, Miss Small, Target Size, Shot Accuracy

References

http://www.debfinnegan.com/2015/07/18/aim-small-miss-small

http://www.GolfChannel.com/media.nobilo-love-spieth's-aim-small-miss-small-mindset-2015

http://www.golfweekjuniortour.com.news/2010/07/18/aim-small-miss-small

http://www.ThePatriot(2000)-Trivia-IMBd

http://www.youtube.com/watch?v=oqVOTE04TbM

Proffitt, D. R., & Linkenauger, S. (2013). Perception viewed as a phenotypic expression. In W. Prinz, M.

Beisert, & A. Herwig (Eds.), Action science: foundations of an emerging discipline (pp. 171-198). Cambridge: MIT Press.

Witt, Jessica, K., Linkenauger, Sally, A., Bakdash, Jonathon, Z., & Proffitt, Dennis, R. (2008). Putting to a bigger hole: Golf performance relates to perceived size. *Psychonomic Bulletin & Review*, 15(3), 581-585.

Witt, Jessica, K., Linkenauger, Sally, A., & Proffitt, Dennis, R. (2012). Get me out of this slump! Visual illusions improve sports performance. *Psychological Science*, 23(4), 397-399.

Wood, G., Vine, S., J., & Wilson, M., R. (2013). The impact of visual illusions on perception, action planning and motor performance. *Attention, Perception, & Psychophysics*, 75, 830-834.

Woodman, T., & Hardy, L. (2003). The relative impact of cognitive anxiety and self-confidence upon sports performance: A meta-analysis. *Journal of Sports Sciences*, 21, 443-457.

The Pinehurst Studies: Discoveries That Defy Conventional Wisdom

Bob Christina & Eric Alpenfels

Abstract

This presentation focuses on what we consider to be the most interesting discoveries emanating from the Pinehurst studies that we conducted over the past 15 years. We consider them to be the most interesting because they are contrary to conventional golf wisdom and traditional golf beliefs and practices. The presentation also focuses the relevance of these evidence-based discoveries for practical application to the teaching, learning and playing of golf. These evidence-based discoveries provide answers to the following questions:

- Do you know the best drills to improve your putting, chipping, pitching, sand shots, correcting a slice and increasing full swing carry distance?
- Do you know the best way to practice with a drill/training aid?
- Do you know the best way to practice to transfer your swing to the golf course?
- Jordon Spieth uses Instinct Putting---should you?
- How accurately do you read putts?
- Are you sure you're playing with the right grip size?
- Are you teeing your ball the right height?
- Is it best to use internal or external cues
- Does aim small, miss small really work?

The answers (discoveries) to each of these questions are

based on studies conducted in golf contexts with players who have a wide range of handicaps. Thus, the answers make for immediate application to golf teaching, learning and playing.

The science and the art of working with golfers with low back pain

Kerrie Evans

Abstract

Low back pain (LBP) is frequently reported by golfers of all ages and all abilities and can cause significant time away from the game. Numerous risk factors for LBP have been proposed but very few prospective studies have been conducted. Nevertheless, it is common for those working with golfers to recommend their clients undergo physical profiling, or golf specific screening, in an attempt to identify risk factors for low back injury and areas that could be targeted by training programs to prevent injury and/or improve performance. While there are several well-marketed screening protocols that are based on reasonable theoretical concepts, there is limited evidence for their effectiveness in reducing injury. This presentation argues that the cause, and therefore, the 'cure' of LBP, will be specific to an individual golfer and that golf specific screenings should be individualised and take into account each golfer's individual physiological, psychological and technical skills. That is, the science of experimental evidence from the literature should be combined with the art of the practitioner who considers their own expertise as well as the values and preferences of the golfer. The presentation will draw from golf-specific research, including gender differences, motor variability, effects of fatigue, reliability of physical tests, relationship of swing kinematics to physical and psychological factors, as well as from research from other sports and the LBP literature. Translating research findings into clinical and coaching practice will be emphasised.

Nutritional Strategies for Professional Golf Players: A Scholary Review

Lena Kadlec

Background

Golf shows a growing interest and numbers of participants are increasing worldwide. The uniqueness of golf lies in its complex swinging technique and multidisciplinary demands of physique, psychology and cognition, while mental stability reflects the key characteristic. Golfers exist in all body sizes and compositions (Table 2), however the athlete golfer will be more in focus related to skill level. Golf can be classified as a low-intensity and high-volume exercise with characteristics of power and high precision, which requires constant cognitive and physical performance. The player´s scoring average is directly related to his financial earning. Playing golf results in a physiological demand that may be influenced by nutritional interventions. However, less focus has been set on specific nutrition programs. Several nutritional challenges, such as busy tournaments schedules (Table 1), multiple competition days, permanent travel and frequent adaptions to new environments and culture variables (quantity/quality of foods and food hygiene), nutritional recommendations should be adjusted according to the golf sport. In particular, the prevention of low energy availability, hunger, muscle fatigue, low-blood sugar and dehydration on competition day are of special interest. Adequate access to foods and fluids whether on or off course (Table 4 & 5) or during travel (Table 3) needs to be considered to avoid nutritional challenges.

Purpose

Most coaches and athletes, among golfers, have inadequate knowledge and may not know how to eat to gain best performance outcomes. The need to close the gap between scientific knowledge and practical application is high within this sport, especially when considering that golf will be again Olympic in 2016. Based on physical and psychological (cognitive) demands, general sport nutrition guidelines and published golf specific nutrition interventions were reviewed to discuss potential nutrition approaches for professional golfers. The purpose of the current review will be focused on nutritional aspects on competition days to provide practical recommendations.

Practical application

Based on continuous sweat rate tests, golfers should follow appropriate fluid-intake strategies to accommodate anticipated sweat losses in hot and humid weather conditions. Intakes of 5-7ml/kg body weight (BW) cooled fluids pre-event and 0.4-0.8ml/kg BW per hour during the tournament seem adequate. Depending on tee-time, carbohydrate (CHO) rich, moderate protein and high antioxidant pre-competition meals (2-4h before) or adequate snacks (30-90 minutes before) are advisable and need to be timed accurately. Energy supply on-course should be mainly placed by frequent ingestion of CHO (25-30g/h) with possible consideration of glycemic index, especially at last 6 holes. The additional intake of low-fat protein sources may have positive effects for golfers, and not lastly to prevent upcoming hunger during a golf round. Nutrition recovery strategies are of high importance due to multiple competition days, while primary dietary goals should be focused on replacement of fluids, electrolytes and glycogen stores. Supplementation of low-caffeine doses (up to 2mg) at later point (last 6-10 holes) during the event seem beneficial.

Further research

Further research to optimize dosage and type (GI) of CHO and protein intake pre- and on-course is necessary. The investigation of recommend ergogenic aids, accurate dosages (range of caffeine intake) and timing will be also required.

Outlook

In addition, teaching athletes, responsible coaches and caddies of sport-specific nutrition strategies is highly recommendable.

Keywords: golf, nutrition, competition

Evolution of the Golf Industry and the Impact Technology has had on the PGA Professional's Ability to Grow the Game

Dawes Marlatt

Abstract

This presentation focuses on the history of golf in America

and the role PGA Professionals have played in the growth of the game. Over the last 100 years there have been significant technological advancements in golf that have made it possible for the game to reach millions of consumers. Specifically, this presentation discusses how technology has advanced the golf industry and the positive impact it has had on both the professional and the consumer. This presentation discusses the following areas:

- Milestones over the last 100 years
- Human, Environmental, and Economic impact of golf
- Role of technology and its impact on instruction
- The future of golf and its next 100 years

In my judgment the game and industry of golf is heading in the right direction and will continue to grow and offer further advancements and opportunities to our professionals and consumers.

Happier, healthier lives- understanding Golf and Health

Andrew Murray & Roger Hawkes

Abstract

Some may say that golf is not a matter of life and death. It may just be that golf, is not *just* a matter of life and death, but also a sport that can improve happiness and health. Evidence is consistent and growing that playing golf is, not only, associated with living longer, but living more healthily. In late 2015, the World Golf Foundation launched a major project aiming to:

- Map the existing literature investigating the relationships and effects of golf and health.
- Summarize the key findings relating to longevity, physical health, mental health for golfers, practitioners and policy makers that may not have the time to do this themselves.
- Share these findings widely and
- Assess the research gaps, and collaborate with individuals, universities and leading organisations to address these.

This interactive tutorial will briefly summarise what is known about golf and health, (specifically golf as a physical activity, health benefits, injury and illness epidemiology related to golf), highlight research gaps, and invite discussion and collaboration. How can we as golfers, practitioners, researchers and scientists work together and uncover more of the overall positive health benefits? And how can we focus the research onto the most important areas relating to golf and health.

Accepted Papers

The Effect of Blocked Versus Random Warm-up on Performance in Skilled Golfers

Christopher Bertram, Mark Guadagnoli, Jennifer Greggain & Aaron Pauls

Purpose

While the beneficial impact of physical/physiological warm-up has been carefully studied and well documented in the literature, the effects of the distribution of the warm-up activities themselves, and their psychological impact on performance have not been considered to date. Furthermore, while randomized practice is known to have positive effects on learning in skilled performers, the contextual interference approach has never been applied to the warm-up setting. The proposed study compared the effects of a group of skilled golfers who warmed-up using traditional 'blocked' methods to a group of golfers who employed a novel 'randomized' warm-up protocol.

Method

Participants were highly skilled golfers (handicap of 2 or better). Each participant was first led through a 15-minute dynamic stretching routine and was then randomly assigned to either the control (Blocked) or experimental (Random) warm-up group. Participants in the control (Blocked) group were asked to hit 36 shots according to a pre-determined order of club-selection (i.e., 9 shots in a row taken with each of 4 different golf clubs). Participants in the experimental (Random) group also hit 36 golf shots, but instead of hitting 9 shots in a row with each of the 4 clubs, the shot sequence was randomized (e.g., one driver, one 5-iron, one pitching wedge, one 8-iron, and so on). After a 10-minute rest period, each participant hit a predetermined series of 9 'test' shots, in an order that they might occur in a typical round of golf (Driver, 7-iron; wedge, etc). In addition to FlightScope data that was collected on all shots throughout the experiment, participants were asked to rate the quality of each of the 9 test shots on a scale from 1-10 (1 being a very poor shot, 10 being a perfect shot in terms of contact and desired trajectory).

Analysis/Results

The qualitative rating data revealed a clear advantage in the Random warm-up group. A good indicator of how prepared participants were after their warm-up was the quality of the first ball hit (a Driver, in all cases) during the test. The Random warm-up group rated their first shots at an average of 8.25/10, while the blocked group average was just 4/10. Independent t-tests suggested that a more variable warm-up routine better prepares a player to get off to a strong start. The quantitative data gathered via FlightScope corroborate these higher ratings in that the first test shots hit by the Random group were struck more solidly (in terms of club head speed, smash factor, etc.) and were much closer on average to the intended target line than were the shots hit by the Blocked warm-up group.

Looking beyond the first test shots, the performance advantage of being in the Random warm-up group persisted. Breaking the results down into sets of three shots (Driver, 7-

iron, PW), repeated measures ANOVA revealed that the Random warm-up group rated their shots higher than the Blocked warm-up group in set 1 (6.92 vs. 5.54) and set 2 (6.58 vs. 6.38), as well as in the overall average rating of the 9 test-shots (6.64 vs. 6.18). Only in the third and final set of test shots did the Blocked warm-up group narrowly rate higher than the Random group. These findings were again corroborated by the FlightScope data in terms how close balls were hit to the intended target line, as well as such indicators as club head speed and smash factor.

Conclusions

While the impact of a good *physical* warm-up on athletes has been documented, the benefits of a well-designed warm-up routine, in terms of its overall structure, are not well understood. The results of the current study are unique in that for the first time, we present data to suggest that adding variability (i.e., randomness) to a warm-up routine increases the likelihood of success in a competitive round of golf. Furthermore, we postulate that the observed performance advantages in the experimental group were brought about by the added challenge, and subsequent psychological readiness, resulting from a more variable, randomized warm-up.

Keywords: warm-up, variability, skilled golfers

The Effects of an Eight-Week Plyometric Training Program on Golf Swing Performance Characteristics in Skilled Adolescent Golfers

Alex Bliss, Harry McCulloch, & Neil Maxwell

Purpose

Achievement of consistent high performance in golf requires the player to have effective physical conditioning that allows them to overcome the on-course demands encountered (Smith, 2010). Recent evidence has shown that professional golfers who drive the ball the furthest distance on the PGA Tour are significantly more likely to achieve lower scores on par-4 and par-5 holes (Hellström, 2014). One method by which golfers can improve their maximum ball displacement is through physical conditioning (Hume et al., 2005). While there is support for the application of athletic conditioning programmes in male and female, recreational and elite, and adult and elderly golfers, little is known about the use in adolescent academy level golfers. The purpose of this study was to determine the effects of an eight-week plyometric training intervention on measures of golf swing performance, such as shot distance, in skilled, adolescent golfers.

Method

Sixteen male golfers were recruited to this study, being placed into two handicap and age-matched groups: intervention (N=8, age=17.3±1.5 years, height= 1.73±0.09 m, body mass= 68.0±7.6 kg, handicap= 4.7±3.0) and control (N=8, age = 17.4±0.9 years, height= 1.74±0.09 m, body mass= 74.3±10.8 kg, handicap = 5.2±2.5). In addition to their golf-specific practice, the intervention group completed an eight-week plyometric training programme, twice-per week, for approximately 60 minutes per session, to study effects on clubhead speed (CHS), ball carry distance (BCD) and other associated measures. CHS and BCD were measured using a simulator (P3ProSwing, Sports Vision Technologies, California, USA). The control group continued to undertake their golf-specific training with no plyometric training.

Analysis/Results

A 2x2 mixed model ANOVA was used to determine interactions between the independent variables: trial and group, and the dependent variables: CHS, BCD. The intervention group demonstrated significant ($p<0.05$) improvements in CHS (increase of ~4km/h) and BCD (increase of ~5m) between pre and post trials. The control group showed no significant ($p>0.05$) changes in golf performance. The results suggest that in skilled adolescent golfers, eight-weeks of plyometric training may help to improve CHS and BCD by approximately 3%. However, large between participant performance differences were observed after the training intervention.

Conclusions

Although the underlying mechanisms for the changes were not established, it was concluded that, for golfers wishing to improve their CHS and BCD, a golf-specific, plyometric training programme could play an important part in the athlete's training programme.

*Keywords***:** *Plyometrics, clubhead speed, adolescents, training*

References

Hellström, J. Drive for Dough: PGA Tour Golfers' Tee Shot Functional Accuracy, Distance and Hole Score. *Journal of Sports Sciences.* 32(5): 465-9. 2014.

Hume, P. Keogh, J. Reid, D. The Role of Biomechanics in Maximising Distance and Accuracy of Golf Shots*. Sports Medicine*. 35 (5): 429-449. 2005

Smith, F. The Role of Physiology in the Development of Golf Performance. *Sports Medicine*. 40(8);635-655. 2010

Accuracy of a Radar Based Shot Distance Measurement Device

Thomas Blobel, Daniel Linke, Michael Schoierer & Martin Lames

Purpose

Recently, measurement devices for stroke characteristics like ball speed, ball direction, stroke length and others have become widespread in golf practice. They are mostly used in indoor and outdoor practice and for several purposes like golf instruction, swing analysis, club fitting and club recommendation. Technologies mostly used are camera based ball detection (Kim & Kim, 2012) and 3D Doppler Tracking Radar (Martin, 1997). The latter is acknowledged as the most precise technology being available for practical purposes at the moment.

The only available accuracy information for the tested radar device is provided by the manufacturer. The error for carry distance is given as about 1-2 yards at 150 yards and 2-4 yards at 250 yards (Manufacturer's website). An other source (Manufacturer's blog) denotes the relative error for carry distance being less than 2% under outdoor conditions. Although widely used in scientific studies as well as practical consulting, to the best of our knowledge an independent test for the accuracy of stroke length doesn't exist.

The purpose of this study is to test the accuracy of a radar based shot distance measurement device.

Method

One experienced male amateur golfer (HC 3) performed 30 strokes with iron 9, 7, and 5 each. He aimed along a target line and was instructed to perform comfortable swings. The weather conditions were cold (6-8°C), no wind, and sunny.

The radar based device was mounted exactly according to the prescriptions of the manufacturer.

As gold standard, a tachymeter (Trimble M3 Total Station, Trimble, Jena, Germany) was used. This device is based on laser Doppler technology and used by professional surveyors for high precision measurements. The manufacturer indicates error tolerances of ± (3+2 ppm * Distance) mm, i.e at 100m this means an error of ± 3.02mm. Each stroke was measured by the radar based device. Carry distance, lateral deviation from aiming line, club head speed at impact, and ball speed after impact were recorded. Immediately after landing, the landing spot was marked with a pole with a reflection pad for laser distance measurement. For each landing position x,y-coordinates were taken. The x-Axis was aligned with the aiming line; y was orthogonal to this line.

Agreement between radar based and tachymetric distance and lateral deviation from aiming line was characterized for each club and all strokes by RMSE and Pearson correlation. A qualitative inspection of the differences was done using Bland-Altman plots (Bland & Altman, 1999).

Analysis/Results

Descriptive statistics of distance and lateral deviation measurements with the two devices are given per club and in total in table 1.

Table 1:

Descriptive statistics

Condition	Statistic	Radar Distance	Tachy Distance	Radar Lateral	Tachy Lateral
Iron 9	Min	108	117.5	-12.6	-26.1
	Max	158	148.1	8.0	17.5
	Mean	135.43	134.67	0.24	1.55
	Sdev	10.99	8.44	5.32	10.13
Iron 7	Min	104	126.6	-18.1	-26.1
	Max	164	168.2	15.8	23.5
	Mean	148.50	152.03	0.23	3.16
	Sdev	12.98	10.09	7.06	10.91
Iron 5	Min	114	136.9	-3.1	-20.1
	Max	175	176.1	18.0	26.1
	Mean	152.60	156.21	3.03	6.26
	Sdev	14.89	9.61	4.27	11.46
All strokes	Min	104	117.5	-18.1	-26.1
	Max	175	176.1	18.0	26.1
	Mean	145.51	147.64	1.17	3.66
	Sdev	14.86	13.20	5.76	10.90

Table 2 gives RMSE for the compared variables to characterize the deviation in meters as well as the correlation between the two measurement methods.

Table 2:

RMSE and Pearson correlations

	RMSE Distance	RMSE Lateral	Correlation Distance	Correlation Lateral
Iron 9	6.83	6.66	.779	.806
Iron 7	10.13	9.11	.675	.596
Iron 5	11.27	9.38	.686	.707
Total	9.60	8.47	.781	.682

Inspection of the Bland-Altman plot for distance measurement revealed a large confidence interval for the differences in distance (36.89m, i.e. 60.5% of range of distances). The plot for the lateral deviation showed a confidence interval width for the differences of 31.64m (87.9% of range of lateral deviation). Moreover, there seems to be a systematic tendency for the radar system to underestimate deviations to the left and to overestimate deviations to the right side of aiming line.

Conclusions

Results show high RMSE and low correlations between distance measurements by a radar device frequently used in golf and a tachyscope used as gold standard. Although these results could partially be attributed to specific weather conditions and ball's aerodynamic properties, the discrepancies remain remarkably high.

It seems worthwhile to test accuracy of measurement devices frequently used in golf science as well as golf practice to obtain error estimates independently from manufacturers. To do so, specially designed studies (Siegle, Martens & Lames, 2013) are to be conducted. Our gold standard, a tachyscope with laser Doppler measuring, allows to control distance and lateral deviation of golf shots; for release angles, release speed and further characteristics other controls have to be implemented (e.g. high-frequency kinematics).

Keywords: Radar based swing analysis, Accuracy study

References

Bland, J.M., Altman, D.G. (1999). Measuring agreement in method comparison studies. *Statistical Methods in Medicine Research, 8*, 135-160.

Kim, J.S. & Kim, M.G. (2012). A cost-effective vision system for virtual sports. *ICT Convergence (ICTC), 2012 International Conference on 15-17 Oct. 2012*.

Martin, J. (1997, 14-16 Oct. 1997). *Range and Doppler accuracy improvement for pulse Doppler radar*. Paper presented at the Radar 97 (Conf. Publ. No. 449).

Siegle, M., Stevens, T. & Lames, M. (2013). Design of an accuracy study for position detection in football. *Journal of Sports Sciences, 31*(2), 166-172.

Measurement of golf-specific explosive strength by a cable pulley system – test development and test validation

Thomas Blobel, Katharina Els & Martin Lames

Purpose

In golf, sequential movement of body segments, timing and velocity are important factors for maximizing carry distance. High velocity is achieved by rotation during back swing, shifting of body centre and acceleration of body segments at follow through (Smith, Roberts, Wallace, Kong, & Forrester, 2015). While segmental kinematics, rotational velocity and body displacement are measured using various motion analysis systems, golf-specific strength measures of muscle groups of the different body segments involved in the golf swing are still lacking. With the help of a special cable pulley system with extensions, which were developed for golf-specific training, it is possible to measure force development in different joints on golf swing trajectories.

The aim of this study was first, to develop golf-specific tests of explosive strength (Bührle & Schmidtbleicher, 1981) using a custom-designed cable pulley system and second, to validate these test with motor tests of trunk strength as well as with angular velocities of player´s swing.

Method

30 male golfers (age 30 – 50 years, M = 40.89, SD ± 5.0) were classified in three groups of different performance categories (HCP 0 to 5, HCP 5 to 12, HCP 12 to 20; age, height and weight is similar between groups). Three tests were used to measure golf-specific explosive strength: explosive strength of hips (HipExp), shoulder (ShExp) and arm (ArmExp). The cable system is equipped with different extensions for shoulder, hip and arm, to execute different golf-specific movements with focus on different body segments. The force development during the exercise was measured by a load cell (Megatron, KM 1506) that was installed between cable system and extension. So, force-development along golf-specific trajectories was measured. Standardization was achieved by controlling initial resistance in starting position and instructing the participants to move from a defined starting position to a determined end position as fast as they could. As the following formula shows, explosive strength (F_{exp}) was measured by taking the maximum increase of the force development curve (2000 Hz).

$$F_{exp} = \frac{\Delta F}{\Delta t}$$

Practice trials were executed before testing until the quality of the exercises was sufficient. The best result out of two attempts was used for further calculations.

Explosive strength on golf specific trajectories was first compared to general explosive trunk strength as underlying ability. Two standardized, unspecific tests (sit-ups and push-ups) according to Bös (2001) were used. The participants had to perform as many repetitions as possible in 20 seconds. Test duration was chosen comparatively short in order to focus on strength abilities as opposed to endurance.

Moreover, explosive strength on golf specific trajectories was compared to swing characteristics. An electromagnetic motion tracking system (Golf Biodynamics) was used to capture the angular velocity of different body segments (hip, upper torso, arm, shoulders). With a 3D Doppler radar based ball tracking system (Flightscope) club head velocity of driver and release speed of ball were measured.

The tests took place under laboratory conditions. At the beginning participants did a standardized warm-up. The tests for each participant took place on one day. Sufficiently large recovery time was granted.

Data processing first calculated retest reliability coefficients for each test. A value of $r_{tt} > .70$ was considered to be sufficient (Lienert, 1969). To determine criterion validity each test was correlated with unspecific trunk strength as well as characteristics of golf swing. A value of $r_{Ct} > .30$ was considered as evidence for criterion validity (Lienert, 1969).

Analysis/Results

The reliability coefficients of the three golf-specific explosive strength test were satisfactory (HipExp: r_{tt} = .744 (lower 95% confidence limit: .524), ShExp: r_{tt} = .776 (.557) and ArmExp: r_{tt} = .974 (.946).

The correlations with unspecific explosive body strength for sit-ups are HipExp: r_{Ct} = .954, ShExp: r_{Ct} = .570 and ArmExp: r_{Ct} = .932. The correlations with push-ups are: HipExp: r_{Ct} = .945, ShExp: r_{Ct} = .947 and ArmExp: r_{Ct} = .964.

The comparison of golf-specific explosive strength to variables of golf swing are shown in table 1.

Table 1:

Mean and standard deviation of swing characteristics and correlation with performances in golf-specific tests of explosive strength.

Swing variable	M	SD	HipExp	ShExp	ArmExp
Maximum rotational speed hip (°/s)	419.33	29.69	.879	.402	.845
Maximum rotational speed upper torso (°/s)	652.33	50.80	-.682	-.090	-.631
Maximum rotational speed arm (°/s)	913.33	49.24	.592	-.027	.537

Maximum rotational speed hand (°/s)	1820.67	125.09	-890	-.424	-.858
Club head velocity (m/s)	47.13	0.83	.979	.648	.963
Ball velocity (m/s)	64.92	1.59	.982	.661	.968

Conclusions

A cable pulley device equipped with special extensions to allow training of golf-specific explosive strength was equipped with a load cell. This construction allows measuring force development on golf-specific trajectories of shoulder, hip and arms. Reliability coefficients appear satisfactory. Criterion validity is of medium level with general explosive trunk strength tests and of different levels with swing variables.

If results can be confirmed with larger samples, the presented equipment allows for training and testing golf-specific explosive strength with one device and even in one session. Comparing these tests to general trunk explosive strength and swing characteristics could improve diagnostics in golf, thus making strength training much more specific, controllable, and efficient.

References

Bös, K. (2001). *Handbuch motorische Tests [Handbook of Sport Motor Tests]* (2. Auflage). Göttingen: Hogrefe.

Bührle, M. & Schmidtbleicher, D. (1981). Komponenten der Maximal- und Schnellkraft [Components of Maximum Strength and Explosive Strength]. *Sportwissenschaft, 11* (1), 11-27.

Lienert, G.A. (1969). *Testaufbau und Testanalyse [Testdesign and Testanalysis]* (3. Auflage). Weinheim: Beltz.

Smith, A., Roberts, J., Wallace, E., Kong, P.W. & Forrester, S. (2015). Golf Coaches‘ Perceptions of Key Technical Swing Parameters Compared to Biomechanical Literature. *International Journal of Sports Science & Coaching, 10*(4), 739–755.

Evaluation of the Spine Axial Rotation Capacity of Golfers and its Distribution: a Preliminary Study

Maxime Bourgain, Christophe Sauret, Patricia Thoreux, Philippe Rouch & Olivier Rouillon

Purpose

The swing movement is a key element in golf performance. During this motion, the pelvis is axially rotated in advance to the thorax (Cheetham et al., 2008), which necessitates an axial rotation of the spine. This ability to rotate the trunk with respect to the pelvis is generally assessed through the computation of both X-factor and crunch factor, following various definitions (Brown, Selbie, & Wallace, 2013, ; Kwon et al., 2013). Those parameters were linked to low back pain (LBP) (Cole & Grimshaw, 2014) which is the most frequent injury in male golfers (Lindsay & Vandervoort, 2014; McHardy & Pollard, 2005). Generally, the X-factor is calculated by the rotation of the line crossing both acromions of the scapulae and the mediolateral axis of the pelvis. As a consequence, the X-factor not only reflects the spine axial rotation capacity but the combined effects of the spine axial rotation and the relative motion of the scapular girdle with respect to the thorax (protraction-retraction of the scapulae). Besides, it could be interesting to be able to assess the distribution of the axial rotation of the spine among the different vertebrae levels because it might be related to the occurrence of low back pain. For that purpose, we propose to use low dose biplanar radiographs (LDPR) with the associated 3D reconstruction method of the spine. This technique was previously used for scoliosis patient (Courvoisier, Vialle, & Skalli, 2014) but the feasibility of its use for large spine axial rotation has not been evaluated yet. The aim of this preliminary study was to investigate the potential of low dose biplanar radiographs for assessing the spine axial rotation and its distribution according to the vertebra level.

Method

One male golfer participated in this preliminary study (47 years old, 183cm height, 67kg, golf teacher of index 1.3, right handed without any physical disorder). After receiving information about the protocol, the volunteer signed a formal consent form allowing his participation in the experiments and the anonymous use of his data for publication. The protocol was previously validated and received agreement from the ethical committee (CPP n°06036).

The volunteer underwent two acquisitions of LDBR (EOS® system, EOS imaging, France) in a standing position. The first acquisition was performed in a neutral position (*c.f.* Figure 1) of the trunk and the second one by turning the trunk on the right side in the maximal comfortable position he could maintain during 30 seconds (time of a whole scan of the subject). Both the pelvis and the full spine were reconstructed in 3D (Skalli, Mitton, de Guise, & Dubousset, 2006) from data of the first acquisition. Then, 3D models of the pelvis, the five lumbar vertebrae and the 7th cervical vertebra were manually registered on the second acquisition with the trunk turned. For that purpose, the 3D model was retro-projected on frontal and lateral images and the operator manually fitted the model silhouette on the radiographs. The registered objects were then used to express the relative orientation of each vertebra with respect to the pelvis (rotational order ZYX). The total rotation, which is the sum of the rotation in the entire spine and the shoulder, was measured thanks to a stick hold by the volunteer, visible on the radiographs - its orientation with respect to the pelvis allowed to approximate the X-factor.

Analysis/Results

The 3D positions of each vertebra of the volunteer with respect to the anatomical axis of the pelvis are summarized in table 1. Lateral bending (X) and flexion-extension (Y) angles did not change significantly between the two positions of the trunk.

Axial rotation of each vertebra (Z) showed that lumbar spine (from the pelvis to L1) accounted for approximately one third of the total axial rotation of the spine (from pelvis to C7). In addition, results showed the spine axial rotation represented about 55% of the whole axial rotation, 45% of the rotation was thus ensured by the scapular girdle rotation. This result shows that shoulder flexibility, which involves both the sterno-clavicular and the acromio-clavicular joints, play a crucial role in the pelvis and scapular girdles dissociation and its magnitude.

Comparison with literature shows that the rotation found between each vertebra was slightly lower to the *in-vitro* angles measured by (Charles, Persohn, Steib, Mazel, & Skalli, 2011). However, in order to discuss the relative rotation between one vertebra and its neighbour, a sensitivity study of the method presented here needs to be performed.

Conclusions

This preliminary study confirms the feasibility and the potential of the use of LDBR for assessing the spine axial rotation, which could be useful in medical golfer follow up, and in the future may help to detect and manage persons at risk of LBP occurrence. As a consequence, this exam may assist in limiting LBP injury occurrence in golfer population.

In this study, it was possible to distinguish the part of the whole axial rotation of the shoulder with respect to the pelvis due to lumbar segment, thoracic segment and the scapular joint complex. It was also possible to evaluate the inter-vertebral rotation for vertebrae of the lumbar segment. If the methodology had been applied to the thoracic segment, the superimposition of the rib and the arm (due to the adopted posture) on the radiograph would not have allowed us to perform the registration confidently and therefore we decided not to express the results here. However, future works would involve another posture during the turned acquisition with the arms raised in order to limit the overlapping to the ribs.

Future work will include more golfers, in particular professional and senior golfers to investigate the impact of the axial rotation distribution on performance and occurrence of LBP. In parallel, improvements of the registration method will allow improved results accuracy and reproducibility, which should also be quantified.

Keywords: Low Back Pain, spine rotation, low dose biplanar radiographs

References

Brown, S. J., Selbie, W. S., & Wallace, E. S. (2013). The X-Factor: an evaluation of common methods used to analyse major inter-segment kinematics during the golf swing. *Journal of Sports Sciences*, *31*(11), 1156–1163.

Charles, Y. P., Persohn, S., Steib, J.-P., Mazel, C., & Skalli, W. (2011). Influence of an auxiliary facet system on lumbar spine biomechanics. *Spine*, *36*(9), 690–699.

Cheetham, P., Rose, G. A., Hinrichs, R. N., Neal, R. J., Mottram, R. E., Hurrion, P. D., & Vint, P. F. (2008). comparison of kinematic sequence parameters between amateur and professional golfers.

Cole, M. H., & Grimshaw, P. N. (2014). The crunch factor's role in golf-related low back pain. *The Spine Journal*, *14*(5), 799–807.

Courvoisier, A., Vialle, R., & Skalli, W. (2014). EOS 3D Imaging: assessing the impact of brace treatment in adolescent idiopathic scoliosis. *Expert Review of Medical Devices*, *11*(1), 1–3.

Kwon, Y. H., Han, K. H., Como, C., Lee, S. & Singhal K. (2013). Validity of the X-factor computation methods and relationship between the X-factor parameters and clubhead velocity in skilled golfers. *Sports Biomechanics,* 12:3, 231-246,

Lindsay, D. M., & Vandervoort, A. A. (2014). Golf-Related Low Back Pain: A Review of Causative Factors and Prevention Strategies. *Asian Journal of Sports Medicine*, *5*(4).

McHardy, A., & Pollard, H. (2005). Lower back pain in golfers: a review of the literature. *Journal of Chiropractic Medicine*, *4*(3), 135–143. http://doi.org/10.1016/S0899-3467(07)60122-0

Skalli, W., Mitton, D., de Guise, J., & Dubousset, J. (2006). The EOS system: New perspectives for musculoskeletal biomechanics. *Journal of Biomechanics*, *39*, S460.

	neurtral position			**Turned position**		
angles	**X (°)**	**Y (°)**	**Z (°)**	**X (°)**	**Y (°)**	**Z (°)**
L5	**-3.1**	**24.1**	**-1.1**	**2.3**	**25.7**	**2.0**
L4	**-2.2**	**4.4**	**-1.1**	**-1.5**	**6.6**	**-5.3**
L3	**-5.7**	**-5.4**	**-1.0**	**-2.1**	**-4.9**	**-5.8**
L2	**-5.3**	**-8.7**	**3.2**	**-2.4**	**-10.2**	**-4.7**
L1	**1.2**	**-15.9**	**1.2**	**-3.7**	**-15.6**	**-7.4**
C7	**0.4**	**22.8**	**0.4**	**-2.2**	**38.0**	**-24.4**
shoulder						**-43.2**

Table 1 : orientations of vertebrae in straight and turned positions with respect to the pelvis. The shoulder angle is calculated from the stick during the turned acquisition. X : lateral bending, Y : flexion-extension, Z : axial rotation.

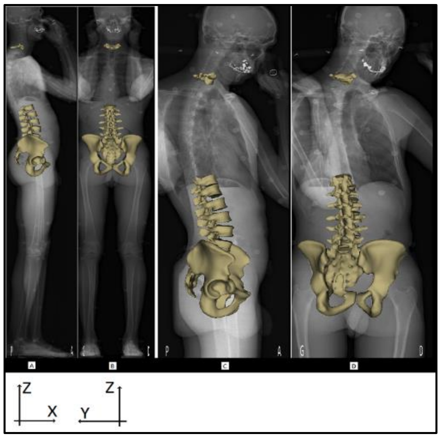

Figure 1: low dose biplanar radiographs. A-B : sagittal and frontal radiographs during the neutral position with superimposed 3D subject specific model, respectively. C-D : sagittal and frontal radiographs during the turned position of the trunk with superimposed 3D subject specific model, respectively. X : lateral bending, Y : flexion-extension, Z : axial rotation.

Elucidating the cognitive mechanisms during golf putting: An eye-tracking and pupillometry study

Mark Campbell, Aidan Moran, Norma Bargary, Sean Surmon, Liz Bressan & Ian Kenny

Purpose

Golf putting provides an ideal natural lab from which to study psychological characteristics of superior performance. 20 years of research has consistently demonstrated that expert performers spend significantly *longer* than their novice counterparts in looking at the target (e.g. basketball hoop for a free throw or golf ball when putting) before initiating their motor action (e.g. putting stroke) (for more see meta-analysis by Mann, Williams, Ward & Janelle, 2007). Vickers (1996) coined the term quiet eye period (commonly referred to as quiet eye or QE) for this consistent phenomena of long and stable gaze behaviours prior to movement initiation. The QE period (indicative durations of 300-2000ms depending on the sport) is the time that elapses between the performer's final fixation on a specific target immediately prior to the initiation of a relevant motor response and finishes when this gaze fixation deviates from this specific location for more than 100ms (Vickers, 2009). It has long been established that pupillary responses provide a valid and reliable window on the 'intensity' of mental activity or cognitive effort (Kahnemann & Beatty, 1966). As these responses are routinely and non-invasively measured during eye-tracking, they constitute a promising tool for the study of the perceptual and cognitive mechanisms underlying skilled performance. Specifically, larger pupil diameter during equiluminance reflects increased cognitive effort. In eye-tracking research, the "quiet eye" (QE) has been consistently shown to be a key predictor of perceptual-motor expertise (Mann et al., 2007; Vickers, 2009). Unfortunately, despite an abundance of QE research, there has been a dearth of theorising on the mechanisms that underlie this distinctive pattern of gaze. Recently, the need to 'explore more precisely the cognitive processes and theoretical mechanisms that underlie the quiet eye effect in target sports' (Campbell & Moran, 2014, p. 371) has been highlighted.

Therefore, the current study aims to tackle this gap in the literature by measuring the timing and magnitude of cognitive load during golf putting using pupilommetry. We generated 3 hypotheses-

1. that skilled golfers (low handicap group) would require less cognitive effort, as demonstrated by attenuated pupillary dilations during the putting task
2. that more difficult putts (task 2) would require more cognitive effort, as demonstrated by greater pupillary dilations during the putting task
3. an exploratory hypothesis predicting that all golfers would deploy more cognitive effort during QE, as demonstrated by higher pupillary dilations

Method

Portable eye-tracking methods recorded gaze behaviors of skilled golfers (N= 24; low skill group n=11; mean handicap 17, SD=3.61 and high skill group n=13; mean handicap 6.923, SD = 3.73) as they undertook 2 blocks of ten putts – easy ones (1.83m) and difficult ones (3.66m). Their respective putting performance was measured on the tasks as well as their gaze behaviors (fixation durations, fixation locations, pupil diameter).

Mean pupil diameter during calibration served as the pupil diameter baseline. Mean pupil diameter was calculated as the average pupil dilation for each participant that they displayed during the calibration process. Task evoked pupillary response was recorded including peak pupil dilation. For peak pupil

dilation analysis of variance was employed. For the remaining pupillary response data

Functional Data Analysis (FDA; Ramsey & Dalzell, 1991; Ramsay & Silverman, (2005) a relatively new statistical technique for analysing time series in a comprehensive way was utilized.

Analysis/Results

Results indicate that, firstly, when examining peak pupil dilation during the putting tasks a paired sample t test revealed that the overall mean peak pupil dilation (M=139.25, SD=4.03) significantly differed from baseline t= 19.246, df=47, p<.0001, 95% CI [35.145, 43.35]. Additionally, peak pupil dilation directly corresponds to the moment of onset of QE. This finding illustrates that QE onset is the most cognitively intense time for skilled golfers. Finally, results revealed that the *magnitude* of pupillary responses was equivalent to various other cognitively demanding tasks (e.g. math multiplication) for both groups of golfers.

Conclusions

In conclusion, our hypothesis that all golfers would deploy more cognitive effort during QE, as demonstrated by higher pupillary dilations was supported. Our remaining 2 hypotheses were not statistically supported as there were no significant group differences between low and high skill level of golfers. This may be on account of the handicap system not adequately differentiating skill level in golf. For example, a low skill level golfer may be a high skill putter but a low skill golfer overall. Finally, by employing a relatively new and innovative statistical technique of FDA, we were able to display and examine the deployment of cognition (via pupillometry) during the putting task, something which has not been done yet in the literature.

Keywords: Quiet Eye; QE; Cognitive Effort; Pupillometry

References

Campbell, M. J. & Moran, A. P. (2014) There is more to green reading than meets the eye! Exploring the gaze behaviors of expert golfers in a virtual golf putting task, *Cognitive Processing*, 15(3):363-72. DOI: 10.1007/s10339-014-0608-2

Kahnemann, D. & Beatty, J. (1966) Pupil diameter and load on memory. *Science,* 154, 1583-1585.

Mann, D. T., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology*, *29*(4), 457.

Mann, D. T., Coombes, S. A., Mousseau, M. B. & Janelle, C. M. (2011). Quiet eye and the Bereitschaftspotential: Visuomotor mechanisms of expert motor performance. *Cognitive Processing*, 12, 223-234. DOI: 10.1007/s10339-011-0398-8.

Ramsay, J. O. and C. J. Dalzell (1991). Some tools for functional data analysis. *Journal of the Royal Statistical Society, Series B, 53*, 539-572.

Ramsay, J. O. and B. W. Silverman (2005). *Functional Data Analysis*. Springer.

Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance*, *22*, 342–354.

Vickers, J. N. (2009). Advances in coupling perception and action: The quiet eye as a bidirectional link between gaze, attention, and action. *Progress in Brain Research, 174*, 279−288.

Is Handicap Rating In Golf An Appropriate Measure of Putting Expertise

Laura Carey, Steven Rosie, Robin Jackson & Malcolm Fairweather

Purpose

Within golf putting literature, expertise is often assumed from handicap status in advance of data collection. Our aim was to profile putting kinematics and putting performance in a low handicap golf population and then contrast this information with tour level data so that an expertise based understanding of low handicap putting status could be assessed.

Method

Fourteen golfers, comprised of 5 professional (Age M = 34. 4, SD = 5.2) and 9 elite amateurs (Age M = 24.1, SD = 7.5), handicap range -2 to +5, (M = +1.3, SD = 1.9) participated in this study. Participants completed 64 putts; eight straight putts and eight sloped putts (four L-R, four R-L) from four distances (3ft, 8ft, 15ft and 25ft) on an indoor artificial surface with a Stimpmeter rating of 10.2. Putting sequence was incompletely counterbalanced across participants. Kinematic variables captured by SAM PuttLab technology (Marquardt, 2009) included clubface angle at impact, clubface angle rotation during the forward swing, and timing. All participants used their own putter and Srixon AD333 Tour golf balls. Participants were assigned to Lower Variability (LV) or Higher Variability (HV) groups based on their consistency rating for clubface angle rotation (LV n = 11 and HV n = 3), impact spot (LV n = 8 and HV n = 6) and timing (LV n = 7 and HV n = 7 for each putt distance) for the first four straight putts at each distance. Participants were classified as LV for impact spot and clubface angle rotation consistency if they scored ≥ 75% and rated HV for consistency scores <75% based on a SAM PuttLab guidance that a consistency rating of 75% indicates performance consistent with 50% of Tour players (Marquardt, 2009). For timing participants were assigned to HV or LV using a median split of their SD values of the ratio of Backswing: Time to Impact (forward swing) for each distance.

Analysis/Results

One way repeated measures ANOVAs evaluating participants' clubface angle at impact and location of ball impact revealed no significant differences for either measure across putt distance. A repeated measures ANOVA 4 (Putt distance) x 2 (Putt phase) revealed a significant Putt Distance x Timing interaction, Wilks' lambda = .114, $F(3,11)=28.49$, $p<0.01$.

One-sample t-tests revealed that participants were not significantly different from Tour players for time to impact at any of the putt distances or for backswing time on 8ft putts (Marquardt, 2009). However, participants were significantly different from Tour players in backswing time at 3ft, $t(13)=3.6$, $p<0.01$ (mean difference -50.57, 95% CI: -80.50 to -20.70, eta squared =.009); 15ft, $t(13)= 4.1$, $p<.01$ (mean difference 61.2, 95% CI: 29.3 to 93.1, eta squared =.001) and 25ft, $t(13)=5.9$, $p<0.01$ (mean difference 81.6, 95% CI: 51.5 to 111.6

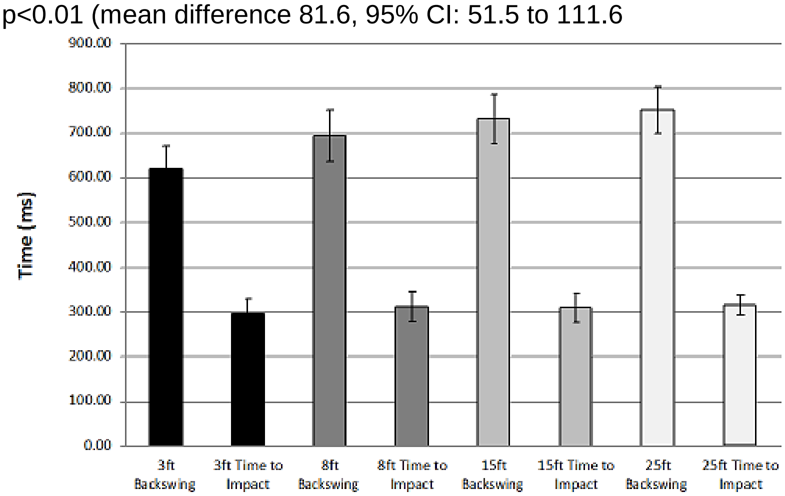

Figure 1: Mean backswing time and time to impact (ms) across the four putt distances, with SD error bars.

There was no significant difference between the professional and elite amateur players in the number of putts holed in the 16 or 64-putt tests. Analysis of HV and LV groups' success rates in the 64-putt test revealed that higher consistency for clubface angle rotation holed significantly more putts than the group with lower consistency ($p<.01$) and the group with higher consistency for impact spot holed significantly more putts than the group with lower consistency ($p<.01$; Figure 3). Consistency of timing did not impact on putts holed.

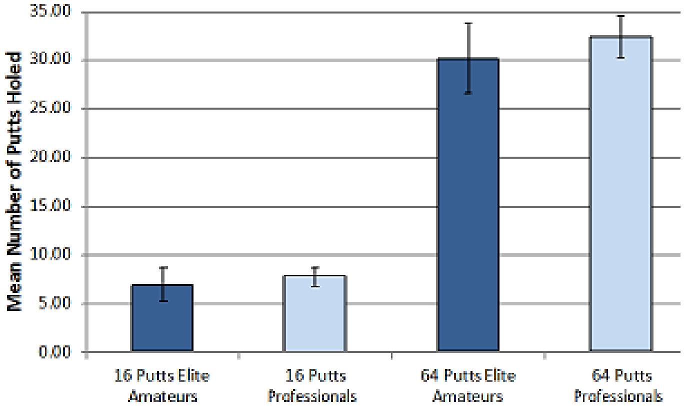

Figure 2. The mean number of putts holed (±SD) for the 16 and 64 putt tests.

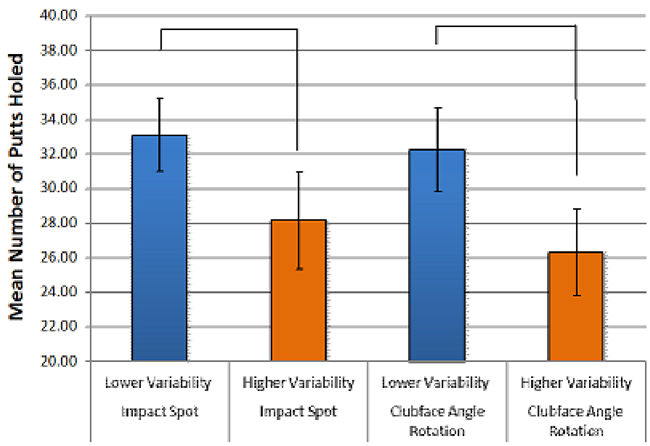

Figure 3: Mean number of putts holed (±SD) in the 64-putt test by the HV and LV groups for impact spot and clubface angle rotation.

Conclusions

Golf putting studies typically define participant expertise by golf handicap. The present study revealed no significant difference in putts holed between the elite amateur and professional golfers on a representative putting test. In contrast, golfers with putting strokes that were more consistent in terms of clubface angle rotation and impact spot holed more putts than golfers displaying greater variability on these measures. While we must be cautious in regard to sample sizes in the present study and the practical challenges regarding the availability of kinematic analysis, this suggests certain kinematic variables may provide a more sensitive measure of putting ability than golf handicap.

Keywords Putting, Expertise, Kinematics

References

Marquardt, C. (2009). The SAM PuttLab: Concept and PGA Tour Data. *International Journal of Sports Science and Coaching*, *2*, 101–120. http://doi.org/10.1260/174795407789705479

Gaze Behaviors of Elite Golfers: Does Task Difficulty Influence Quiet Eye?

Laura Carey, Robin Jackson, Malcolm Fairweather, Joe Causer & Mark Williams

Purpose

Improving putting performance is of significant interest to elite golfers and coaches as the potential for performance gains and lucrative financial rewards are high (Hellstrom, 2009). A critical element of golf putting is visual gaze control, specifically the Quiet Eye period (QE), the final fixation on a target before action execution (Vickers, 2007). QE has been found to be a predictor of expertise in a range of aiming sports such as, golf, basketball, shooting with experts having a longer duration of QE and earlier onset of QE (see Mann et al., 2007; Vickers, 2009 for reviews). To date, researchers examining visual gaze in golf putting have tended to use laboratory-based tasks focusing on relatively short, straight putts. The primary aim of this study was to examine QE in elite golfers using a more representative putting task in which task difficulty was systematically manipulated by both the length and lateral slope of the putts.

Method

Participants were twenty-two experienced golfers (18 males and 4 females aged between 17 years and 78 years) including 15 amateurs (handicaps ranging from -2 to +5) and 7 professionals. Participants were assigned to More Successful (MS) or Less Successful (LS) groups by using the median split technique using the within-task criterion of the number of putts holed at 8ft and 15ft distances on the task outlined below. Participants completed a representative putting task on an indoor artificial surface, which had a STIMP rating of 10.2. Task difficulty was manipulated through varying the distance (3ft, 8ft, 15ft, 25ft) and lateral slope of the putt (slope, no slope). Participants completed 16 putts at each distance, comprising eight straight and eight sloped putts (four R-L putts and four L-R putts), giving 64 putts in total; incompletely counterbalanced across participants. Participants were given forty seconds to complete each putt and asked to carry out their normal putting routines. Visual search behavior was captured using the ASL Mobile Eye XG Mobile Eye Tracker. Performance was assessed by recording the number of putts holed and by calculating absolute error: the distance from final resting position of the ball to the hole (cm).

Analysis/Results

Quiet Eye. QE was analysed using a 4 (Distance) x 2 Putt Type (Slope/No slope) x 2 (Success Rate) mixed-factor ANOVA, with distance and slope entered as within-participant factors. The analysis revealed a significant main effect for slope, Wilks' Lambda=.72 $F(1,16)=6.05$ $p=.026$, see Figure 1. This reflected longer QE duration for straight putts than for sloped putts, which was contrary to expectations. All other main effects and interactions were non-significant, thus, there was no difference in QE between the MS and LS counterparts.

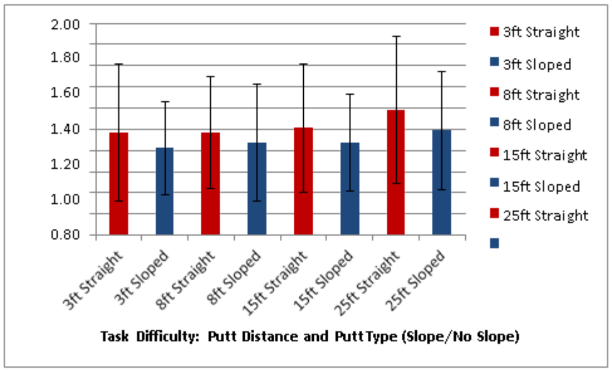

Figure 1: Mean QE duration for sloped and straight putts across 3ft, 8ft, 15ft, 25ft distances.

Performance. Performance (putts holed) was analyzed using a 4 (Distance) x 2 (Putt Type) x 4 (Putt Number) x 2 (Success Rate) repeated measures ANOVA. Analysis revealed significant main effects for success rate, F(1,20)=22.64, p<.01, putt distance, Wilks' Lambda =.01, F(3,18)=543.33, p<.01, putt type, Wilks' Lambda =.47 F(3,18) = 6.77 p<.01. There was also a significant interaction for success rate by distance, Wilks' Lambda =.37, F(3,18)=10.13, p<.01. There were non-significant effects for putt number Wilks' Lambda = .808, F(3,18) = 1.421, p = .269 and the 4 (Putt Number) x 2 (Success Rate) interaction, Wilks' Lambda = .964, F(3,18) = .224, p = .88, suggesting there were no practice effects. Performance (absolute error, distance from the hole) was analyzed using a 4 (Putt Distance) x 2 (Putt Type) x 2 (Success Rate) repeated measures ANOVA. There was a main effect for putt distance, Wilks' Lambda = .064, F(3,18) = 87.36, p < .01, the other main effects and interactions were non-significant.

Independent sample t-test explored the differences in Success Rate (putts holed) and putt type (slope/no slope) and putt numbers between MS and LS golfers (see Table 1 for the significant differences between MS and LS golfers).

Trial	*P* Value	Effect Size
8ft R-L Putt 1	*p* = 0.008	0.5
15ft Straight Putt 5	*p* = 0.001	0.67
15ft Straight Putt 7	*p* = .024	0.8
15ft R-L Putt 3	*p* = .007	0.6
15ft L-R Putt 1	*p* = .016	0.5
15ft L-R Putt 4	*p* = .016	0.5
25ft R-L Putt 3	*p* = .038	0.6

Table 1. Putt Type (Slope/No Slope) with significant differences between more successful and less successful golfers

Conclusions

A more ecologically valid task, compared to previous laboratory-based protocols, was designed to represent better the perceptual-cognitive demands of high-performance golf putting. The data revealed considerable within-participant variability in both QE and performance measures. The within variability of participants in putts holed and QE highlight that within experienced amateur and professional golfers there is inconsistency within their putting accuracy and their routines. There was between-participant variability in putts holed but not in error distance. Contrary to our predictions, we found QE to be longer for straight putts than for sloped putts, particularly in the longer putt distances of 8ft, 15ft, and 25ft. We further note that planning time was not measured in this study and this may influence QE duration. Further research is also required to help understand the mechanisms underlying QE and their relationship with successful golf putting.

Keywords: Quiet Eye, Putting, Perceptual-Cognitive, Elite

References

Hellstrom J. (2009). Competitive elite golf: a review of the relationships between playing results, technique and physique. *Sports Medicine, 39,* 723–741.

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport & Exercise Psychology*, *29*, 457_478.

Vickers J. N. (2007). *Perception, cognition and decision training: the quiet eye in action.* Champaign, IL: Human Kinetics.

Vickers, J. N. (2009). *Advances in coupling perception and action: the quiet eye as a bidirectional link between gaze, attention, and action. Progress in Brain Research* (Vol. 174). Elsevier. http://doi.org/10.1016/S0079-6123(09)01322-3

Kinematic Sequence Parameters Expose Technique Differences Between Male and Female Professional Golfers

Phillip Cheetham & Jeffrey Broker

Purpose

According to 2015 PGA/LPGA Tour statistics, the top ten longest drivers on the PGA tour average 318 yards (291 m), while the top ten longest drivers on the LPGA tour average 267 yards (244 m). Although the differences probably arise due to multiple factors including stature and strength, technique differences may be involved (Tinmark et al., 2010; Zheng et al., 2008). These differences may have application to performance enhancement and training. Cheetham et al. (2008) exposed differences in kinematic sequence parameters between amateurs and professionals. The purpose of this study was to compare magnitude and timing parameters of the proximal-to-distal kinematic sequence (PDS) between elite male and female golfers. It is hypothesized that driver clubhead speeds at impact will be significantly slower in females, and these slower speeds will develop from differing segmental (pelvis, thorax and lead upper arm) accelerations/interactions. We further hypothesize that the relative timing of sequencing parameters between males and females will be similar.

Method

The subject database included 31 LPGA and 95 PGA golfers. Representative driver swings were captured at the Titleist Performance Institute or participating venues using the 240 Hz, Polhemus-based, AMM 3D Motion Analysis system. This full-body system uses sensors placed on the head, thorax, pelvis, upper arms, hands, shins, feet, and club. Body sensors are referenced to anatomical reference frames in a manner similar to Cappozzo et al. (1995). For this study, the PDS describing the development of clubhead speed used the standard AMM analysis procedure, isolating pelvis and thorax axial rotations around local reference frames, arm rotations around a normal vector to the lead arm swing plane, and club rotations around a normal to the instantaneous club swing plane. Downswing PDS variables were computed including peak pelvis, thorax, lead upper arm and club segment rotational accelerations and decelerations, rotational speed gains between adjacent segments (pelvis to thorax, thorax to arm, arm to club), timing of peak rotational segment speeds in relation to impact (absolute and as a percentage of downswing), and clubhead speed at impact. General PDS ordering (pelvis-thorax-arm-club, pelvis-arm-thorax-club) was noted for each subject. Significant differences between groups were detected using t-tests with Bonferroni correction for multiple tests (test-wise significance = 0.011).

Analysis/Results

Several subjects displayed classic, proximal-to-distal movement sequencing (25% PGA, 39% LPGA). Close temporal alignment in peak thorax versus arm rotational velocities, however, caused many subjects to display pelvis-arm-thorax-club sequencing, counter to PDS theory (41% PGA, 19% LPGA). The remaining orderings involved the arm's rotational velocity peaking first, with just a few in each group demonstrating a thorax peak velocity first. As expected, clubhead speeds at impact were significantly greater for PGA subjects (PGA: 107 +/- 6 mph; LPGA: 90 +/- 5 mph). Segment accelerations were not significantly different between groups, although PGA subjects displayed greater club angular acceleration (PGA: 9050 +/-1295 deg/sec^2; LPGA 6845 +/- 898 deg/sec^2). Significant differences were also observed in rotational speed gain between the arm and shaft (PGA: 1269 +/- 92 deg/sec; LPGA: 958 +/- 104 deg/s), and percent rotational speed gains from the pelvis to the thorax (PGA: 21 +/- 3; LPGA 26 +/- 4), and from the wrists to the club (PGA: 56 +/- 3; LPGA 50 +/- 4). Peak segment rotational velocities occurred at different absolute times relative to impact, due to longer duration downswings for the LPGA subjects, but when expressed as a percentage of the downswing, the timing of these peaks were not significantly different.

Conclusions

Although smooth proximal-to-distal sequencing dominates the overall swing styles in these professional golfers, slight departures from the strict pelvis-thorax-arms-club ordering are used, with success. These findings raise questions as to the source(s) of swing sequencing variability, potentially coupled to swing effectiveness and success. The anticipated greater clubhead speeds developed by PGA golfers arose due to differing intersegmental actions. In particular, expressed as contributions to rotational velocity using the kinematic sequence model, the LPGA golfers developed a greater percentage of their rotational velocity from their legs and pelvis (nearly one quarter of the total club velocity), compared with PGA golfers. By contrast, PGA golfers relied more heavily on wrist actions, demonstrating greater club rotational accelerations with greater rotational speed gains across the arms-to-club link (wrists). These results are in agreement with similar studies involving elite golfers using different kinematic approaches (Zheng et al., 2008), and highlight critical differences in pelvic versus wrist actions between elite male and female golfers. Such observed differences motivate further studies into the segmental actions of golfers and related issues concerning golfer anatomy, technique, training and strength development.

Keywords Enter Keywords: Proximal-Distal Sequence, Kinematic Sequence

References

Cappozzo, A., Catani, F., Della Croce, U., & Leardini, A. (1995). Position and orientation in space of bones during movement: Anatomical frame definition and determination. *Clinical Biomechanics*, *10*(4), 171-178.

Cheetham, P. J., Rose, G. A., Hinrichs, R. N., Neal, R. J., Mottram, R, E., Hurrion, P. D., & Vint, P. F. (2008). Comparison of Kinematic Sequence Parameters between Amateur and Professional Golfers. In D. Crews & R. Lutz (Eds.), *Science and Golf V* (pp. 30-36). Mesa, Arizona: Energy in Motion.

Tinmark, F., Hellström, J., Halvorsen, K., & Thorstensson, A. (2010). Elite golfers' kinematic sequence in full-swing and partial-swing shots. *Sports Biomechanics*, *9*(4), 236-244.

Zheng, N., Barrentine, S. W., Fleisig, G. S., & Andrews, J. R. (2008). Swing kinematics for male and female pro golfers. *International Journal of Sports Medicine*, *29*(12), 965-970.

Distal Upper Extremity Kinematic Differences Between Male and Female Professional Golfers

Phillip Cheetham & Jeffrey Broker

Purpose

Recent golf biomechanics research suggests that the proximal-distal sequencing (PDS) of male professional and amateur golfers during the downswing incorporates higher gains in segment angular velocity across the wrists than that of amateur female golfers (Tinmark et al., 2010). Zheng et al. (2008) reported greater wrist extension velocities in male versus female professionals, but "extension" referred to a single axis movement defined by forearm and club orientations. Wrist mechanics differences between low and high handicap golfers have also been reported (Fedorcik et al., 2011). These observations suggest that upper extremity actions/interactions with the club are critical in developing clubhead velocity. The purpose of this study is to expand on these findings by analyzing wrist, elbow and club kinematics during the late downswing, between male and female professional golfers. This involves the quantification of 3D wrist/forearm actions including flexion-extension, radial/ulnar deviation and supination/ pronation. We hypothesize that PGA players will exhibit greater multi-plane wrist angular velocities than LPGA players. We also hypothesize that wrist-set angles and shaft lean will be different in LPGA compared to PGA players –connected with differing club/ball impact conditions.

Method

The subject database included 31 LPGA and 95 PGA golfers. Representative driver swings were captured at the Titleist Performance Institute or participating venues using the 240 Hz, Polhemus-based, AMM 3D Motion Analysis system. This system uses sensors placed on the head, thorax, pelvis, upper arms, hands, shins, feet, and club. Body sensors are referenced to anatomical reference frames, per Cappozzo et al. (1995). Late downswing upper extremity and club shaft variables were computed, including 3D lead wrist angular velocities, trail elbow extension velocity, club handle axial velocity, lead wrist “release” velocity, lead-wrist flexion-extension angle at impact, wrist “set” angle when the lead arm is 30 degrees to the vertical – just before impact, and shaft lean at impact. Pronation/supination was calculated from the upper arm and forearm coordinate systems, and flexion/extension and radial/ulnar deviation were calculated from the forearm and hand local coordinate systems. Wrist “set” and “release” describe the angle between the long axis of the forearm and the long axis of the club shaft; wrist “set” describing angles closer to 90 degrees, and “release,” occurring near ball impact, describe an angle closer to 160 degrees. Significant differences between groups were detected using t-tests, with Bonferroni correction for multiple tests (test-wise significance = 0.011).

Analysis/Results

PGA golfers demonstrated several significantly different late downswing kinematic characteristics compared to LPGA golfers, including higher lead wrist supination velocity (PGA: 1540 +/- 355 deg/sec; LPGA: 1399 +/- 396 deg/sec), greater lead wrist ulnar deviation velocity (PGA: 892 +/- 161 deg/sec; LPGA: 697 +/- 369 deg/sec), greater trail elbow extension velocity (PGA: 850 +/- 185 deg/sec, LPGA: 647+/- 369 deg/sec), higher wrist release velocity (PGA: 1212 +/- 155 deg/sec, LPGA: 943 +/- 125 deg/sec), greater lead wrist flexion at impact (flexion positive, PGA: 1.0 +/- 11 deg, LPGA: -13 +/- 13 deg), increased wrist set with lead arm 30 degrees from vertical (PGA: 101 +/- 10 deg, LPGA: 111 +/- 8 deg), and increased forward shaft lean at impact (PGA: 13 +/- 5 deg, LPGA: 7 +/- 5 deg). These differences accompanied significant differences in clubhead velocity at impact (PGA: 107 +/- 6 mph; LPGA: 90 +/- 5 mph). Of the upper extremity parameters measured between these elite populations late in the downswing, only lead wrist extension velocities were similar (PGA: 460 +/- 205 deg/sec, LPGA: 440 +/- 162 deg/sec).

Conclusions

PGA golfers exhibit dynamic wrist actions late in the downswing that serve to increase club swing angular velocity and thus clubhead speed, more so than their LPGA counterparts. These late downswing upper extremity actions are logically associated with differences in player size, strength, and perhaps technique. As suggested by Suzuki et al. (2009), a primary difference between the swing motions of expert and beginner golfers involves the timing of the wrist release. They indicate that skilled players release the club later, timed/tuned to their golf shaft’s flex characteristics. Zheng et al. (2008) reported lower lead wrist extension velocities in female than male professionals, but “extension” referred to a single axis movement defined by instantaneous forearm and clubshaft orientations. Our results support the importance of rapid elbow, forearm and three-dimensional wrist actions during the late downswing – necessary to achieve high clubhead speeds in coordination with clubface squaring. The sources of the differences between PGA and LPGA golfers on these critical distal upper extremity functions are of considerable interest, relevant to technique, strength and conditioning and injury, and warrant further study.

Keywords: Proximal-Distal Sequence, Kinematic Sequence, Wrist Biomechanics

References

Cappozzo, A., Catani, F., Della Croce, U., & Leardini, A. (1995). Position and orientation in space of bones during movement: Anatomical frame definition and determination. *Clinical Biomechanics*, *10*(4), 171-178.

Cheetham, P. J., Rose, G. A., Hinrichs, R. N., Neal, R. J., Mottram, R, E., Hurrion, P. D., & Vint, P. F. (2008). Comparison of Kinematic Sequence Parameters between Amateur and Professional Golfers. In D. Crews & R. Lutz (Eds.), *Science and Golf V* (pp. 30-36). Mesa, Arizona: Energy in Motion.

Suzuki, S., Hoshino, Y., & Kobayashi, Y. (2009). Skill analysis of the wrist release in the golf swings utilizing shaft elasticity. *Journal of System Design and Dynamics*, *3*(1), 47-58.

Tinmark, F., Hellström, J., Halvorsen, K., & Thorstensson, A. (2010). Elite golfers’ kinematic sequence in full-swing and partial-swing shots. *Sports Biomechanics*, *9*(4), 236-244.

Zheng, N., Barrentine, S. W., Fleisig, G. S., & Andrews, J. R. (2008). Swing kinematics for male and female pro golfers. *International Journal of Sports Medicine*, *29*(12), 965-970.

Exploring the Impact of Academic Timing and the Relative Age Effect Among NCAA Golfers

Laura Chittle, Sean Horton & JessDixon

Purpose

Developmental advantages resulting from differences in age among children grouped into the same cohort often lead to relative age effects (RAEs; Barnsley et al., 1985). Typically, those born in the early months after a selection date experience benefits (e.g., selected to all-star teams) associated with advanced physical characteristics, while those born in the latter months often have more negative sporting experiences (Barnsley et al., 1985). Relative age effects have been found in a number of sports and countries (e.g., Cobley et al., 2009).

However, there have been few RAE studies focused on intercollegiate athletes. This may be due to student-athletes entering university at different ages, leading to a complicating yet important factor known as ‘academic timing’ (AT; Glamser & Marciani, 1992). Academic timing can explain how differences in student-athletes’ actual versus expected athletic eligibilities may influence their participation and/or success in intercollegiate sport (Dixon et al., 2013). When students' actual athletic eligibility years correspond with their projected athletic eligibility years (based on their birthdates), they are considered to be 'on-time.' Alternatively, if students' athletic eligibility years correspond with a younger cohort, they are considered to be 'delayed.'

To date, there have been just three published studies that have examined the moderating effects of AT on the RAE among National Collegiate Athletic Association (NCAA) student-athletes (Glamser & Marciani, 1992; Dixon et al., 2013; Chittle et al., in press). Generally, these studies suggest traditional RAEs among those who are on-time (i.e., an over-representation of student-athletes born in the early months of the selection year) and reversed RAEs among those classified as delayed (i.e., an over-representation of student-athletes born in the latter months of the selection year). Consequently, delaying one's athletic eligibility may equalize elite playing opportunities for relatively younger athletes.

Little is known about the state of RAEs among athletes competing in individual sports like golf. Côté et al. (2006) witnessed no RAE among Professional Golfers' Association (PGA) tour players. Similarly, no RAEs were found among male professional golfers in Japan (Nakata & Sakamoto, 2011). While the RAE appears to be absent within the professional ranks for male golfers, no research has examined the RAE in women's golf at any level. Furthermore, isolating for AT provides a new level of complexity and permits the elucidation of subtleties that would typically be overlooked in a traditional RAE analysis (Chittle et al., in press). This knowledge will provide relevant stakeholders with important information as to whether NCAA golfers are systematically disadvantaged due to their date of birth. Thus, it is possible that exploring the RAE within the context of the NCAA may reveal new findings. Therefore, the purpose of this study is to examine the impact of AT and the RAE among female and male NCAA golfers.

Method

The top 300 ranked (based on *Golfweek*) female and male NCAA golfers during the 2015-16 academic year were targeted for inclusion in this study. In cases where the birthdates of student-athletes were unavailable, individuals were removed from the sample. After delimitation, there were 164 female and 186 male student-athletes included. Consistent with Côté et al. (2006), we relied on an August 1st cut-off date to group athletes into quartiles. Therefore, quartile one represented student-athletes born in August, September, and October, quartile two consisted of those born in November, December, and January, and so forth. Student-athletes were also identified as on-time or delayed based on their year of birth and current athletic eligibility. For the 2015-2016 NCAA season, on-time student-athletes ought to have been born in 1994 through 1997, and competing in their first through fourth years of eligibility. Conversely, student-athletes born in 1996 who are in their first year of athletic eligibility would be considered delayed. Chi-square goodness of fit tests (X^2) were conducted on the overall samples of NCAA golfers, followed by sub-analyses on those classified as on-time and delayed.

Analysis/Results

Similar to previous studies (e.g., Côté et al., 2006; Nakata & Sakamoto, 2011), no RAEs were observed among the overall samples of NCAA golfers. Likewise, no RAEs were found among on-time females, or among on-time or delayed males. However, we did find a traditional RAE among the female student-athletes who were delayed (X^2 = 10.067, p = .018, φ = .366).

Conclusions

Previous research in certain team sports suggests that the RAE is both powerful and pervasive in the NCAA, and that relatively younger athletes must delay their entrance to university in order to neutralize the disadvantage associated with being younger. Based on our analysis, there is no evidence to suggest that relatively younger golfers are similarly disadvantaged.

Keywords: relative age effects, academic timing, intercollegiate athletics, NCAA

References

Barnsley, R. H., Thompson, A. H., & Barnsley, P.E. (1985). Hockey success and birthdate: The RAE. *Canadian Association for Health, Physical Education, and Recreation, 51*, 23-28.

Chittle, L., Horton, S., & Dixon, J. C. (in press). Time out or fast break? Relative age effect in NCAA Division I basketball. *Journal of Sport Behavior*.

Cobley, S. Baker, J., Wattie, N., & McKenna, J. M. (2009). Annual age-grouping and athlete development: A meta-analytic review of relative age effects in sport. *Sports Medicine, 39*(3), 235-256.

Côté, J., MacDonald, D. J., Baker, J., & Abernathy, B. (2006). When 'where' is more important than 'when': Birthdate and birthplace effects on the achievement of sporting expertise. *Journal of Sports Sciences, 24*, 1065-1073.

Dixon, J. C., Liburdi, V., Horton, S, & Weir, P. (2013). An examination of the impact of relative age effects and academic timing on intercollegiate athletics participation in women's softball. *Journal of Intercollegiate Sports, 6*, 147-163.

Glamser, F. D., & Marciani, L. M. (1992). The birthdate effect and college athletic participation: Some comparisons. *Journal of Sport Behavior, 15*(3), 227-238.

Nakata, H., & Sakamoto, K. (2011). Relative age effect in Japanese male athletes. *Perceptual and Motor Skills, 113*(2), 570-574.

***Tee It Forward*: Using PGA TOUR Pros as a Reference Group for Amateur Golfers**

Steven Clark

Purpose

The *Tee It Forward* initiative began in 2011 as a joint effort of the PGA of America and the United States Golf Association (USGA). It is an outgrowth of Barney Adams' frustration with losing distance due to age and his concern for the number of people leaving golf because it is too difficult and takes too long to play (Auclair, 2011). Tee It Forward encourages golfers to play from an appropriate set of tees to make the game faster and more enjoyable. This research examines the marketing of the initiative, the online discussions of golfers about selecting tee boxes, and the approach shots of PGA TOUR players to propose a new marketing campaign for Tee It Forward.

Method/Analysis/Results

Tee It Forward Marketing. I did a quantitative content analysis of materials published by the PGA of America and the USGA to identify what type of guidance they provide to golfers regarding teeing it forward (Riffe, Lacy, & Fico, 2014). Fifty-six articles and five videos promoting the initiative were found at pga.com or usga.org and were analyzed. Three guidance themes emerged: *how far to tee it forward*, *criteria for teeing it forward*, and *approach shot clubs* that will be used when golfers tee it forward. Regarding how far to tee it forward, there were six categories of guidance, with *forward tees* being the most common (f = 22, 57.9%). Regarding the criteria for teeing it forward, there were ten categories of guidance, with *driver distance* being the most common (f = 15, 30.6%). Regarding approach shot clubs, there were six categories of guidance with *irons instead of hybrids or fairway woods* being the most common (f = 10, 37.0%). I also found that current and former tour players were used as a reference group in an attempt to influence golfers' attitudes and behaviors (Newcomb, Koenig, Flacks, & Warwick, 1967). The marketing materials failed to provide clear and consistent guidance because of the mixed messages.

Golfers' Criteria for Selecting Tee Boxes. Because of the mixed messages, I did a quantitative content analysis of online discussions to see what criteria golfers use for selecting tee boxes. I limited the analysis to discussions that were posted after the Tee It Forward initiative had begun in order to determine whether it had shaped golfers' attitudes. I analyzed six forum discussions and two articles related to selecting tee boxes that were found at golfwrx.com. The content analysis revealed 24 categories of criteria for selecting tee boxes. The three most frequent were *driver distance* (f = 38, 12.0%), *score* (f = 38, 12.0%), and *approach shot club* (f = 36, 11%). The largest subcategory of driver distance was *Tee It Forward endorsements* (f = 20, 6.3% overall). There was little agreement among golfers on the criteria for selecting tee boxes and relatively few appeals to Tee It Forward.

Analysis of PGA TOUR Players. Because tour players were used as a reference group in marketing materials and because approach shot club appeared in both marketing and golfers' criteria for selecting tee boxes, I obtained ShotLink™ Data from the PGA TOUR, Inc. to see if it could provide simple guidance for golfers wishing to tee it forward. I did an analysis of approach shot distance on par four holes for 2015 and used Trackman data to assign a club to each approach shot (Trackman, 2014). Overall, PGA TOUR players had the following cumulative percentages for their approach shots: wedges 25%, pitching wedge or less 42%, 9 iron or less 55%, 8 iron or less 68%, and 7 iron or less 78%.

Conclusions

Based on the above findings, I propose a new marketing campaign for Tee It Forward that would focus on three key elements. First, using driver distance as a starting point for the selection of tee boxes. Second, identifying PGA TOUR players as a reference group for evaluating amateur approach shots. Third, establishing an objective measure of whether golfers have played an appropriate tee box, namely, have they hit 9 iron or less for half of their par four approach shots. The advantage of this approach is that it provides a starting point (driver distance), a clear comparison to tour players, and an assessment point of the outcomes (approach shots). A marketing campaign focused on these elements could help promote the Tee It Forward initiative.

Keywords: Tee It Forward, Tee Box, Approach Shots, Reference Group, Marketing

References

Auclair, T. J. (2011). *Tee It Forward: Barney Adams makes his case on how to make the game more enjoyable*. Retrieved from http://www.pga.com/pga-america/pga-feature/tee-it-forward-barney-adams-makes-case-how-make-game-more-enjoyable

Newcomb, T. M., Koenig, K. E., Flacks, R., & Warwick, D. P. (1967). *Persistence and change: Bennington College and its students after twenty-five years*. New York: Wiley.

Riffe, D., Lacy, S, & Fico, F. (2014). *Analyzing media messages: Using quantitative content analysis in research* (3rd ed). New York, NY: Routledge.

Trackman. (2014). *Trackman average tour stats*. Retrieved from http://blog.trackmangolf.com/trackman-average-tour-stats/

The PGA TOUR, Inc. is the source of ShotLink™ Data.

Impact Clubhead Kinematics for the Draw and Fade Golf Shots

Andrew Collinson, Paul Wood, David Mullineaux & Alexander Willmott

Purpose

Impact can be considered the most important phase during the golf swing as this is where the collision between the clubhead and ball occurs, dictating the resultant ball flight. Previous studies have investigated the impact clubhead velocity and more recently, the three dimensional orientation of the clubhead together with the clubface impact location (Williams & Sih, 2002; Betzler et al. 2012; Sweeney et al. 2013). The aim of this study was to investigate the kinematics of the clubhead through the impact region for the draw and fade golf shots. In particular, the direction of the clubface relative to the target line and the clubhead plane, and the impact location were all analysed to determine whether these differed between the two shots.

Method

Fifteen male, right-handed Category 1 golfers participated in the study (age 21.7 ± 6.7 yr.; height 169.4 ± 18.4 cm; mass 73.2 ± 13.4 kg; handicap 3.1 ± 2.9; mean ± SD). Participants selected a club from a range of hybrid woods (26° static loft) that were all of the same make and model (G30, PING, Inc., Phoenix, AZ) but differed in lie and length. Three spherical retro-reflective markers (14.0 mm diameter) were attached to the crown of the clubhead and participants were then asked to hit five successful draw shots and five successful fade shots. The clubhead kinematics were recorded at 2000Hz using four Raptor-E cameras (Motion Analysis Corporation, Santa Rosa, CA) positioned around a golf mat. The clubhead data points were resampled to 8000Hz and used to create four virtual clubface markers; a virtual clubface centre was produced from these clubface markers to quantify the impact location. The clubface centre marker was also used to quantify the direction of the clubhead plane during the last 30cm of the downswing. Paired t- tests were run to determine whether there were any differences for the selected variables between the draw and fade during the impact region.

Analysis/Results

The direction of the clubface at pre-impact differed significantly between the two shots: the clubface for the fade pointed to the left of the target and to the right of the target of the draw (table 1). There was also a significant difference between the two shots for the clubface direction at impact relative to the clubhead plane: the clubface at impact pointed to the left relative to the clubhead plane for the draw and to the right relative to the clubhead plane for the fade (table 1). The point of contact between the clubface and ball was also significantly closer to the toe for the draw compared to the fade (table 1).

The difference in the direction of the clubface relative to the target between the two shots was also evident 30cm before pre-impact; the clubface direction for both shots pointed to the right of the target, although the draw clubface direction pointed further to the right compared to the fade (figure 1).
Differences were observed during the first 30cm after pre-impact for the clubface direction between the draw and fade: the clubface direction rotated to the left to a greater extent for the fade compared to the draw during the first 20cm after post-impact (figure 1).

Conclusions

Examination of the clubhead kinematics during impact for the draw and fade has shown that the clubface direction at pre-impact differs between the two shots. The clubface direction relative to the clubhead plane also differed between the draw and fade, and it is likely that this difference between the clubface direction and clubhead plane is used to create the side-spin required to the move the ball in the air for the draw and fade shots. However, differences in impact location between shots may also be another method that creates the desired side-spin necessary for the draw and fade shots through the gear effect.
Coaching theory has previously suggested differences in impact clubface direction relative to the target and the clubhead plane should be used to differentiate between the draw and fade, although to the author's knowledge, altering the impact location between shots has not been previously advocated.

References

Betzler, N.F., Monk, S.A., Wallace, E.S. & Otto, S.R. (2012). Variability in clubhead presentation characteristics and ball impact location for golfer's drives. Journal of Sports Sciences, 30(5), 439-448.

Sweeney, M., Mills, P., Alderson, J. & Elliot, B. (2013). The influence of club-head kinematics on early ball flight characteristics in the golf drive. Sports Biomechanics, 12(3), 247-258.

Williams, K.R., & Sih, B.L. (2002). Changes in golf clubface orientation following impact with the ball.
Sports Engineering, 5, 65-80.

Appendix

Table 1. The clubhead kinematics during the impact region.

	Draw	Fade
Impact clubface direction (°)	2.1 ±2.6*	-2.6 ± 1.6*
Clubface to plane (°)	-5.6 ± 5.5*	2.6 ± 3.3*
Impact location (mm)	12.9 ± 11.2*	3.6 ± 8.8*

**p < 0. 017 difference between the draw and fade*

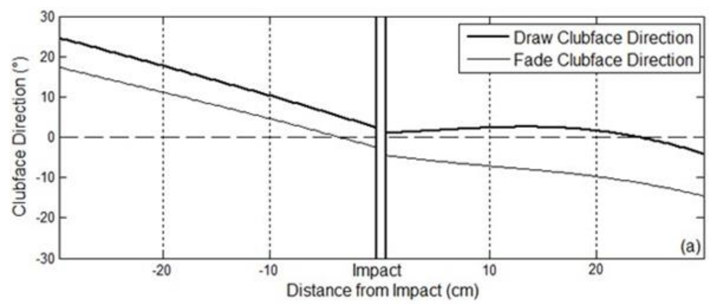

Figure 1. The clubface direction for 30cm before and after impact. A positive clubface direction denotes the clubface is pointing to the right of the target. The solid vertical lines at impact indicate pre-impact and post impact. The dashed vertical lines denote 10cm and 20cm before and after impact, respectively.

The Effect of Brain Synchrony Neurofeedback Training on Golf Putting Performance

Debbie Crews

Purpose

Golf putting is a task that can be performed by most anyone (young and old, skilled and unskilled). However, at every level of skill putting has the ability to save strokes. Electroencephalographic (EEG) brain patterns of elite and novice golfers have been compared to define the patterns associated with best performance (Babiloni, et al., 2008; Crews & Landers, 1993). Neurofeedback studies (Kerick, Douglass & Hatfield, 2004; Zhu, Poolton, Wilson, Maxwell, & Masters, 2011) have trained specific states in the brain associated with best performance. It was the purpose of this investigation to determine the effect of training a pattern of whole brain synchrony on the golf putting performance of a range of skill levels. It was hypothesized that learning the skill of creating synchrony in the brain would enhance putting performance.

Method

Twenty-six individuals (male = 18, female = 8) volunteered to participate in this investigation. The average age was 38.42 ± 15.73 (range 14-81) years and the average handicap was 8.46 ± 14.54 (range +5-40). Total years playing golf was 22.92 ± 14.82 (range 0-68) and total years competing was 12.81 ± 14.72 (range 5-40). Golfers putt 20, 12ft putts on an indoor putting mat as their baseline measure. Quality of feel (1-10, 10 is high), cm error and total putts made were recorded for each putt. Golfers were then randomly assigned to experimental or control condition. Experimental participants were introduced to the synchrony neurofeedback training for 5 trials (in a putting stance with no ball) and then trained with the feedback system while putting the next 15 balls. Control participants simply putted another 15 balls. The feedback system algorithm was designed to divide their baseline putts into three levels of performance (thirds). Music volume was assigned to each level (loud, medium and soft). EEG data were recorded using Emotiv from 14 modified brain locations (FPI, FP2, F3, F4, F7, F8, C3, C4, T3, T4, P3, P4, O1, O2) according the International 10/20 system (Jasper, 1958). The final second prior to the beginning of the motion was analyzed and compared to performance. Fast Fourier transform of the EEG data allowed for comparisons of theta (4-7 Hz), alpha (8-12 Hz), beta (13-20 Hz) and beta2 (21-30 Hz). A club (X, Y, Z) accelerometer provided a time marker for impact of the club and the ball. The brain patterns were fed back to the golfer as loud, medium or soft music representing the least to most brain synchrony, respectively. The golfer was instructed that they were running the feedback program and to use their normal putting routine to create soft music right before they initiated the stroke. Following the 15 training trials all golfers putt 10 posttest trials in which they rated the quality of each putt, and cm error and number of putts made were recorded.

Results

Results indicated that both the experimental and control participants significantly, $F(1,24) = 4.71$, $p = .04$, increased the number of putts made and significantly, $F(1,24) = 9.61$, $p = .005$, reduced cm error from baseline to the posttest. "Quality of putts" improved for both groups but the results were not significant. There was no significant interaction between groups from the pre- to posttest measures. However, the synchrony feedback group made 16% more putts than the physical practice control group. The effect size for the experimental group for putts made was .75 (large) compared to .44 (moderate) for controls. The reduction in cm error was 10% greater for the synchrony feedback group (34%) compared to the control group (24%). The cm error effect size for synchrony feedback golfers was .66 compared to .47 for controls. Lastly, the quality rating for putts improved 3% for synchrony feedback golfers compared to 1% among controls.

Discussion

While the interaction effects were not significant, the large effect size (indicating the meaningfulness of the result) and the practical application of a 16% increase in putts made is important. Additional research is necessary to verify the effectiveness of synchrony feedback. It would be on interest to look at the results of feedback training among different levels of skill and based on the importance on the putt.

Practical Application/Clinical Relevance

Neurofeedback programs offer a unique approach to train golfers to improve performance. Furthermore, the neurofeedback training can be individualized to the golfer using their baseline data to specify the feedback training.

References

Babiloni, C., Del Percio, C., Iacoboni, M., Infarinato, F., Lizio, R., Marzano, N., Crespi, G., Dassu, F., Pirritano, M., Gallamini, M., & Eusebi, F. (2008). Golf putt outcomes are predicted by sensorimotor cerebral EEG rhythms. Journal of Physiology, 586(1), 131–139 131.

Crews, D. and Landers, D. (1993). Electroencephalographic measures of attentional patterns prior to the golf putt. Medicine & Science in Sports & Exercise, 25(1), pp.116-126.

Jasper, H. (1958). Report of the committee on methods of clinical examination in electroencephalography. Electroencephalography and Clinical Neurophysiology, 10(2), 370-375.

Kerick, S. Douglass, L., and Hatfield, B. (2004). Cerebral cortical adaptations associated with visuomotor practice. Medicine and Science in Sports and Exercise, 108, 118-129.

Zhu, F., Poolton, J., Wilson, M., Maxwell, J. and Masters, R. (2011). Neural co-activation as a yardstick of implicit motor learning and the propensity for conscious control of movement. Biological Psychology, 87(1), pp.66-73.

Comparing the Differing use of Meso-Level Processes Employed by Elite and Pre-Elite Golfers

Thomas Davies

Purpose

Much research on psychological skills and thought processes used during a round of golf has focused primarily at the micro-level including the pre-shot routine and shot execution. However, as identified by Davies, Collins and Cruickshank (2014) thought processes and physical behaviors that occur in the time periods whilst out on the course outside of the pre-shot routine (i.e. the meso-level before and after a shot, as well as time in between shots and holes) such as the reaction to, and evaluation of shots may have an impact on performance and are important to consider. Furthermore, and based upon the opinions of golfers and support team members, Davies, Cruickshank and Collins (*under review)* identified best practice guidance for what golfers should be thinking and doing before and after shots, as well as during the time periods in between shots and holes. This included: caddie contributing to meso-level processes, pre^2-shot routine, and post-shot routine. Whilst these processes may seem face valid and resonate with anecdotal evidence and some previous research in golf and other sports, there is a need to address if golfers follow these guidelines in competition. Consequently the purposes of this study were firstly to identify if golfers in competition follow this best practice guidance, and secondly if there exists any differences in the implementation of this guidance dependent upon performance (i.e. playing well vs. poorly) and level of player (i.e. elite vs. pre-elite).

Method

Four elite golfers (M_{age}= 24.75, $M_{experience=}$ 11.25 years) and two pre-elite, university team players (Handicaps= 0 & +2; Ages = 19 & 20; Playing experience= 6 & 8 years) were recorded and observed over four competitive rounds each. Three of the elite golfers were were PGA professionals two of whom played regularly in regional and national competitions, and one who played full-time on the EuroPro Tour. The fourth elite golfer was a professional who played full time on the EuroPro Tour. Immediately after each round discussion took place between the researcher and participant to identify a minimum of 3 good and 3 bad shots ($Range_{good}$= 5-8, $Range_{bad}$= 4-9) to be assessed before footage captured by the lead researcher was used to stimulate discussion in a semi-structured interview. Shots selected included tee shots, approach shots, and short game shots. No putts were used. Each participant was interviewed no more than 30 minutes after the completion of each round, four interviews were carried out with each participant, 24 interviews were conducted in total. Interviews last between 32 and 45 minutes (*M*= 38, *SD*= 3.5).

Analysis/Results

A deductive qualitative analysis of the interviews was carried out using the meso-level processes and actions identified by Davies, Cruickshank and Collins (*under review).* Results provide support for the use of pre^2 and post-shot routines as a way of effectively regulating attention before and after shots. These processes were used more regularly and effectively by elite golfers compared to pre-elites. Furthermore, when playing well both groups reported dissociating their attention from their performance after shots, however, when playing poorly pre-elite golfers spent more time than elite golfers in between shots and holes thinking about past and future events.

Conclusions

Based upon the evidence provided in this study, players and practitioners (i.e. coaches and sports psychologists) should consider the effect that thoughts and behaviors at the meso-level can have on golf performance. In particular this study suggests that elite and pre-elite golfers employ the meso-level processes and actions (i.e. structured pre^2 and post-shot routine) outlined by Davies et al. (*under review)* level more consistently when playing well versus poorly. Based on the evidence presented practitioners should consider training golfers to improve these processes. However, further research is required to examine if training golfers in the use of Davies et al.'s suggested meso-level processes and actions has a positive performance benefit.

Keywords: *Psychology, Attention, Dissociative attention, Post-shot Routine, Pre^2-shot Routine*

References

Davies, T., Collins, D., & Cruickshank, A. (2014). So What Do We Do With the Rest of the Day? Going Beyond the Pre-shot Routine in Elite Golf Support. *International Journal of Golf Science,* 2, 163-175.

Davies, T., Cruickshank, A., & Collins, D. (2016). So This Is What We Do With the Rest of the Day, Manuscript submitted for publication.

Can the Golf Swing be Therapeutic Hip Exercise?

Andrea Du Bois & George Salem

Purpose

Anecdotally, golf has been viewed as a leisure time activity; however, biomechanical analysis suggests the golf swing could have therapeutic implications. The golf swing requires a mediolateral weight shift (Ball & Best, 2007), as the golfer moves his/her body through a large range of motion at a rapid velocity (Lynn et al., 2014). Initiation of the golf swing requires near maximal activation of the proximal hip musculature, specifically the gluteus maximus and medius (Bechler, Jobe, Pink, Perry, & Ruwe, 1995), resulting in hip moments equivalent to those measured in activities such as vertical jumping or incline running (Foxworth et al., 2013).

The gluteus medius and maximus abduct the hip and are important for daily functional activities, including gait (Powers, 2010). Additionally, in both younger and older adults, individuals with superior hip abductor muscle performance have greater mediolateral postural control (Chang, Mercer, Giuliani, & Sloane, 2005; Lee & Powers, 2014). We posit that the high hip joint demands of the golf swing could act as therapeutic stimuli to enhance hip skeletal muscle performance and postural control. While postural control is traditionally a focus of older adult research, physical activity earlier in life is associated with better functional outcomes, including improved mediolateral postural control, later in life and can act to prevent sarcopenia (Akune et al., 2014).

Therapeutic hip exercises have been shown to have similar effects on hip musculature and balance; however, they are typically performed in a single plane, whereas the gluteal musculature controls hip motion across all three planes (Neumann, 2010). Consequently multi-planar activities such as the golf swing could serve as a superior training stimulus and subsequently improve functional outcomes. Therefore, the purpose of this preliminary investigation in *younger adults* was to examine the triplanar hip demands of the golf swing as compared to commonly utilized therapeutic hip exercises.

Method

Six healthy, male (25.7±2.8 y) recreational golfers (5 right-handed) were recruited (Golf experience: 9.9±5.0 y). Participants completed five, 7-iron golf swings, followed by 2 sets of 5 repetitions of commonly utilized therapeutic hip exercises including: Squat, quadruped hip extension with a flexed knee (QuadFlex), quadruped hip extension with an extending knee (QuadExt), unilateral bridge (UniBr), and bilateral bridge (BiBr). These exercises were chosen due to their reported high activation of the gluteal musculature and common use in physical therapy clinics (Selkowitz, Beneck, & Powers, 2013). A lower extremity marker set was used to track body segments with a 10-camera 3D motion capture system (Swing: 250 Hz, Exercises: 60 Hz). Two turf covered force platforms measured ground reaction forces (1500 Hz). Ball trajectory was measured with 3D Doppler tracking radar. Three golf swings with similar club head velocities/ball trajectories and the middle 3 repetitions of the second set of each hip exercise were used for comparative analysis.

Kinematics and kinetics were low-pass filtered with a 12 Hz and 6 Hz cutoff for the swings and hip exercises, respectively. The means and standard deviations of the average net hip joint extensor, abductor, external rotator, and triplanar (vector summation in all three planes) moments for the lead (LEAD) and trail (TRAIL) limbs during the swings and the dominant limb during the hip exercises were calculated. Repeated Measures ANOVA with Bonferroni post-hoc tests assessed the differences across activities (p≤0.05).

Analysis/Results

The contributions of the net individual moments to the triplanar net moment during the golf swing were approximately 56% extensor, 29% abductor, and 15% external rotator. Comparatively, the moment contributions of the therapeutic exercises were approximately 88% extensor, 2% abductor, and 10% external rotator. Table 1 displays the average moment across all three planes and activities. The LEAD triplanar moment was significantly smaller than that of the Squat and UniBr (p≤0.022) moment. The TRAIL triplanar moment was significantly smaller than the UniBr (p=0.003) triplanar moment; however, it was significantly greater than the QuadFlex, QuadExt, and BiBr (p≤0.024) triplanar moments.

Conclusions

Our study demonstrated that the triplanar hip demands of the golf swing were similar to or greater than the demands of commonly-used therapeutic hip exercises, with the exception of the unilateral bridge. While the sagittal-plane demands were greater during the therapeutic hip exercises, the golf swing generated greater frontal-plane demands; thus, we believe the golf swing can be used to improve or preserve hip ***abductor*** muscle performance and consequently mediolateral postural control (Lee & Powers, 2014).

The golf swing is a multi-planar movement and could have important implications for preserving functional activities that require multi-planar control (Powers, 2010). Additionally, as individuals age, there is a preferential loss of Type II muscle fibers; therefore, the high velocity component of the swing and it's associated high muscular demands, suggest the golf swing could be viable stimulus for preserving skeletal muscle health across the lifespan (Chodzko-Zajko et al., 2009).

This preliminary study was performed in young, experienced golfers; however, our future aims are to determine if these potential training stimuli persist across the lifespan and in seniors. Additionally, given the high hip demands of the golf swing, our findings suggest that proper, progressive movement preparation in a novice golfer is prudent. The asymmetrical demands during the swing may also require that the golfer perform swings in both directions or include supplemental hip exercises to prevent muscular imbalances. Future research investigating swing mechanics during partial and full swings in novice and older golfers will allow for the development of safe and effective introductory golf programs aimed at improving hip muscle performance, ML postural control, and functional activity, across the lifespan.

Table 1. Internal net joint hip extensor, abductor, external rotator, and triplanar moments during the golf swing and therapeutic hip exercises.

	LEAD	TRAIL	Squat	Quad Flex	Quad Ext	UniBr	BiBr
Extensor (Nm/kg)	0.34 ±0.06	0.53± 0.05*	0.61±0.12	0.38± 0.03	0.44± 0.03	1.10±0.12*^	0.37± 0.05^
Abductor (Nm/kg)	0.18 ±0.12	0.27± 0.07	0.01±0.004^	0.01± 0.02^	0.01± 0.02^	0.001± 0.001^	0.01± 0.01^
External Rotator (N/kg)	0.10 ±0.05	0.13± 0.05	0.05±0.02	0.05± 0.03	0.05± 0.04	0.05±0.04	0.07± 0.02
Triplanar (Nm/kg)	0.41 ±0.10	0.62± 0.05	0.61 ±0.12*	0.39± 0.03^	0.44± 0.03^	1.10±0.12*^	0.38± 0.04^

*, significant pairwise difference from the lead limb; ^, significant pairwise difference from the trial limb (p<0.05)

Keywords: Postural Control, Muscle Performance, Swing Mechanics

References

Akune, T., Muraki, S., Oka, H., Tanaka, S., Kawaguchi, H., Nakamura, K., & Yoshimura, N. (2014). Exercise habits during middle age are associated with lower prevalence of sarcopenia: The ROAD study. *Osteoporosis International*, *25*(3), 1081–1088. http://doi.org/10.1007/s00198-013-2550-z

Ball, K. A., & Best, R. J. (2007). Different centre of pressure patterns within the golf stroke I: Cluster analysis. *Journal of Sports Sciences*, *25*(7), 757–70. http://doi.org/10.1080/02640410600874971

Bechler, J. R., Jobe, F. W., Pink, M., Perry, J., & Ruwe, P. A. (1995). Electromyographic analysis of the hip and knee during the golf swing. *Clinical Journal of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine*, *5*(3), 162–166.

Chang, S. H. J., Mercer, V. S., Giuliani, C. A., & Sloane, P. D. (2005). Relationship between hip abductor rate of force development and mediolateral stability in older adults. *Archives of Physical Medicine and Rehabilitation*, *86*(9), 1843–1850. http://doi.org/10.1016/j.apmr.2005.03.006

Chodzko-Zajko, W. J., Proctor, D. N., Singh, M. A. F., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S. (2009). Exercise and Physical Activity for Older Adults. *Medicine and Science in Sports and Exercise*, *41*(7), 1510–1530. http://doi.org/10.1249/MSS.0b013e3181a0c95c

Foxworth, J. L., Millar, A. L., Long, B. L., Way, M., Vellucci, M. W., & Vogler, J. D. (2013). Hip joint torques during the golf swing of young and senior healthy males. *The Journal of Orthopaedic and Sports Physical Therapy*, *43*(9), 660–5. http://doi.org/10.2519/jospt.2013.4417

Jonsson, E., Seiger, Å., & Hirschfeld, H. (2004). One-leg stance in healthy young and elderly adults: A measure of postural steadiness? *Clinical Biomechanics*, *19*(7), 688–694. http://doi.org/10.1016/j.clinbiomech.2004.04.002

Lee, S. P., & Powers, C. M. (2014). Individuals with diminished hip abductor muscle strength exhibit altered ankle biomechanics and neuromuscular activation during unipedal balance tasks. *Gait and Posture*, *39*(3), 933–938. http://doi.org/10.1016/j.gaitpost.2013.12.004

Lynn, S. K., Frazier, B. S., New, K. N., Wu, W. F. W., Cheetham, P. J., & Noffal, G. J. (2014). Rotational kinematics of the pelvis during the golf swing: Skill level differences and relationship to club and ball impact conditions. *International Journal of Golf Science*, *2*(2).

Neumann, D. A. (2010). Kinesiology of the hip: a focus on muscular actions. *The Journal of Orthopaedic and Sports Physical Therapy*, *40*(2), 82–94. http://doi.org/10.2519/jospt.2010.3025

Powers, C. M. (2010). The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *The Journal of Orthopaedic and Sports Physical Therapy*, *40*(2), 42–51. http://doi.org/10.2519/jospt.2010.3337

Selkowitz, D. M., Beneck, G. J., & Powers, C. M. (2013). Which exercises target the gluteal muscles while minimizing activation of the tensor fascia lata? Electromyographic assessment using fine-wire electrodes. *The Journal of Orthopaedic and Sports Physical Therapy*, *43*(2), 54–64. http://doi.org/10.2519/jospt.2013.4116

Does Warming-Up Reduce the Risk of Injury to Golfers? A Cluster Randomized Controlled Trial

Andrea Fradkin

Purpose
Golf is a popular sport that is enjoyed by millions of people worldwide of differing ages and abilities. The game of golf is considered relatively benign in nature, however, it has been well documented that injuries do occur (Fradkin et al., 2007, 2006b, 2005, 2003). A number of studies have revealed the prevalence of golf injuries could potentially be prevented by a commonly proposed countermeasure – warming-up (Fradkin et al., 2010, 2008, 2006a, 2004, 2001). There are three factors that have been recommended to be incorporated in a warm-up routine including a period of aerobic exercise, a period of sport-specific stretching, and a period of specific activity. Results of studies carried out to clarify the assumed performance gains of a warm-up have been conflicting, however, a review of the literature has shown that a warm-up improves performance in many different activities, with 79% of the studies reviewed showing improvements in performance after a warm-up, only 17% showing detrimental effects, and 3% finding non-significant results (Fradkin et al., 2010). There are however, very few long-term studies that have investigated the protective effect of a warm-up program, and to date, no published studies in golf.

Therefore, the purpose of this study was to investigate the effect of a golf-specific warm-up program on the reduction of injury risk to golfers.

Method
This study was a cluster randomized controlled trial (RCT). A total of 267 golfers aged 18 – 73 years were randomly allocated to either the control or warm-up group. All injuries, participation in practice and games, and, in the warm-up group, compliance to the warm-up program were monitored. The severity of the injuries sustained was calculated using both treatment length, and time away from golf play and practice.

Analysis/Results
There were no differences between the groups in relation to number of golfers, age, handicap, gender, and previous 12-month injury status. During the study period, 70 injuries occurred, eight in the warm-up group and 62 in the control group ($p<0.001$). The rates of first injuries per 1000 rounds played were 1.2 in the warm-up group and 12.2 in the control group. The lower back was the most frequently injured region with over half of all injuries being to this area. This was followed by injuries to the shoulder, elbow, and wrist. Golfers in the warm-up group were at a lower risk of injury compared to golfers in the control group (OR = 8.2, 95% C.I. 4.3, 15.1). The warm-up group sustained their injuries later in the round (median hole 16) compared to the control group (median hole 7), and the severity of the injuries was more pronounced in the control group compared to the warm-up group both in treatment length and time lost. The warm-up group did not sustain any severe injuries, and the majority of the injuries sustained were mild (< 7days) under both conditions, while the injuries in the control group were classified moderately severe (7 – 21 days) under both conditions. The non-injured warm-up group golfers warmed-up appropriately 91% of the time compared to the injured warm-up group golfers 53% of the time. Further, the eight injuries in the warm-up group were sustained to either those who did not comply well with the warm-up program, or were injuries that could not have been prevented by a warm-up (e.g., rolling a golf cart). Additionally, the injuries sustained by the warm-up group were to golfers who tended to not perform the aerobic component of the warm-up program, suggesting that aerobic exercise may be a key element for injury prevention, which is in agreement with other golf warm-up studies.

Conclusions
The risk of injury in golfers using a golf-specific warm-up program prior to play and practice was significantly reduced, especially the rate of severe injuries. The reduction in the relative risk is highly significant and has been adjusted for the cluster sampling. Further, as the injuries were sustained significantly later in the round by the warm-up group compared to the control group, this also adds weight to show that performing a warm-up is protective as the body eases its way into activity. This is the first randomized controlled trial with sufficient sample size to show that golf injuries can be prevented by performing a golf-specific warm-up program. The ability to sell this warm-up program to golfers should be further enhanced, as it has previously been shown to improve golf performance when used both immediately prior to play (minus four strokes), and as a golf-conditioning program (minus seven strokes).

Keywords: Warm-up, Injury, RCT

REFERENCES
Fradkin A, Zazryn T, Smoliga J. Effects of warming-up on physical performance: A systematic review with meta-analysis. *Journal of Strength and Conditioning Research.* 2010; 24 (1): 140 – 148.

Fradkin A, Windley T, Myers J, Sell T, Lephart S. Describing the warm-up habits of recreational golfers and the associated injury risks. IN: Crews D, Lutz, R (Eds.) *Science and Golf V*. 2008; Chapter 13: 112– 119.

Fradkin A, Windley T, Myers J, Sell T, Lephart S. Describing the epidemiology and associated age, gender, and handicap comparisons of golfing injuries. *International Journal of Injury Control and Safety Promotion.* 2007; 14 (4): 264 – 266.

Fradkin A, Cameron P, Gabbe B. Does warming-up prevent injury in sport? The evidence from randomised controlled trials. *Journal of Science and Medicine in Sport.* 2006a; 9: 214 – 220.

Fradkin A, Cameron P, Gabbe B. Opportunities for prevention of golfing injuries. *International Journal of Injury Control and Safety Promotion.* 2006b; 13 (1): 46 – 48.

Fradkin A, Cameron P, Gabbe B. Golf injuries: Common and potentially avoidable. *Journal of Science and Medicine in Sport.* 2005; 8 (2): 163 – 170.

Fradkin A, Sherman C, Finch C. Improving golf performance with a warm-up conditioning program. *British Journal of Sports Medicine.* 2004; 38: 762 – 765.

Fradkin A, Finch C, Sherman C. Warm-up attitudes and behaviours of amateur golfers. *Journal of Science and Medicine in Sport.* 2003; 6 (2): 210 – 215.

Fradkin A, Finch C, Sherman C. Warm-up practices of golfers: Are they adequate? *British Journal of Sports Medicine.* 2001; 35: 125 – 127.

'Life in the Travelling Circus': A Sociological Analysis of the Lives of Touring Professional Golfers

John Fry

Purpose

As sports have become more professionalised and international in scope, sport workers are increasingly constrained to ply their trade in a variety of locations and experience varying levels of dislocation (Maguire, 2011b; Roderick, 2013). Professional golfers, in particular, have been described as the "nomads" of the sporting world with constantly shifting workplaces and places of residence (Maguire, 2011b, p.1104). However, the views and experiences of such professional sportspeople regarding the consequences of globalization is a largely neglected and under-explored area (Butler & Dzikus, 2015). Furthermore, there is a general perception, which tends to get reinforced by the media, that professional sportspeople lead glamorous lifestyles characterised by earning large sums of money. This study, therefore, critically examines the effects of frequent workplace circulation on the lives of touring professional golfers.

Method

This study adopted a 'case study' approach involving an in depth analysis of the lives of touring professional golfers, and the detailed patterns of relationships, interdependencies and interactions between people accompanying this (Bryman, 2012; Dopson, 2003; Roderick, 2006). The primary data was taken from a set of semi-structured interviews with 20 male professional golfers aged between 22 and 56. Initial interviewees were recruited from personal contacts that stemmed from the researchers' close links with the golf industry, and a snowball sample developed from these initial contacts. 'Purposive sampling' was utilised in order to select players based on their ability to provide an insight across the different levels of touring professional golf (Bryman, 2012).
The semi-structured interviews facilitated discussions in the golfers' own words, using their own frames of reference, and expressing their ideas and thoughts in their own way. The interview questions were designed to encourage players to discuss their views about the reality of work as a professional golfer and focused on the ways and extent to which the nomadic lifestyle inherent to work in professional golf contoured their workplace experiences. All interviews were face-to-face and took place in a private area of a golf club selected by the participant. Transcripts were recorded and then transcribed verbatim. Common themes were identified and analyzed from a figurational sociological standpoint. Nvivo computer package was used to code interview transcripts and organize themes.

Analysis/Results

Results indicate that, contrary to the general media perception that professional sports people lead glamorous lives characterized by earning large sums of money, the lives of the vast majority of professional golfers are far less glamorous and subject to various stresses on their personal wellbeing. Virtually all professional golfers interviewed explained that they spend long periods of time away from home and experience feelings of loneliness and isolation. They are not isolated in terms of people physically around them while on tour – which often includes many others – but rather in terms of lack of contact with people who they have positive, affective feelings towards, such as family and friends. The contact with home that players crave is difficult even despite advances in communications technology. As such, professional golfers develop temporary alliances with other players they perceive to be similar to themselves to help reduce these negative feelings associated with increases in their workplace mobility. People in these groups are friends, characterized by bonds of togetherness, while also enemies showing evidence of conflicts and tensions that develop given they are in direct competition for a share of the prestige and prize money that comes from being successful in golf.
The prize money on offer continues to rise for the golfers in the higher echelons of the professional game, both in terms of actual prize money and endorsements. These elite groups, playing at the top of the European main tour, are usually focussed on by the media, however, the reality is such that the large rewards are not disseminated far down the golfing hierarchy meaning many fare poorly. This increasingly top-heavy prize breakdown fosters a habitus whereby many players 'gamble' on pursuing golf as their main source of income even despite the odds against them. The work presented here builds on research in football (Roderick, 2006, 2013, 2014) by highlighting the money issues, isolation, superficial relationships and uncertainty ever present in the world of touring professional golf. However, this study's unique contribution is to help sensitise the reader to the global aspect of professional golf, whereby players' place of work is constantly moving, thus meaning golfers undergo a qualitatively different experience.

Conclusions

It is argued that professional golfers are required to make various adaptations to cope with life on tour, such as to behave in a manner that conforms to particular group norms, while, at the same time, to be individual and distinguished from others, which can bring about numerous tensions and difficulties.

Golf attracts a lot of research focused on the 'playing' aspects of the game, whereas, social and cultural factors, such as the lifestyle of professional golfers presented here, tend to be somewhat overlooked. However, a former Official World Golf Ranking top 10 player interviewed for this study argued that the "challenge isn't so much adapting your game ... the challenge is how you adapt to the lifestyle". This golfer was specifically referring to the importance of considering how players cope with the lifestyle of working in the 'travelling circus' that is touring professional golf.

References

Bryman, A. (2012). Social research methods. (4th Ed.). Oxford: Oxford University Press.

Dopson, S. (2003). The potential of the case study method for organizational analysis. Policy & Politics, 31(2), 217–226.

Maguire, J. (2011b). Power and global sport: zones of prestige, emulation and resistance. Sport in Society: Cultures, Commerce, Media, Politics, 14(7), 1010–1026.

Roderick, M. (2006). The work of professional football: A labour of love? Routledge: London.

Roderick, M. (2013). Domestic moves: An exploration of intra-national labour mobility in the working lives of professional footballers. International Review for the Sociology of Sport. 48(4), 387–404.

Roderick, M. (2014). From identification to dis–identification: case studies of job loss in professional football. Qualitative Research in Sport, Exercise and Health, 6(2), 143–160.

Butler, B.N., & Dzikus, L. (2014). Sport labour migration: Understanding leisure activities of American professional basketball players abroad. Leisure Studies. doi:10.1080/02614367.2014.964292.

Enhanced Longevity in Successful Professional Golfers

Phillip Greenspan & Krysten Greenfield

Purpose

It has now been universally accepted that lifelong exercise is associated with increased longevity and the exercise can be confined to a walking routine (Lee & Paffenbarger, 2000). One group who has not been studied is golf professionals who successfully played on the PGA tour. Since these individuals played several times a week for decades and a seven thousand yard course is equivalent to a minimum of a four mile walk, these golfers form a unique group to document the importance of exercise in promoting longevity.

Method

Successful professional golfers, for this study, were those who played and won one PGA tour event in the 1950s (1950-1959). Eighty-seven golf professionals met that criterion *("Golf magazine's*," 1993) Biographical information was obtained from the USGA, Far Hills, NJ and Wikipedia; golfer information on this website has been confirmed to be accurate (Coate & Schwenkenberg, 2013). Two players could not be fully documented. For comparison, successful baseball players who participated in All-Star games in the 1950s ("http://www.espn.go.com/mlb") were also studied; the biographical information of the one hundred and ninety-eight athletes was obtained ("http://www.baseball"). Since the first black winner on the tour was Pete Brown in 1964, only white baseball All-Stars were included in the analyses. The longevity of the U.S. white male population, using the birth year of 1930 for the survival function curve, was obtained (Arias, 2009). The survival function curves were started at age forty and ended on August 1, 2014.

Analysis/Results

When compared to white males born approximately at the same time as the professional golfers, the median age of death of the golfers was approximately eighty-two years of age, twelve years greater than the general population. When professional golfers were compared to All-Star baseball players, the median age of death was quite similar (eighty-two vs eighty years). However, a striking difference is observed in the rate of premature death. Only 11% of the professional golfers died prior to age sixty-five; this compared to 21% for the baseball players and 35% for the general male population. Finally, 58% of the professional golfers lived to the age of eighty; this was similar to the rate in baseball players (53%). Both group of athletes had a far greater longevity than the general population for only 21% of white males lived to eighty years old.

Conclusions

A lower mortality rate in golfers has been documented (Farahmand, Broman, Faire, Vågerö, & Ahlbom, 2009); similar results were found for those who played on the Senior PGA Tour (Coate & Schwenkenberg, 2013). However, in both studies, the majority of the golfers examined were still alive; here, approximately 20% were alive as on August 1, 2014. What is of greater interest is the apparent protection against premature death seen in these golfers; the mortality rate before 65 was approximately half that of the baseball players and one-third of the general population. Heart disease was the major cause of death during this time, including males under the age of 65 (Yang, 2009). While other factors (socioeconomic and marital status, smoking, alcohol intake, etc.) are important determinants of mortality, these results reaffirm the strong relationship between lifelong exercise and longevity.

Keywords: Lifespan, PGA tour, All-Star baseball players, United States Male Population

References

Arias, E. (2009). United States Life Tables, 2009. *National Vital Statistics Report, 62*, 1-63.

Coate, D., & Schwenkenberg, J. (2013). Survival Function Estimates for Champions Tour Golfers. *Journal of Sports Economics, 14*, 656-663

Farahmand, B., Broman, G., Faire, U., Vågerö, D., &

Ahlbom, A. (2009). Golf: A game of life and death - reduced mortality in Swedish golf players. *Scandinavian Journal of Medicine &Science in Sports,19*, 419-424
Golf magazine's encyclopedia of golf: The complete reference (2nd ed.). (1993). New York, N.Y.: HarperCollins.

Lee, IM., & Paffenbarger, RS Jr. (2000). Association of light, moderate and vigorous intensity physical activity with longevity. The Harvard Alumni Health Study. *American Journal of Epidemiology, 151*, 293-299.

Retrieved from http://www.baseball-reference.com

Retrieved from
http://www.espn.go.com/mlb/allstargame/history
Yang, Y. (2009.).Trends in U.S. Adult Chronic Disease Mortality, 1960–1999: Age, Period, and Cohort Variations. *Demography,45,* 387-416.

Current Status and the Determinants of Golfers' Satisfaction: An Exploratory Study

Joseph Groch & Lan Jiang

Purpose

According to the 2014 National Golf Foundation (NGF) Report, there are 16,000 golf courses, 24.7 million golfers in the U.S., and $76 Billion in revenues (including real estate) generated from the golf industry (NFG, 2014). However, the golf industry is in decline. The number of golfers has been reduced from 30 million in 2005 to 24.7 million in 2013 (NFG, 2014). This poses a serious threat to the future of golf. The purpose of this study is to examine the current state of golfers' satisfaction and to explore the determinants of golfers' satisfaction. Specifically, this study is designed to help golf facility managers identify key variables to both the factors that influence a golfers' satisfaction and the elements that drive that satisfaction.

Method

In order to establish golfer satisfaction associated with major operational components of their golfing experience, 27 golf club managers were interviewed in the southwest Florida area. Based upon these interviews, 21 items were included as possible determinants of golfer's satisfaction. Survey instruments were then developed predicated upon these 21 items for data collection. Golfer satisfaction data were collected through a series of surveys conducted at 10 golf facilities in Southwest Florida, where 237 golfers participated in the golfer satisfaction survey.
Overall satisfaction was added in order to develop a comprehensive view on golfer's satisfaction. These 22 items/questions were scored on a 5 point scale: 1= Completely Dissatisfied, 2= Somewhat Dissatisfied, 3= Neither Satisfied or Dissatisfied, 4=Somewhat Satisfied, 5= Completely Satisfied.
In the study, data were analyzed in three stages. First, the descriptive statistics showed an overview of the golfers' satisfaction on the services they received. Second, factor analysis was conducted to reduce the numbers of items that predict golfers' satisfaction. Finally, a multiple regression was employed to identify which factors were related to overall golfers' satisfaction (factors generated from previous step were used as independent variables).

Analysis/Results

Female golfers, which represented 69 (29%) of the 237 golfers surveyed, have a higher overall satisfaction score at 4.67, while male golfers which represented 168 (71%) of the 237 golfers have a lower score at 4.53. It is interesting to note that most of the golfers are satisfied: 96% of female golfers and 93% of male golfers answered 4 "somewhat satisfied" or 5 "completely satisfied" when being asked about their overall satisfaction.
Using SPSS 22, a principal component analysis was conducted on 21 attribute items to reduce the data. The procedure used a loading cutoff value of 0.45 for item inclusion (Tabachnik & Fidell, 1996), and varimax (orthogonal) rotation with both eigenvalue criterion and Scree Test to identify the number of dimensions. The reliabilities of dimensions were assessed by Cronbach's Alpha.
The principal component analysis with varimax rotation of 21 attributes produced 5 component dimensions based on by both latent root and Scree Test criteria. Both Bartlett test of Sphericity ($p<0.000$) and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (0.829) indicated that using factor analysis on these attributes was highly appropriate (Norusis, 1992). The components were averaged for composite scores and labeled as "Appearance", "Outside Service", "Inside Service", "Tee Time", and "Conditions". The reliabilities (Cronbach's Alpha) ranged from 0.76 to 0.807, which indicated acceptable internal consistency (Nunnally & Bernstein, 1994).
To identify which factors were related to overall golfers' satisfaction, a stepwise multiple regression analysis was performed on the independent variables of these 5 factors versus the dependent variable of overall satisfaction.
The stepwise solution indicated that outside service ($p<.0001$), condition ($p<.0001$), and inside service ($p<.0001$) contributed to the prediction of overall golfers' satisfaction. The variance in overall quality explained by these three predictors was 47.2% (R^2). The regression equation based on these factors was:

$$y = -.177 + .443\,inside\ service + .316\,condition + .286\,outside\ service$$

Conclusions

The significance of this study not only provides a guidepost for future research but also provides practical data for practitioners. In addition, this study can act as a standard upon which other facilities can measure their own relative strengths and weaknesses. Specifically, the research indicates that golf operations need to invest in training and communications in order to have a well informed and knowledgeable Pro Shop staff (.809). They may also need to employ queuing studies to minimize customer wait times (.615). Golf courses also need to provide superior course conditions (.822) and, in particular, excellent greens (.750). This may require golf course operators to engage in such practices as fertigation and over-seeding to achieve these results. Finally, country clubs need to ensure members experience an efficient bag room (.870) and bag drop (.766) operation with a courteous staff (.513). This small factor cannot be overlooked because the first and last service experience a golfer has is with outside services.

Keywords: Golf, Satisfaction, Determinants, Exploratory

References

Nunnally, J. C., & Bernstein, I. H. (1994). The theory of measurement error. *Psychometric theory*, 209-247.

NFG, (2014). National Golf Foundation Member Resources. Jupiter, FL.

Norusis, M. J. (1992). *SPSS for Windows: Professional Statistics User's Guide, Release 5.0*. SPSS Incorporated.

Tabachnick, B. G., & Fidell, L. S. (1996). Using multivariate statistics. *New York: Harper Collins Tabachnick Using multivariate statistics1996*.

Differences in Swing Kinematics Between Male and Female Elite Junior Golfers

Tomáš Gryc, František Zahálka &Tomáš Malý

Purpose

Golf swing technique depends on anatomical, physiological, and morphological characteristics of individuals, such as flexibility and strength. Gender differences in golf swing technique are well known and movement parameters during the golf swing and its differences between genders were studied (Horan, Evans, & Kavanagh, 2011; Zheng, Barrentine, Fleisig, & Andrews, 2008). However, there was no research conducted in gender differences in golf swing kinematic parameters of elite junior golfers. The aim of the study was to identify the differences between male and female junior golfers in selected movement parameters of the upper body and the golf club. It also analysed the relation between upper body movement parameters and golf club parameters for male and female junior golfers.

Method

Eight female (age: 14.5 ± 1.6 years; height: 167.3 ± 5.9cm; weight: 59.3 ± 12.3kg; hcp: 2.1 ± 1.2) and six male (age: 15.1 ± 1.2 years; height: 177.7 ± 6.9cm; weight: 70.85 ± 15.8; hcp: 1.8 ± 2.1) elite junior golfers participated in this study. Each player had 30 minutes to warm up individually and performed practical swings in laboratory conditions. The golfers used their own golf clubs 7 iron. Movement data were captured by a 3D kinematic analyser CODA Motion System. Active markers were placed on the selected points of the golfer's body (left and right acromion, left and right spina iliaca anterior superior) and on the golf club shaft (on the end of the grip and 0.1m from the leading edge). The evaluated parameters were maximum shoulder rotation (Smax), maximum hip rotation (Hmax), maximum X-Factor (Xmax), X-Factor Stretch (X-FS), and golf club velocity (GCV). Smax, Hmax, and Xmax were evaluated in a horizontal plane. Xmax was evaluated as the maximum difference found between shoulder and hip rotation angle in a horizontal plane. X-Factor stretch was defined as the time difference between the moment of the maximum hip rotation and the top of the backswing although its value is typically reported in degrees. Golf club velocity was defined as the velocity of the active marker placed on the shaft closer to the club head. Multivariate analysis of variance (MANOVA) was used to identify differences in kinematic parameters between genders. The Pearson Correlation coefficient was used to analyse the relation between upper body movement parameters and the golf club velocity of males and females.

Analysis/Results

Higher hip rotation and X-Factor stretch were found to be higher among the female golfers while higher shoulder rotation, X-Factor and golf club velocity was higher among the male golfers (Table 1).

Gender		Parameters				
		Smax (˚)	Hmax (˚)	Xmax (˚)	X-FS (s)	GCV (m/s)
Male	Mean	104.6	34.78	75.04	0.07	24.0
	SD	15.73	7.7	13.95	0.04	2.34
Female	Mean	103.1	40.85	66.73	0.09	20.65
	SD	9.32	6.44	5.27	0.07	1.50

Table 1.: Kinematic data of male and female golfers

MANOVA showed a significant gender effect in parameters Hmax ($F = 6.28$; $p < 0.05$; $\eta^2 = 0.21$), Xmax ($F = 5.41$; $p < 0.05$; $\eta^2 = 0.18$) and GCV ($F = 31.98$; $p < 0.01$; $\eta^2 = 0.57$). We found no relation between upper body movement parameters and golf club velocity for female golfers. For male golfers, we found a significant relation between Smax and GCV ($r = .904$; $p < 0.01$) and Xmax and GCV ($r = .826$; $p < 0.05$).

Conclusions

There was found gender effect in Hmax, Xmax and GCV. Although we found very similar shoulder rotation, there are differences in hip rotation and, in response to it, also in X-factor between genders. It suggests that male golfers use more upper body strength by stretching in a coiling motion of the upper body against a more stable lower body during the backswing when compared to the female golfers. As a response to the higher X-Factor, it results in a higher GCV and likely in a longer ball flight. In the group of male golfers, Smax and X-factor correlated with GCV. The female golfers use more coiling motion of the hips during the backswing, but there was no relation found to GCV. Based on the presented results, golf coaches should consider different movement patterns of male and female golfers while teaching golf swing technique, particularly with golfers of junior age.

References

Horan, S. A., Evans, K., & Kavanagh, J. J. (2011). Movement variability in the golf swing of male and female skilled golfers. *Medicine and Science in Sports and Exercise, 43*(8), 1474-1483.

Zheng, N., Barrentine, S. W., Fleisig, G. S., & Andrews, J. R. (2008). Swing kinematics for male and female pro golfers. *International Journal of Sports Medicine, 29*(12), 965-970.

Negative Emotional Reactivity of Golfers

Amy Harris, Daniel Sachau, Luke Simmering, Cindra Kamphoff & Warren Ryan

Purpose

Negative emotional reactivity (NER) is the tendency to display strong behavioral and affective responses to failure. These responses include self-denigration and humiliation. NER is characterized by frequent unpleasant outbursts and is not simply a momentary response to a solitary mistake but is a persistent pattern of behavior and is accompanied by lasting negative affect. In this paper, we introduce a measure of NER and test the degree to which the new measure is related to a variety of popular personality measures used by sport psychologists including obsessive and harmonious passion, self-esteem, contingent self-worth, and ability of avid recreational golfers. **Passion.** Vallerand and his colleagues (Mageau, Carpenter & Vallerand, 2011; Vallerand, et al., 2003) suggest people with a harmonious passion for an activity participate out of intrinsic interest and the desire to fulfill needs for autonomy, competence, and relatedness (Deci & Ryan, 1985). Harmonious passion is positively related to life satisfaction, positive affect, and vitality (Curran, Appleton, Hill, & Hall, 2013; Gustafsson, Hassmen & Hassmen, 2011). People with an obsessive passion participate because of a felt obligation to participate (Mageau et al., 2011; Vallerand et al., 2003). The obsessively passionate tend to seek competence in their focal activity in order to maintain, enhance, or protect feelings of self-worth (Crocker & Wolfe, 2001; Stenseng & Dalskau, 2010; Vallerand et al., 2003). Obsessive passion is positively related to emotional exhaustion, rigid persistence on task, life conflict, stress, and negative affect (Curran et al., 2013; Gustafsson et al., 2011). We predicted that harmonious passion would be negatively correlated and obsessive passion would be positively correlated with negative emotional reactivity. **Global Self Esteem.** People with low self-esteem tend to have more negative reactions to failure than do people with high self-esteem (Brown, Dutton, & Cook, 2001; Brown & Dutton, 1995, 1997; Mackinnon, Smith, & Carter-Rogers, 2015). Thus, we proposed that golfers with low self-esteem would score higher on NER than golfers with high self-esteem. **Contingent Self Worth**. Crocker et al. (2003) developed the Contingencies of Self-Worth Scale to assess the extent to which people find self-worth from seven sources. We hypothesized that NER would be greatest for golfers who derived self-worth from external domains including social approval, physical appearance and outdoing others in competition. We also predicted that NER would be higher for golfers who derived their self-worth from golf competence.

Method

A total of 1,947 golfers completed an online survey comprised of the Passion Scale (Vallerand et al., 2003), an adapted version of the Contingencies of Self-Worth Scale (Crocker et al., 2003), Rosenberg's Self-Esteem Scale (Rosenberg, 1965), and a newly created Negative Emotional Reactivity Scale. Scale items focused specifically on negative emotional reactions on the golf course. Items include: "After I hit a bad shot or miss a putt, I often insult myself (e.g. "You're stupid," or "You suck."). I often hit myself when I make a mistake on the golf course. My golf round determines how I feel and act for the remainder of the day. When I'm playing golf poorly, my playing partners do not enjoy my company. I feel ashamed after a poor round of golf. I need to play golf well in order to feel pride. I am humiliated whenever I lose a match or place poorly in a tournament." The mean age of participants was 56.85 years and 85% were males. The mean USGA handicap index was 13.4. The mean number of rounds played per month during the golf season was 12.

Analysis/Results

The NER Scale had reasonably high reliability (*alpha* = .80). All items loaded on a single component when a principal components analysis was conducted. The mean scale score was (15.1 out of a possible 35 points, *SD* = 3.70). Alpha and factor structure did not vary across age, gender or golf experience groups. Scores on the NER Scale were negatively related to harmonious passion $r = -.10$, $p < .001$ and positively related to obsessive passion $r = .32$, $p < .001$. NER was negatively related to self-esteem $r = -.40$, $p < .001$, positively related to CSW Family $r = .11$, $p < .001$, CSW Competition $r = .43$, $p < .001$, CSW Appearance $r = .35$, $p < .001$, CSW Golf Competence $r = .57$, $p < .001$, CSW approval $r = .22$, $p < .001$ and negatively but minimally related to CSW Virtue $r = -.07$, $p < .001$. NER was modestly related to age $r = -.12$, $p < .001$ and golf handicap $r = -.07$, $p < .05$. Because many of the variables were inter-correlated, we tested a regression model wherein NER served as the dependent variable and the other variables served as predictors. The model was significant $F(7,1277)=144.45$, $p < .001$ ($R^2 = .44$). NER was higher for players who were younger (*Beta* = -.06), who scored lower on Harmonious Passion (*Beta* = -.22) and Self-Esteem (*Beta* = -.19), and who scored higher on Obsessive Passion (*Beta* = .18), CSW Competition (*Beta* = .10), and CSW Golf Competence (*Beta* = .42). CSW Virtue was no longer a significant predictor.

Conclusions

The picture we get of the golfer who tends to have negative emotional outbursts on the course is of a somewhat younger golfer, with relatively low self-esteem, who derives his/her self-worth from golf performance, and has an obsessive passion for the game. The NER scale may help coaches identify players who are highly susceptible to frustration and prone to leaving the game. The NER scale might also work as a self-assessment tool providing golfers with the opportunity to think about their own behavior. The NER might be used in a battery of assessments to examine a healthy orientation to sport in general and golf in particular.

Keywords: Golf, Satisfaction, Emotional Reactions, Performance, Personality

References

Brown, J. & Dutton, K. (1995). The thrill of victory, the complexity of defeat: Self-esteem and people's emotional reactions to success and failure. *Journal of Personality and Social Psychology, 68*(4), 712-722

Brown, J. & Dutton, K. (1997). Global self-esteem and specific self views as determinant of People's reactions to success and failure. *Journal of Personality and Social Psychology, 73*(1), 139-148

Brown, J. D., Dutton, K. A., & Cook, K. E. (2001). From the top down: Self-esteem and self-evaluation. *Cognition and Emotion, 15,* 615–631

Deci, E. L. & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior.* New York: Plenum. ISBN 0-306-42022-8.

Crocker, J., Luhtanen, R. K., Cooper, M. L., & Bouvrette, A. (2003). Contingencies of self-worth in college students: Theory and measurement. *Journal of Personality and Social Psychology, 85*, 894-908.

Crocker, J., & Wolfe, C. T. (2001). Contingencies of self-worth. *Psychological Review, 108*(3), 593-623.

Curran, T., Appleton, P., Hill, A., & Hall, H. (2013). The mediating role of psychological need satisfaction in relationships between types of passion for sport and athlete burnout. *Journal of Sports Sciences 31*(6), 597-606. doi: 10.1080/02640414.2012.742956

Gustafsson, H., Hassmen, P., & Hassmen, N. (2011). Are athletes burning out with passion? *European Journal of Sport Science, 11*(6), 387-395.

Mageau, G., Carpenter, J., & Vallerand, R. (2011). The role of self-esteem contingencies in the distinction between obsessive and harmonious passion. *European Journal of Social Psychology 41*, 720-729. doi: 10.1002/ejsp.798

Mackinnon, S. P., Smith, S. M., & Carter-Rogers, K. (2015). Multidimensional self-esteem and test derogation after negative feedback. *Canadian Journal of Behavioural Science/Revue Canadienne Des Sciences Du Comportement, 47*(1), 123-126. doi:http://dx.doi.org/10.1037/a0038364

Rosenberg, M. (1965). *Society and the adolescent self-image*. Princeton, NJ: Princeton University Press.

Stenseng, F., & Dalskau, L. H. (2010). Passion, self-esteem, and the role of comparative performance evaluation. *Journal of Sport & Exercise Psychology, 32*, 881-894.

Vallerand, R.J., Mageau, G.A., Elliot, A.J., Dumais, A., Demers, M-A., & Rousseau, F. (2003). Passion and performance attainment in sport. *Psychology of Sport and Exercise, 9,* 373–392.

Analysis of Brain Activity in Elite Golfers

Nicholas Hool & Andrea Carpenter

Purpose

The purpose of this experiment was to analyze the brain activity of elite golfers before, during, and after a five-foot putt and to compare activity between made and missed putts. The area of the brain that best differentiates made and missed putts will be identified. Data will be compared before, during and after the putt. It was hypothesized that power would be higher in both the theta and alpha bandwidths during a missed putt compared to a made putt (Babiloni, 2008; Critchley, 2001). It was hypothesized that power would be higher in the right hemisphere (RH) compared to the left hemisphere (LH) during made putts (Crews & Landers, 1993). Previous studies have analyzed brain activity in the seconds leading up to a putt, but past research has not compared EEG activity immediately before, during and immediately after the putt; thus, the null hypothesis will be tested.

Method

Electroencephalographic (EEG) data were recorded from 10 volunteer golfers (18-30 years of age, 6 years minimum competitive experience, handicap less than 10) while they performed a putting task, hitting nine putts spaced uniformly around a hole each exactly five feet away from the hole. The testing was performed on a public putting green at Karsten Golf Course in Tempe, AZ. Data were collected using the Emotiv headset at three time periods: 1-2 seconds before the start of the motion, the 1-2 seconds during the motion of the putt, and the 1-2 seconds after the motion of the putt. Fast Fourier transform of the EEG data allowed for comparisons of theta (4-7 Hz) and alpha (8-13 Hz) bandwidths in 11 different scalp locations (AF3, AF4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1) according to the International 10/20 system (Jasper, 1958). Absolute power spectrum was used to quantify the EEG data.

Results

It was found that there was a higher magnitude of power in theta bandwidths across all brain locations and higher power in alpha in 8/11 brain locations for a missed putt than there was for a made putt ($p<0.05$).

Channel	Avg Theta Miss	Avg Theta Make	Avg Alpha Miss	Avg Alpha Make
AF3	16.51 ± 15.21	13.22 ± 11.15	4.05 ± 5.04	3.43 ± 2.39
AF4	18.57 ± 15.23	15.21 ± 12.53	3.71 ± 2.82	3.64 ± 2.54
F7	24.57 ± 24.70	9.52 ± 7.73	4.51 ± 5.09	2.14 ± 1.71
F8	25.28 ± 21.56	17.35 ± 12.93	5.61 ± 4.09	4.33 ± 3.20
FC5	10.18 ± 13.59	4.12 ± 3.30	2.93 ± 5.01	1.68 ± 1.36
FC6	15.42 ± 15.56	11.37 ± 10.31	3.89 ± 4.63	3.99 ± 2.88
O1	11.16 ± 13.85	4.98± 4.56	2.81 ± 1.88	3.27 ± 2.34
P7	9.94 ± 13.31	4.85 ± 4.32	3.59 ± 3.83	2.72 ± 2.37
P8	12.92 ± 13.58	11.07 ± 12.78	4.21 ± 2.84	4.81 ± 3.60
T7	9.56 ± 13.17	4.55 ± 3.71	2.86 ± 3.64	2.45 ± 1.97
T8	17.71 ± 19.46	9.91 ± 8.73	3.98 ± 3.39	3.90 ± 2.48

It was found that there was a higher average power in the RH for both made putts and missed putts than there was in the LH for both made putts and missed putts.

	LH Make	LH Miss	RH Make	RH Miss
Theta	6.64 ± 6.61	13.78 ± 16.71	12.37 ± 11.11	19.49 ± 19.82
Alpha	2.67 ± 2.21	3.40 ± 4.20	3.94 ± 2.62	4.31 ± 3.69

In both the LH and RH, there was a significant difference in theta activity between the 1-2 seconds before the putt (higher) and the 1-2 seconds during the putt (lower), for all made putts. The same was found in alpha activity for made putts (higher before and lower during), but only in the RH. There were no significant differences found between before the putt and after the putt, or during the putt and after the putt.

Theta Made	RH p-value	LH p-value
Before-During	1.5E-8	1.2E-7
Before-After		
During-After	0.048	0.004

Alpha Made	RH p-value	LH p-value
Before-During	0.002	8.5E-11
Before-After		
During-After		1.8E-6

Discussion

The results indicate that theta and alpha power were lower during a made putt than during a missed putt, in both hemispheres. There was also a trend seen between the time periods before the putt and during the putt, but no significant trend between the time periods before and after or during and after the putt. Before the putt, brain activity was higher and then it significantly decreased during the putt and then slightly, not significantly, increased after the putt. This is most likely due to the decrease in conscious processing that occurs during the putt. Elite golfers attempt to putt automatically using subconscious processing not detected with EEG electrodes.

There was a general trend for theta and alpha power to be higher during a missed putt compared to a made putt. This supports the concept that during successful performance, the brain is efficient and requires less processing to perform the task.

Application

Data such as this is important to train successful performance in golf. Neurofeedback programs can be designed to train golfers to get into a successful state of mind prior to their performance. Furthermore, the neurofeedback training can be individualized to the golfer using their baseline data to specify the feedback training.

References:

1. Babiloni, Claudio, Claudio Del Percio, Marco Iacoboni, Francesco Infarinato, Roberta Lizio, Nicola Marzano, Gianluca Crespi, Federica Dassù, Mirella Pirritano, Michele Gallamini, and Fabrizio Eusebi. "Golf Putt Outcomes Are Predicted by Sensorimotor Cerebral EEG Rhythms." The Journal of Physiology 586.1 (2008): 131-39. Web.
2. Crews, Debra J., and Daniel M. Landers. "Electroencephalographic Measures of Attentional Patterns Prior to the Golf Putt." Medicine & Science in Sports & Exercise 25.1 (1993): 116-26. Web.
3. Critchley, Hugo D., Christopher J. Mathias, and Raymond J. Dolan. "Neural Activity in the Human Brain Relating to Uncertainty and Arousal during Anticipation." Neuron 29.2 (2001): 537-45. Web.
4. Jasper, H. (1958). Report of the committee on methods of clinical examination in electroencephalography. Electroencephalography and Clinical Neurophysiology, 10(2), 370-375.

Analysis of the Effect of Club Head Shape on Players' Club Delivery

Alex Hope, Erik Henrikson & Paul Wood

Purpose

Certain players prefer and perform better with different types of iron replacements (e.g. hybrids and fairway woods). Some players refer to using a different technique to swinging the different clubs such as a "sweeping" swing for fairway woods and a steeper, "iron" like swing for hybrids. Understanding the reasons behind this phenomenon can help determine if a player's swing can be influenced by head shape and help fit a player in to the correct type of club, where the fitting consists of an optimization of the launch conditions, distance and forgiveness. This study analyses the effect of both different head shapes and club length on the delivery of longer iron replacement clubs.

Method

An initial test comparing the club delivery of an iron, hybrid and fairway wood of similar loft (21-22°) was conducted at each clubs respective standard length, using its respective standard shaft. Fifteen male golfers, average HCP 3.9 (±5.2) participated in this test. Club data was captured using the PING ENSO motion capture system (utilizing Vicon cameras) at 720Hz and ball data was collected using a Foresight GC2. A second test was conducted comparing the delivery of an iron, hybrid and fairway wood of similar lofts (21-22°), with all clubs built to the same length (39.75") and the same shaft to isolate the variable of head shape. Fifteen male golfers, average HCP 0.6 (±2.7) participated in the second test and data was captured in the same format as the first test. In each test players hit 8 shots with each club, rotating clubs every 4 shots.

Analysis/Results

In the first test comparing the clubs at standard length, the fairway wood was delivered with a significantly shallower angle of attack, 1.5° shallower than the hybrid and 2.2° shallower than the iron. Similarly the fairway wood was delivered with significantly less forward shaft lean at impact, 0.8° less than the hybrid and 2.2° less than the iron. As such, the fairway wood was delivered with a significantly higher spin loft than the hybrid and iron.

The second test comparing the iron, hybrid and fairway at a single length with the same shaft showed the difference in angle of attack between the different head types to be much smaller than the previous test, although the differences between the clubs were still significant. The fairway was delivered 0.4° shallower than the hybrid and 0.9° shallower than the iron. A similar effect was seen when looking at shaft lean where the fairway wood was delivered 0.3° less forward than the hybrid and 1.1° less forward than the iron.

Conclusions

Head shape has a small but statistically significant effect on club delivery. For a given club length, deeper heads such as fairway woods and hybrids are delivered with a shallower angle of attack and less forward shaft lean compared to an iron. A larger effect on delivered angle of attack and shaft lean is noticed when considering the length of the club where longer clubs show a much shallower angle of attack and decrease in forward shaft lean. The results somewhat support the theory that players "sweep" a fairway wood, however the exact cause of whether this is due to the head shape and length or whether this is simply due to players being taught to swing the fairway wood in this manner is not known. The data also suggests that for players with significantly forward shaft lean causing the club to be delivered with lower loft and causing a lower ball flight, a hybrid or fairway wood may be more suitable to help the player deliver the club with more loft and give them a higher ball flight. Further, while the lower CG location of hybrids and fairway woods generally yield higher launch, the head shape and additional length of these alternatives can also help the player deliver the clubs with more loft.

Speed Changes Everything – an investigation into the effect of launch characteristics on putting performance

Paul Hurrion, James MacKay, Mark Sweeney & Andrew Collinson

Purpose

A putt hit with the perfect line and initial start speed might still miss the hole due to varying amounts of skid, roll and launch angle. The following study investigated the variation of launch characteristics during putting to determine how these differences affect the outcome of ball speed. Speed has a significant effect on putting results and should be considered an important factor when putting at any level (Pelz, 2000). Despite this, the ability to control ball speed can often be overlooked and focus in coaching and performance predominantly aims to control the speed of the putter head. Aim and green reading are the primary determinant of putting direction consistency (Karlsen et al. 2008), however little or no focus is aimed towards 'clubhead twist', centre contact or even the launch characteristics of the golf ball. The purpose of the study was to better understand a player's ability to control ball speed and distance control, despite their normal variability in putter head speed by changing launch and spin conditions.

Method

The Quintic Ball Roll system uses a high speed camera (360fps) to measure a variety of factors including ball speed, roll, spin, launch and skid during the first 16 inches of a putt. Ten putts were performed by an elite professional (Top 60 World golf Rankings – Sept 2015) outside on a flat green (0% slope; Stimp 11). The putt distance was 12ft and each putt was recorded individually using the Quintic Ball Roll system.

Speed control of the participant was paramount, therefore the participant selected is widely considered to be one of the best 'pace putters' in the world. The data collected by Quintic Ball Roll was mathematically modelled using AimPoint software, a green reading tool that helps to understand break speed and aim by assuming true roll over the entire length of the putt. All 10 putts were simulated across different angles (12 angles around the clock face over 30 degree increments) and three different slope percentages (1%, 2% and 3%) to determine the outcome of the ball. The modelling used a surface stimping at 11.

Analysis/Results

Table 1 shows the raw data collected for each of the ten putts on the flat surface. The range in ball speed at 0 inches was 0.28 mph (5% variance from the mean) and this increased to 0.41 mph at 16 inches (14% variance from the mean). Due to differences in launch angle, roll and skid, this equates to a further difference of 0.56 mph between the fastest and the slowest putt by the time the golf ball reached true roll (zero skid). AimPoint software was used to quantify exactly how much a range of 0.41 mph might change the outcome of a putt given the same start direction. Figure 1 highlights the results of what percentage of putts would still go in the hole, based on the gradient and angle. The red lines indicate a miss, blue indicate holed and black is the average putt line. When putting using the 3% slope, 60 degree down, there was over a 3ft variation in the finishing distance between the fastest and slowest putt. Figure 2 highlights a composite image of the ball roll.

Conclusions

The results clearly show that as the slope gets steeper the variance in launch characteristics accentuates the variance in ball speed, causing the ball to slow down at difference rates. The participant tested had world-class speed control with only a 0.24 mph variance across 10 putts, however a greater variance will accentuate this even more. The results also showed that smaller uphill angles are more forgiving of speed variances than cross-hill or downhill angles. From a strategic perspective, it should be obvious where the ideal position to putt from is and from a performance perspective it is important to understand that having consistent launch conditions can have a big effect on distance control. Despite this, some natural variance in speed must be expected (golf is an outdoor sport), and when facing a steep fast downhill putt, it is dramatically harder to make than the equivalent uphill putt (Wesson, 2008 & Holmes, 1991). This brings implications to players of all abilities and probes the question should golfers be more concerned with finishing a certain distance past the hole or optimising the effective size of the hole to give them the best chance of putting.

Putting is a game of percentages - be sure you know where the odds lay in your favour. Given that the golf ball can lose up to 30% of its initial speed before it gets to true roll, identifying this point is clearly important for a player to be consistent on the putting green. From a coaching perspective, a player needs to be able to consistently control ball speed, along with launch, spin and roll values in order to achieve a consistent end distance. A consistent strike point is also required for this to occur. The authors would also stress, that the golfer in question is inside the top 60 in the world ranking (September 2015) and in their experience don't believe a human can be much more consistent with ball speed immediately after impact.

Keywords: putting; slope; speed; performance

References

Pelz, D. (2000). Dave Pelz's Putting Bible: The Complete Guide to Mastering the Green. New York: Doubleday.

Karlsen, J., Smith, G, Nilsson, J (2008). The stroke has only a minor influence on direction consistency in golf putting among elite players. Journal of Sports Science, February 1st 2008; 26(3): 243-250

Holmes, B. W. (1991). Putting: How a golf ball and hole interact. American Journal of Physics, 59, 129- 136.

Wesson, J. (2008). The Science of Golf. Oxford: Oxford University Press.

Appendix

Green Stimp - 11	1	2	3	4	5	6	7	8	9	10	Average
Impact Ball Speed (mph)	6.06	6.12	6.33	6.07	6.24	6.14	6.16	6.05	6.32	6.13	**6.16**
+ Hook / - Cut Spin (RPM)	-11	4	8	2	32	14	-7	-13	7	-1	**3.41**
Initial Ball Roll (RPM)	16.06	19.54	46.69	13.40	10.48	30.29	21.30	38.80	21.04	46.67	**26.43**
Start of Forward Roll (inches)	0.53	0.00	0.00	0.14	2.45	0.00	0.00	0.00	0.00	0.00	**0.31**
Zero Skid occurs after (inches)	18	21	22	16	20	19	17	20	23	15	**19.10**
Launch Angle (degrees)	1.33	1.56	1.89	3.61	2.80	2.20	3.40	1.67	1.99	0.91	**2.14**

Distance (inches)	Speed (mph)										Average	Min	Max	Diff
0	6.06	6.12	6.33	6.07	6.24	6.14	6.16	6.05	6.32	6.13	6.16	6.05	6.33	0.28
1	5.72	5.95	6.05	5.78	6.03	5.85	5.92	5.89	6.05	6.04	5.93	5.72	6.05	0.33
2	5.73	5.96	6.06	5.75	5.99	5.80	5.91	5.85	6.06	6.04	5.92	5.73	6.06	0.33
3	5.72	5.83	5.99	5.78	6.01	5.80	5.86	5.82	6.05	5.88	5.87	5.72	6.05	0.33
4	5.63	5.84	5.90	5.66	5.85	5.63	5.76	5.70	5.92	5.89	5.78	5.63	5.92	0.29
5	5.38	5.53	5.71	5.43	5.63	5.55	5.60	5.51	5.68	5.62	5.56	5.38	5.71	0.33
6	5.33	5.55	5.66	5.33	5.59	5.45	5.56	5.42	5.66	5.40	5.50	5.33	5.66	0.33
7	5.26	5.51	5.52	5.26	5.61	5.35	5.58	5.42	5.56	5.39	5.45	5.26	5.61	0.35
8	5.19	5.51	5.52	5.24	5.46	5.15	5.39	5.34	5.59	5.40	5.38	5.19	5.59	0.40
9	4.98	5.37	5.28	4.98	5.23	5.15	5.21	5.14	5.51	5.42	5.23	4.98	5.42	0.44
10	4.86	5.02	5.20	4.90	5.16	5.01	5.13	4.96	5.19	4.99	5.04	4.86	5.20	0.34
11	4.78	4.96	5.10	4.81	5.03	4.85	5.09	4.93	5.13	4.86	4.95	4.78	5.13	0.35
12	4.48	4.89	4.99	4.55	4.82	4.64	4.74	4.84	5.08	4.71	4.77	4.48	5.08	0.60
13	4.56	4.73	4.73	4.48	4.70	4.53	4.63	4.60	4.92	4.70	4.66	4.56	4.92	0.36
14	4.20	4.64	4.61	4.38	4.62	4.32	4.64	4.35	4.59	4.37	4.47	4.20	4.64	0.44
15	4.10	4.64	4.32	4.13	4.38	4.27	4.42	4.25	4.50	4.32	4.33	4.10	4.5	0.40
16	4.05	4.45	4.26	4.03	4.20	4.12	4.31	4.18	4.46	4.12	4.22	4.05	4.46	0.41

Table 1: Individual data for the 10 putts on a flat green (stimp 11) from a European Tour Golfer.

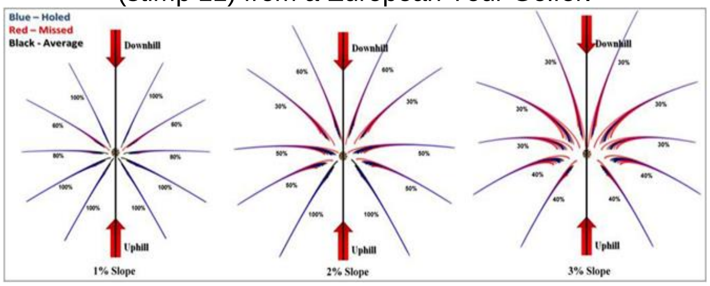

Figure 1: A visual representation of the 10 putts simulated across a 1%, 2% and 3% uniform slope

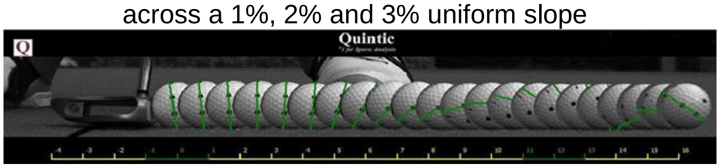

Figure 2: A composite image of the golf ball rolling

Hedonic Pricing of Green Fees in Golf Sports – the Case of Germany

Christopher Huth

Purpose

Knowledge of consumers' willingness to pay for different product attributes received when purchasing green fees is of great importance to golf clubs. With a share of 18 percent, green fees are the second most important source of revenue for European golf clubs (Sports Marketing Surveys, 2013). Using a dataset of German golf clubs (n = 670), we investigated whether or not 17 objectively measurable product attributes have a significant impact on green fee price by applying the hedonic price technique (Rosen, 1974). With 728 golf courses and nearly 640,000 golfers (DGV, 2015), Germany is one of the most important golf markets in the world (KPMG, 2013). In contrast to other European golf destinations, Germany is known neither as a popular golf tourism destination nor as a traditional golf region. Hence, the German golf market is not influenced by special demand circumstances, rendering this "neutral" market an interesting and potentially objective research setting. Findings from our research should support golf clubs in setting green fees and communicating their strengths (e.g., traditional golf club, different facilities, challenging golf course). The central findings should also allow conclusions to be drawn that are generally applicable, wherever possible and appropriate, to other golf markets (e.g., Great Britain or southern countries like Spain or Portugal).

Method

Focusing on the dependent variable first, we opted for two different green fee prices: green fees on weekends and green fees during the week. Several product attributes are expected to influence green fee prices. The considered product attributes were selected on the basis of a literature review (e.g., Limehouse, Maloney, & Rotthoff, 2012; Limehouse, Melvin, & McCormick, 2010; Shmanske, 1998). In addition, we chose variables that have never been included in previous analyses to provide deeper understanding of green fee pricing. In total, we selected five general golf club characteristics, two golf course-related and three golf club infrastructure-related attributes, three golf-related certificates and one golf course ranking system, as well as three fixed effects. The fixed effects describe the general infrastructure and economic situation in a golf club's environment.

Data (golf season 2015) were primarily collected from the website, www.1golf.eu, which is the leading website for German golf courses.

Analysis/Results

For the empirical analysis, we used the hedonic pricing approach because this method can identify important attributes from consumers' viewpoints (Falk, 2008) and is generally used to gain insight into specific markets (Sirmans, Macpherson & Zietz, 2005). The hedonic price method is a regression-based approach that explains the price of a product as a function of its characteristics by estimating the value of the individual attributes of the product. While hedonic theory addresses various types of explanatory variables, it is not informative regarding the selection of the functional form of the estimation model (Boatto, Defrancesco, & Trestini, 2011). However, Ekeland, Heckman & Nesheim (2002) noted that hedonic models are essentially nonlinear. Consequentially, the most frequently used functional form is log-linear (Sirmans et al., 2005). An alternative to the log-linear form is Box-Cox regression. We considered the Box-Cox estimation approach to verify and possibly improve the log-linear model.

Our findings indicated that attributes such as the number of holes, the existence of a challenging golf course that has ideally received a certificate, and the presence of various facilities have a significantly positive impact on green fee prices. Additionally, we found that golf clubs located in a competitive market and an economically prosperous region can impose higher prices. In contrast, the club's degree of professionalization and proximity to a large city have no impact on green fee prices.

Conclusions

According to empirical findings, a golf club aiming to maximize its revenue should concentrate on providing a relatively high number of holes. Additionally, green fee golfers want to play golf courses characterized by challenging features. Ideally, golf clubs should also have received a certificate for their course, and findings indicated that inclusion in *Golf Magazine*'s top 50 ranking has the highest impact on green fee prices among the types of certifications and rankings considered. Further, tradition and longevity help clubs increase their green fees. In sum, findings generally indicated that older golf clubs should highlight their age and their associated history. By contrast, younger, more newly established golf clubs should ensure that they build a challenging golf course that has the potential to attract above-average golf players. Both older and younger clubs should try to obtain specific golf certificates and provide adequate infrastructure.

Keywords: green fees, hedonic pricing, certificates, German golf market

References

Boatto, V., Defrancesco, E., & Trestini, S. (2011). The price premium for wine quality signals: does retailers' information provision matter?. *British Food Journal*, *113*, 669-679.

DGV (2015). *Zahl der Golfspieler wächst leicht*. Retrieved from: http://www.golf.de/publish/dgv-services/golfmarkt/statistiken/60105661/zahl-der-golfspieler-waechst-leicht.

Ekeland, I., Heckman, J.J., & Nesheim, L. (2002). Identifying Hedonic Models. *The American Economic Review*, *92*, 304-309.

Falk, M. (2008). A hedonic price model for ski lift tickets. *Tourism Management*, *29*, 1172-1184.

KMPG (2013). *Golf participation in Europe 2013*. Budapest.

Limehouse, F.F., Maloney, M., & Rotthoff, K. (2012). Peak-Load Versus Discriminatory Pricing: Evidence from the Golf Industry. *Review of Industrial Organization*, *40*, 151-165.

Limehouse, F.F., Melvin, P.C., & McCormick, R.E. (2010). The Demand for Environmental Quality: An Application of Hedonic Pricing in Golf. *Journal of Sports Economics*, *11*, 261-286.

Rosen, S. (1974). Hedonic Prices and Implicit Markets: product Differentiation in Pure Competition. *The Journal of Political Economy*, *82*, 34-55.

Sirmans, G.S., Macpherson, D.A., & Zietz, E.N. (2005). The Composition of Hedonic Pricing Models. *Journal of Real Estate Literature*, *13*, 3-43.

Shmanske, S. (1998). Price discrimination at the links. *Contemporary Economic Policy*, *16*, 368-378.

Sports Marketing Surveys (2013). *The economic impact of golf on the Economy of Europe*. Surrey.

Managing League Reforms in Sports – the Case of the German Golf League

Christopher Huth

Purpose

As a result of its global popularity and its successful series of individual tournaments (Bramley, 2009), golf has been added to the 2016 Olympics in Rio de Janeiro, Brazil. In order to have realistic chances to win a gold medal in 2020 the German Golf Association (DGV), the league's governing body, implemented the German Golf League (DGL) in 2013. This study aims to analyze golf players' acceptance of the established league system after the third season. The purpose is to identify (1) those league characteristics that are considered particularly significant and (2) those characteristics that need to be reformed from the players' point of view. So, the DGV underlines that if required, there will be a major revision of the league system after DGL's third season in 2015. Therefore, the findings deliver important insights into the DGL's future product development and give a league-governing body that wants to introduce a national golf league valuable support.

Method

For the present study, a standardized questionnaire was developed which evaluated players' acceptance of different league characteristics (Creswell, 2008; Skinner, Edwards, & Corbett, 2015). We considered eleven general (e.g., league size, number home and away matches, point system) and five golf-specific (e.g., stroke play, number of scratch results) league characteristics of DGL's current league system. To ensure consistent operationalization, 5-point Likert scales (from 1 = do not agree to 5 = fully agree) were applied throughout the attitude measurement in the questionnaire (Li, Pitts, & Quarterman, 2008; Revilla, Saris, & Krosnick, 2014). The survey was distributed in September 2015 after the last match day of the regular season and the Final 4 competition. The Qualtrics questionnaire tool was used for online sampling. The survey link was e-mailed to all of the participating golf clubs in the DGL (N = 317). The online questionnaire was available for three weeks. One week prior the closing of the survey, an e-mail reminder was sent. In total, N = 640 players (32% of them females) participated in the survey. The average age of the participants was 34.62. Of the participant players, 28% were relegated, 29% moved up and 44% remained in their original league division.

Analysis/Results

For the empirical analysis, group comparisons by league levels (Kruskal & Wallis, 1952) are conducted and different regressions are estimated by ordered logit and probit estimation techniques (Baum, 2006; McKelvey & Zavoina, 1975; Winship & Mare, 1984). The impact of eleven general and five golf-specific league characteristics on three dependent variables is evaluated. The dependent variables are the overall grade for the new league system, the statement that the new introduced league system is better than the previous system as well as the statement that the introduction of the system was good. Additionally, different variables are considered which also include the sporting criteria of the players (such as league level or sporting success).

First results indicate that the players are quite satisfied with the league system which was established three years ago. The evaluation of the general and golf specific league characteristics shows that the players are especially pleased with the home match (mean value (MV) = 4.47), the away matches (MV = 4.40), the Final 4 competition (MV = 4.10), the number of scratch results (MV = 4.14) and the number of singles matches (MV = 3.90). However, less accepted is the number of foursome (MV = 3.21) and the relegation system with two relegated teams (MV = 2.96). Also, the game modus – stroke play instead of match play – is criticized by the players (MV = 3.46). They prefer more match play elements in the competition system.

Conclusions

Based on the first findings, the German Golf Association should think about reforms in different areas. First, they should introduce more exciting elements such as match play.

Hansen and Gauthier (1993) show that – taking the example of the Ladies PGA Tour – excitement and drama are important factors for different stakeholders. Second, the current relegation system with 40% relegated teams should be reformed. In this context, relegation games appear to be a realistic alternative.

In general, it is to see that the established league system with its different characteristics is accepted by the players. Therefore, the current league system can be seen as a good example for a national golf league which has the aim to strengthen the competition level of its amateur players in order to develop a second Martin Kaymer.

Keywords: golf league, reforms, players, Olympics

References

Baum, C.F. (2006). *An Introduction to Modern Econometrics Using Stata*. Texas: Stata Press.

Bramley, C. (2009). Golf. In W. Andreff and S. Szymanski (Eds.), *Handbook on the Economics of Sport* (pp. 369-373). Cheltenham & Northampton: Edward Elgar.

Creswell, J.W. (2008). *Educational research* (3rd edn.). Upper Saddle River: Pearson.

Hansen, H., & Gauthier, R (1993). Spectators' views of LPGA golf events. *Sport Marketing Quarterly*, *2(1)*, 17–25.

Kruskal, W.H., & Wallis, W.A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, *47*, 583-621.

Li, M., Pitts, B., & Quarterman, J. (2008). *Research Methods in Sport Management*. Morgantown: Fitness Information Technology.

McKelvey, R.D., & Zavoina, W. (1975). A statistical model for the analysis of ordinal level dependent variables. *Journal of Mathematical Sociology*, *4*, 103-120.

Revilla, M. A., Saris, W. E., & Krosnick, J. A. (2014). Choosing the number of categories in agree–disagree scales. *Sociological Methods & Research*, *43*(1), 73-97.

Skinner, J., Edwards, A., & Corbett, B. (2015). *Research Methods for Sport Management*. New York: Routledge.

Winship, C., & Mare, R.D. (1984). Regression models with ordinal variables. *American Sociological Review*, *23*, 512-525.

Excursion Pattern on Center of Pressure And Trunk Motion During Golf Swing in Collegiate Golfer

Youka Izumoto, Toshiyuki Kurihara, Mutsuko Nozawa & Tadao Isaka

Purpose

Weight transfer during golf swing is one of the most important factors for improving golf performance. The weight transfer strategies are categorized into two types in professional golfers (Ball, et al,. 2007), defined as "Front foot" (Ff) and "Reverse" (Rv). In short, Ff means that center of pressure (COP) travels from back to front foot smoothly and COP is on the front foot at the ball impact. While, in Rv, their COP showed similar excursion patterns from backswing to early downswing, but it abruptly traveled to the backward just before the impact of ball hitting (Ball, et al,. 2007).

Previous studies showed that trunk motion during golf swing differed in player levels (professional vs. amateur) and genders (Okuda, et al,. 2010: Horan, et al,. 2010). Such a trunk motion affects to the weight transfer pattern, but no study has been focused on the relationship between trunk motion and weight transfer patterns.

The purposes of this study were 1) to investigate whether the two excursion patterns of COP exist among collegiate golfers, and 2) to examine the linkage of the trunk motion and the excursion pattern.

Method

Twenty-four collegiate golfers (11 male, 13 female) were participated in this study. They have practiced golf for long time (10.5±3.0 years) and their golf performances were relatively high (76.6±3.4 strokes). All players completed 10 shots with their usual stance using driver and 7-iron, respectively. Each foot was placed on two separate force plates. The ground reaction forces of each foot were measured at 1000Hz and the COP in medio-lateral and anterior-posterior directions (COPx, COPy) were calculated. COPx was normalized as the stance interval between both feet (front foot = 100%stance, rear foot = 0%stance), and COPy was normalized as the foot length between toe and heel (toe = 100%foot length, heel = 0%foot length). Three-dimensional kinematics were measured using a motion capture system recorded at 250 Hz. Independent t-tests (significant level was set at $p<0.05$) were used for examining the significant difference between two groups.

Analysis/Results

Nine subjects (3 male, 6 female) were assigned to the Ff since their COPx% were over 50%COPx at ball impact on driver, and fifteen subjects (8 male, 7 female) were the Rv (Figure 1).

COPx[%stans]

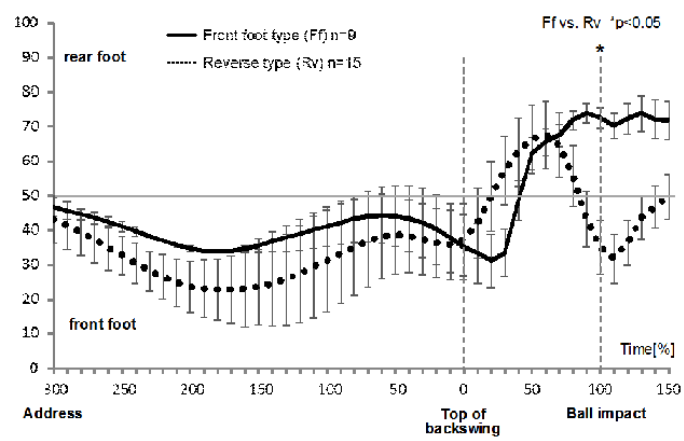

Figure 1. The group-averaged excursion pattern on COPx% during golf swing. Data. The time (%) was normalized to the downswing phase (0%-100%).

There was no significant difference between Ff and Rv groups in average golf score (77.5±4.0 strokes, 76.0±3.3 strokes) and club head speed (43.8±3.8m/s, 42.8±3.6m/s). COPy% had no significant difference between two groups using driver, but COPy% on 7-iron showed the significant difference between two groups (Table 1). COMx% at ball impact of Ff was significantly larger than Rv using D and 7I, but COMy% was not significantly different (table 1).

Table 1. Displacement of COPx%, COPy%, COMx% and COMy% at ball impact on driver (D) and 7-iron (7I)

			Front foot (Ff) n=9	Reverse (Rv) n=15	p
D	COP	x[%stance]	79.2 ± 23.9	38.8 ± 14.5	<0.05
		y[%foot]	71.4 ± 11.4	79.5 ± 8.4	n.s
	COM	x[%stance]	60.3 ± 8.5	52.4 ± 7.7	<0.05
		y[%foot]	58.6 ± 10.5	65.1 ± 7.3	n.s
7I	COP	x[%stance]	88.6 ± 16.7	54.1 ± 15.0	<0.05
		y[%foot]	60.2 ± 11.8	75.3 ± 9.0	<0.05
	COM	x[%stance]	55.4 ± 6.4	46.3 ± 6.1	<0.05
		y[%foot]	61.6 ± 8.3	64.8 ± 7.7	n.s[TK1]

Moreover, at the ball impact, medio-lateral trunk tilt on the rear foot for Rv groups tend to be larger than that of Ff groups (16.7±4.7deg, 13.8±3.0deg, p=0.07), and anterior-posterior trunk tilt on the anterior side for Rv groups significantly larger than Ff groups (15.6±3.6deg, 12.0±2.7deg, p<0.05).

Conclusions

This study confirmed that the excursion patterns among the collegiate golfers were separated into two types as well as professional golfers. Moreover, these excursion patterns did not change in different golf clubs and did not stand for their golf skills. These findings were the same as the previous study in professional golfers (Ball, et al,. 2007; 2011). The results of this study indicates that a larger medio-lateral trunk tilt for rear foot side and lager anterior trunk tilt at ball impact is the characteristics of Rv style.

Keywords: Golf player, Weight transfer, Golf swing movement

References

1. Ball, et al,. (2007). Different centre of pressure patterns within the golf stroke I: Cluster analysis. *Journal of Sports Sciences*, 25(7): 757–770
2. Ball, et al,. (2011). Golf style and center of presser patterns when using different golf clubs. *Journal of Sports Sciences*, 29(6): 587–590
3. Horan, et al,. (2010) Thorax and pelvis kinematics during the downswing of male and female skilled golfers. *Journal of Biomechanics*. 43: 1456–1462
4. Okuda, et al,. (2010) Trunk rotation and weight transfer patterns between skilled and low skilled golfers. *Journal of Sports Science and Medicine* 9, 127–133

Do Golfers Really Need to be Strong and Flexible?

Ian Kenny, Tom Quinn, Sarah Cunningham, Mark Campbell

Purpose

It is well established that expert performance in golf requires specific biomotor abilities, and that through tailored training many of these abilities can be improved (Doan, Newton, Kwon & Kraemer, 2006; Fletcher & Hartwell, 2004; Smith, Callister & Lubans, 2011; Torres-Ronda, Sanchez-Medina & Gonzalez-Badillo, 2011). In more recent years there has emerged a growing body of literature on 'strength and conditioning' and fitness for golf, and physical preparation has become an integral part of the skilled golfer's preparation (Sell, Tsai, Smoliga, Myers, & Lephart, 2007). An area of particular interest to strength and conditioning (S&C) and other healthcare practitioners involved with the sport, is determining which physical attributes contribute directly to performance and how these attributes can be manipulated to improve performance. Primary goals for healthcare practitioners are to design comprehensive exercise programs that A) optimise performance, and B) condition the body to withstand the demands of the sport with the least risk of injury. However, there remains a lack of clear information on individual components of muscular strength, muscular power, and flexibility and their effects on golf performance. The purpose of this research was to investigate potential relationships between shoulder and hip rotational strength, flexibility, and power, with golf driving performance in low-to-medium handicap (<20 golf handicap) amateur golfers.

Method

Thirty eight participants were recruited (all right handed, age 35.1 ± 14.5 years, height 1.76 ± 0.08 m, mass 76.76 ± 14.41 kg, golf handicap 7.9 ± 5.8) including twenty five male and thirteen female participants. Testing took place in a dedicated indoor golf performance laboratory. Participants' golf swings were analysed for club head speed at impact (CHS), projected carry distance (CD) and projected shot accuracy using a high speed stereoscopic launch monitor. Clinical tests for shoulder and hip range of motion (ROM), shoulder and hip rotator isometric strength, grip strength, counter-movement vertical jump (CMJ) height power test, and rotational medicine ball throw (RMBT) distance, were also administered.

Analysis/Results

Data were analysed using IBM SPSS Statistics v22 software to determine if relationships existed between the shot performance dependent variables (CHS, CD, accuracy) and independent variables (ROM, strength, and power tests). The strongest Pearson's correlations reported were between CMJ height (r=0.70; p<0.01), RMBT distance (r=0.77; p<0.01) and CHS. Moderate correlations were reported between CHS and right arm grip strength (r=0.66; p<0.01), CHS and left arm grip strength (r=0.66; p<0.01); carry distance and right arm grip strength (r= 0.53; p<0.01), carry distance and left arm grip strength (r= 0.53; p<0.01), carry distance and CMJ height (r= 0.57; <0.01), and carry distance and RMBT (r= 0.67; p<0.01). Weak significant correlations (r = 0.30-0.50) were reported for all other strength tests against shot performance indicators. A multiple stepwise regression analysis was performed to determine the influence of independent measures on shot and performance dependent measures. Stepwise regression testing order blocked firstly golf handicap, height, mass, age, then blocked shoulder and hip range of motion (ROM), shoulder and hip rotator isometric strength, grip strength, counter-movement vertical jump (CMJ) height power test, and rotational medicine ball throw (RMBT) distance. The regression analysis determined CMJ height as the greatest predictor of CHS explaining 81% percent of the variance. Accuracy regression analysis relationship was deemed 'trivial', thus not significantly or meaningfully correlated with any measured independent variable. Data showed no sex differences for variable relationship analysis.

Conclusions

We found countermovement jump performance to be the greatest predictor of drive shot club head speed, suggesting this test is a valid field test for use with low-to-medium handicap amateur golfers, and combined with trunk rotational exercises such as medicine ball throws, could be incorporated into golfers' training regimes. The results of this study support the suggestions of previous interventional studies on the use of plyometric exercises, such as the slow stretch-shortening cycle countermovement jump (CMJ) and rotational medicine ball throw (RMBT) for the development of total body explosive power to augment golf driving performance. The strength and power testing modalities presented offer viable options for screening and assessment purposes. Further analyses for shot performance and ball impact characteristics is merited, as well as strength and flexibility injury implication.

Keywords: golf drive performance, flexibility, strength

References

Doan, B., Newton, R., Kwon, Y., & Kraemer, W. (2006). Effects of conditioning on intercollegiate golfer performance. *Journal of Strength and Conditioning Research*, 20, 62-72.

Fletcher, I., & Hartwell, M. (2004). Effect of an 8-week combined weights and plyometrics training programme on golf drive performance. *Journal of Strength and Conditioning Research*, 18, 59-62.

Sell, T., Tsai, Y., Smoliga, J., Myers, J., & Lephart, S. (2007). Strength, flexibility, and balance characteristics of highly proficient golfers. *Journal of Strength and Conditioning Research*, 21, 1166-1171.

Smith, C., Callister, R., & Lubans, D. (2011). A systematic review of strength and conditioning programmes designed to improve fitness characteristics in golfers. *Journal of Sports Sciences*, 29, 933-943.

Torres-Rhonda, L., Sanchez-Medina, L., & Gonzalez-Badillo, J. (2011). Muscle strength and golf performance. *Journal of Sports Sciences*, 10, 9-18.

A Study on the Development of Golf Clubs for Beginners

Tetsuro Kita

Purpose

In many physical education classes taught in universities in Japan, golf is incorporated as a teaching tool. That number is a total of approximately 580 classes. Almost all of the students of the classes are beginner golfers, meaning they have never played or practiced before.

The objective of this study was to develop a club that even beginners could easily allow them to hit the ball straight. Beginners are prone to slice the ball as their hands cannot keep up with the centrifugal force of the head at the moment of impact. In order to improve this point, a club was fabricated by shifting the conventional connection section of the club head and the shaft towards the center of the head. By positioning the shaft near the center of the head, it would be more likely to concentrate with pinpoint accuracy on the center, without dispersing the force of the accompanying hand at the moment of impact. In other words, even if the ball hits any spot on the face, the angle of the face would not change, and it was considered that it would be easy to hit towards the targeted direction. This study was conducted as a joint study with Japan's Bridgestone Golf Corporation.

Method

Experiment 1

15 Japanese college students taking golf lessons (11 male, 4 female) hit shots with the fabricated clubs (driver and short irons). Responses of their awareness of the sensation between conventional clubs and fabricated clubs were obtained and analyzed. Please include numbers that indicate perhaps The number of positive responses, negative responses and neutral responses for each club. We need numbers.

Experiment 2

Three male students volunteered to hit 10 balls using the fabricated club (driver and short iron) and the conventional club (driver and short iron). The order of hitting was….? The number of straight shots (please define how straight was measured) was compared between the four clubs.

Results

Numbers must be included. You can give one or two examples but include numbers.

The results of experiment 1 are as below. When iron clubs that were fabricated were used, each noted two instances of comments such as "It felt like the shot became faster," "the sound became sharper," "easy to hit," and "the ball is easy to see," were noted.

There were other comments such as the "sweet spot felt wider," "there is a sense of stability," "face appears widely." However, on the contrary there were also comments such as "it was difficult to hit".

Then, when they used the fabricated the driver, comments such as "easy to swing", "felt like the ball was caught" "feel like it was hit with the correct trajectory", "sweet spot felt wide", and "good balance as the shaft is in the center of the head" were obtained. For both the iron and driver, in general several comments of "easy to hit" were obtained.

The results of experiment 2 are as below. Three male students, hit 10 shots each using the newly fabricated clubs (driver and short irons). A comparison was made with the number of straight shot using conventional clubs. The proportion of straight shots was as below.(Fig.1) subject A: 20% with use of conventional clubs, 60% with use of fabricated clubs. subject B: 50% with use of conventional clubs, 80% with use of fabricated clubs. subject C: 10% with use of conventional clubs, 50% with use of fabricated clubs.

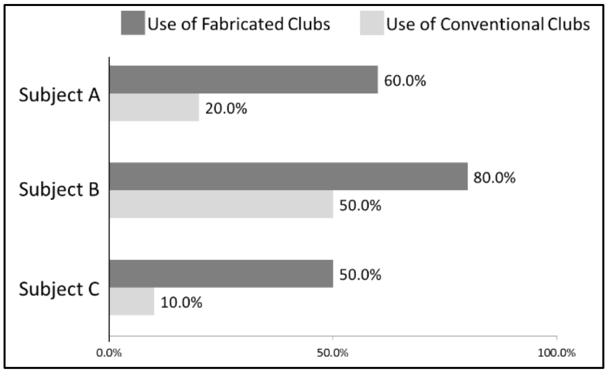

Fig.1 Ratio of straight shot with each clubs.

Fig.2 Iron for beginners

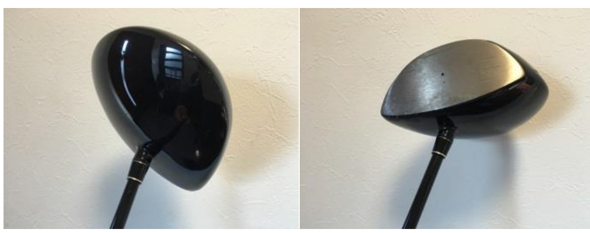

Fig.3 Driver for beginners

Conclusions

When the clubs, which were newly fabricated with the help of this Bridgestone Golf Corp., where used by beginner college students, the club was easy to swing for beginners, and the percentage of straight shots actually increased. However, student's comments was seen due to the fact that they had already become accustomed to conventional clubs. The clinical significance of the club was demonstrated through this experiment. It is necessary to conduct reviews towards the practical use of the club in the future.

Keywords: Golf Clubs for Beginners, Shaft Shifted Towards the Center Position of the Head

Examining the Irish Male High Performance Programme: Talent development, Coaching Practices and Regional Differences

Niamh Kitching & Mark Campbell

Purpose

In recent years Irish men's professional golf has enjoyed much global success, resulting in a focus on golfer development and talent pathways in Ireland. With a view to augmenting and optimizing the programme for future golfers, a review was carried out on the male amateur high performance golf programme from regional to national level in Ireland. This study compares and contrasts the performance programmes in two of the four regions.

Method

A mixed-methods approach was employed consisting of player (n=100) and coach (n=30) questionnaires, focus groups (n=5) and semi-structured qualitative interviews (n=6). A spectrum of views were collected from various stakeholders such as junior and adult players, parents, coaches, physiotherapists and officials, with a focus on a) programme management, b) coaching practices and the role of coaches and c) player selection, de-selection and transitions.

Analysis/Results

In terms of programme management, in Region 1 five coaches worked with 154 players across 12 squads, from one location and amounting to 260 coaching hours. In Region 2, six coaches worked with 234 players across 14 squads and in six coaching locations, constituting a 450 hour coaching commitment. While players in Region 2 were satisfied with the coaching facilities and coach liaison, players in Region 1 were dissatisfied with the quality of the facility, the opportunity to play on the course and access to the coaches.

Coach roles, responsibilities, engagement and education were contrasting in both regions. While coaches in Region 2 had a central role in squad selection and de-selection, coaches in Region 1 highlighted their lack of involvement and identified their preference for a more prominent role in player selection. Other concerns from coaches in Region 1 centred on the decline in numbers and quality of players, and poor player attendance at coaching sessions. While coaches in Region 1 identified coach education as a goal, in Region 2 coaches were more invested and in control of their educational outcomes, where they discussed the potential for a broad and flexible coaching curriculum, coach specialisms and coach to coach collaboration.

Regional differences were evident in the pathways for emerging golfers and late developers. Region 2 had a full programme in place for golfers from eight years of age to adult men's level, but the programme in Region 1 effectively stopped once a player reached 18 years of age. By providing wider access to their coaching programme Region 2 thereby offered an alternative route for both emerging talent and late developing adult players. In spite of this, coaches in Region 2 had some concerns with the pathway to the national coaching programme. It was suggested by the participants that as soon as adult players finish or withdraw from regional coaching they fall into a 'black hole', whereby unless their performances were exceptional to merit a place on the national men's elite panel then the coaching and performance programme for these individuals ceased.

References

Fletcher, D., & Hanton, S. (2003). Sources of organizational stress in elite sports performers. *The Sport Psychologist*, 17(2), 175-195.

Gulbin, J., Croser, M.J., Morley, E., & Wissensteiner, J. (2013). An integrated framework for the optimisation of sport and athlete development: A practitioner approach. Journal of Sport Sciences, 31(12), 1319-1331.

Gaze Behaviour Analysis of High and Low Handicap Golfers during Putting

James Koch

Purpose

Gaze behaviour is an important factor in visuomotor performance and can indicate the level of skill (Vickers, 2007). Since it has not been done before, one purpose of this present paper was to examine gaze movements in the pre-preparation phase in putting in relation to skill level. Another aim was to relate these gaze movements to club head factors during putting. Additionally the effects of psychological elements of action orientation (i.e. the ability to regulate emotion and behaviour in order to fulfill intentional movements) and state orientation (i.e. the inability to regulate emotion and behaviour in certain situations) related to gaze behaviour during the putting action were explored.

Method

A group of 9 low handicap (LH) golfers (hcp 4.8 ± 2.3) and a group of 10 high handicap (HH) golfers (hcp 19.4 ± 3.1) were instructed to perform five shots with their own putter on an artificial green towards a hole 2.5 metres away. The golfers wore SMI eye-tracking glasses and the club head movements were registered by the Science & Motion Sports PuttLab system. The participants were also divided into groups with higher action orientation (n = 12) and higher state orientation (n = 7) according to the questionnaire HOSP by Beckmann et al. (2008). The Quiet Eye (QE) durations of these groups were compared.

Analysis/Results

The LH golfers putted significantly better than the HH golfers and displayed longer QE durations during the putting stroke. The results also show a significant difference of the fixation time on the club head in both the pre-preparation phase (LH golfers: 633 ms ± 175 ms versus HH golfers: 301 ms ± 192 ms) and the preparation phase (LH golfers: 1447 ms ± 960 ms versus HH golfers: 490 ms ± 399 ms). No significant differences of the QE duration and the deviation of the clubface at impact were noted. Nor was there any significant relationship detectable between the QE duration and psychological elements.

Conclusions

This study confirms the presence of the QE phenomenon first described by Vickers (1996). The significantly longer duration of the fixations on the club head in the pre-preparation phase and the preparation phase for the LH golfers suggests that this measure also plays an important role in high putting performance like the QE duration during the putting stroke itself. Therefore, the eye movements before setting up into the address position should also be taken into account in training.

Keywords: Eye-tracking, Quiet Eye, action orientation, state orientation

References

Beckmann, J., Elbe, A. (2008): Praxis der Sportpsychologie im Wettkampf- und Leistungssport, Spitta Verlag GmbH & Co. KG.

Vickers, J. N. (1996): Visual control when aiming at a far target. Journal of Experimental Psychology: Human Perception and Performance, 22: 342-354.

Vickers, J. N. (2007): Perception, Cognition and Decision Training. Champaign, IL: Human Kinetics.

Differences in Postural Control During Single-Leg Stance Between Young Golfers And Healthy Controls

Toshiyuki Kurihara, Youka Izumoto & Tadao Isaka

Purpose

Elderly golfers have better static balance control compared to the non-golfing healthy controls (Tsang and Hui-Chan, 2010). Since weight shifting from rear to front feet during golf swing requires a high level of balance control (Okuda et al., 2002), repeated golf practice is supposed to enhance the postural control (Gao et al., 2011). Previous studies suggested that the golf practice was a good maneuver for fall prevention of the elderly. It could be also applied to the younger subject groups. The purpose of this study was to investigate if differences exist in postural control between young golfers and non-golfers.

Method

Thirty collegiate golfers (male 16, female 14, 20.8 ± 1.4 years, body height 167.5 ± 6.8 cm, body weight 62.2 ± 8.5 kg, average golf score 78.3 ± 4.5 strokes) and twenty three healthy and active age-matched non-golfers (male 13, female 10, 21.9 ± 1.0 years, body height 166.7 ± 8.8 cm, body weight 62.0 ± 8.0 kg) were participated. Golfers regularly practiced (4.8 ± 1.8 /week) and at least 4 years of experience in golf practice (10.5 ± 3.0 years). Subjects completed 4 types of quiet standing tests: single-leg standing on the right (RO) or left limbs (LO) with eyes open, and bilateral standing with eyes open (2O) and eyes closed (2C) . Each trial lasted 30 seconds and the order of the trials were randomized. Subjects were asked to stand on a force plate with barefoot and placing their hands on the hips. Trials were discarded and repeated if a touchdown (the non-stance leg touching the ground) or hand release occurred during the trial. The ground reaction force data were sampling at 1000 Hz and filtered with a sixth order Butterworth, zero-phase low-pass filter at 10Hz. The sway velocities were calculated by absolute values of resultant velocity of COP over each first 15 sec and latter 15 sec, respectively. COP was measured in the anterior-posterior, medial-lateral, and resultant direction; however, only the results of the resultant direction are included. .Three-way analysis of variance (ANOVA) was performed on the mean sway velocity (subject groups x tasks x times). Tukey's post hoc tests were used for multiple comparison. The level of significance was set at $p < 0.05$.

Analysis/Results

No significant group differences were found for the COP velocity in four types of standing tests (Figure 1). The main effect of tasks was significant, and revealed significant differences between both leg situations (2O, 2C) and single-leg situations (RO, LO). No significant difference was found between 2O and 2C, and RO and LO. The significant decreases were found for the COP velocity between over first 15 sec and latter 15 sec on both limbs standing with eyes closed for non-golfers. For golfers, significant decreases of COP velocity between over first 15 sec and latter 15 sec were found in all the standing tests (Figure 1) .

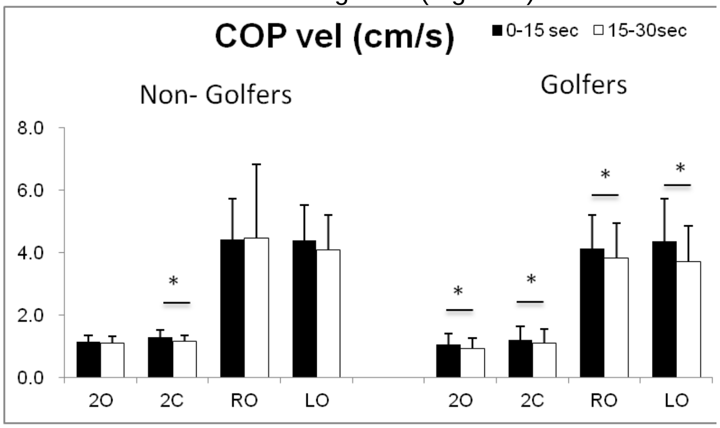

Figure.1 Comparison of COP velocity. No significant difference were found between golfers and non-golfers in any situation. *: p<0.05, significant differences between first 15 sec and latter 15 sec.
2O: standing on both limbs with eyes open. 2C: standing on both limbs with eyes closed. RO: standing on right leg with eyes open. LO: standing on left leg with eyes open.

Conclusions

Although the COP velocities of golfers were not significantly different compared to non-golfers in any standing tests, the golfers showed the significant decreases of COP velocity over latter 15 sec than first 15 sec in any situations. The previous study (Tsang and Hui-Chan, 2010) indicated a better balance control in golfers than non-golfers on elderly subjects (golfers 66.2 ± 6.8 years, control 71.3 ± 6.6 years). It is assumed that a well-executed golf swing requires to maintain good balance during weight shift (Okuda et al., 2002; Gao et al., 2011), but the results of this study indicated the effect of golf practice on postural control could be exemplified when the subjects have a weakness in muscle and/or deficits in gait or balance abilities. The non-golfers in this study were young healthy and active enough to control their balance in simple balance tasks. Their balancing ability might be challenging by other sports/activities in a similar way to golf. However, the golfers might have the better postural control during a prolonged static balancing situation, which is uncommon in a daily life.

Keywords: Golfers, Static balance, Center of pressure

References

1. Tsang WWN, Hui-Chan CWY, Static and dynamic balance control in older golfers. Journal of aging and physical activity, (2010) 18: 1-13.

2. Okuda I, Armstrong CW, Tsunezumi H, Yoshiike H, Biomechanical analysis of professional golfer's swing; Hidemichi Tanaka. (2002) In: Thain E (ed) Scine and golf IV. Routledge, London, pp 18-27.

3. Gao KL, Hui-chan CWY, Tsang WWN, Golfers have better balance control and confidence than healthy controls, Eur J Appl Physiol, (2011) 111: 2805-2812.

Golf Clubhead and Ball Tracking Using a 3D Optical Measurement System

Robert Leach, Steph Forrester & Jon Roberts

Purpose

Increasingly, with technology, coaches, golfers, club-fitters, equipment manufacturers and researchers use impact parameters as performance outcomes of golf shots. Launch monitors and motion analysis systems offer insight into impact mechanics and have begun to show its complexity (Ellis et al., 2010; Betzler et al., 2014). Application of the GOM optical measurement system (GOM mbH, Germany), which tracks points to an accuracy of microns (GOM, 2015), has potential to delve deeper. The study aimed to analyse the quality of the clubhead-ball tracking from GOM and demonstrate how parameters pre-impact are influenced by their definition.

Method

GOM set-up

Four Photron (Photron, San Diego, CA) high speed video cameras (5400 Hz; 1/50000 sec) captured each shot. The cameras operated as two pairs, one tracking the clubhead, the other the ball. The measurement volumes were calibrated which generated a local coordinate system (LCS) for each pair. A subsequent transformation aligned each camera pair with a common global coordinate system (GCS), defined by a bespoke rig consisting of two perpendicular arms (target and perpendicular), supported on adjustable feet. The 3D positions of randomly spaced markers that covered the rig were measured using GOM software (TRITOP) and used to create three best-fit orthogonal planes, intersecting at an origin subsequently forming the GCS.
A target line was defined using a vertical plane of laser light projected through the tee. The rig was positioned such that the target arm was aligned with the laser beam and legs adjusted so that the arms formed a horizontal plane. Images of the rig in this position were captured with each camera pair, following which it was removed. The TRITOP model of the rig was fitted to the markers in view of the cameras, which independently transformed the LCS of each pair to a GCS defined by the rig.

Data collection

A right-handed scratch golfer volunteered. Three clubs were used and ten shots hit with each. Markers were placed on each clubhead and the ball (Figure 1). They were scanned (GOM ATOS), creating a surface mesh along with marker positions.

Figure 1: GOM marker placement on the: a. driver; b. 7-Iron; c. utility wedge and d. ball

Club and ball analysis

Clubhead and ball data were processed separately in GOM software (Inspect Professional) and MATLAB (Mathworks, Natick, MA). For each trial, a best-fit sphere, radius 21.3 mm, was fitted to the surface markers on the ball. Furthermore, a virtual marker was created at the centre of gravity (COG) of each clubhead mesh. Each mesh was fitted to the tracked points using the points on the clubhead identified during the scanning process. The 3D coordinates of the virtual ball centre, tracked points and clubhead COG were exported to MATLAB. The parameters in Table 1 were calculated.

Data Quality

Three distances between markers on the driver clubhead and seven angles between lines joining these markers were measured separately using a SmartScope Flash 200 (OPG, Rochester, NY). The same measurements from GOM were compared. Additionally, frame-to-frame differences in the 3D coordinates of the virtual ball centre stationary on the tee were calculated. Finally, for each trial the average deviation distance of the clubhead surface mesh to each tracked point was identified.

Table 1: Definition of the clubhead parameters

Clubhead Velocity[1]	mph	Rate of change in position of a. the clubhead COG, b. the geometric centre of t clubface, and c./d. the furthest points at the toe and heel of the clubface at the vertical level of the geometric centre.
Attack Angle[2]	°	Angle between the curve fitted through the vertical target plane coordinates of t clubhead COG[1], therefore this represented attack angle projected onto the vert target plane. A negative angle meant a descending clubhead COG.
Club Direction[2]	°	Angle between the curve fitted through the horizontal coordinates of the clubhe COG[1], therefore this represented the club direction projected onto the horizonta plane. A positive value meant a club direction moving to the right of the target li an in-to-out path for a right handed golfer.
Face Angle[3]	°	Angle between the normal to the clubface at a. the impact location and b. the geometric centre and the target vertical plane.
Dynamic Loft[3]	°	Angle between the normal to the clubface at a. the impact location and b. the geometric centre and the horizontal plane.
Impact Location[3]		Projection of the position of the centre of the ball onto the clubface of the mesh providing a normal to the mesh

[1] Over 20 frames pre-impact [2] Immediately before impact [3] At first ball contact

Analysis/Results

GOM tracking

Table 2: Differences in measured distances and angles between GOM and the SmartScope Flash 200.

Measurement	Difference
Distance 1 (microns)	25 (12)
Distance 2 (microns)	141 (22)
Distance 3 (microns)	15 (10)
Angle 1 (°)	0.047 (0.034)
Angle 2 (°)	0.041 (0.031)
Angle 3 (°)	0.059 (0.039)
Angle 4 (°)	0.044 (0.033)
Angle 5 (°)	0.176 (0.094)
Angle 6 (°)	0.148 (0.112)
Angle 7 (°)	0.251 (0.054)

Average differences between SmartScope and GOM for each measured distance and angle are shown in Table 2. The overall means were 64 ± 62 microns and 0.11 ± 0.09º for the distances and angles respectively. The coordinates of the virtual ball centre showed differences less than 40 microns for all trials; with mean 12 ± 11 microns. Finally, the average deviation distance of the clubhead surface mesh to the tracked points for each trial was less than 100 microns.

Table 3: Mean (standard deviation) values across each parameter

Parameter		Driver	7-Iron	Wedge
Clubhead velocity (mph)	COG	108.0 (1.9)	88.8 (1.6)	78.1 (2.2)
Clubhead velocity (mph)	Toe	113.2 (1.9)	93.5 (1.7)	82.5 (2.0)
Clubhead velocity (mph)	Geometric centre	108.4 (1.8)	89.0 (1.6)	78.0 (2.0)
Clubhead velocity (mph)	Heel	103.6 (1.8)	85.7 (1.6)	74.6 (2.1)
Attack angle (°)		2.1 (2.0)	-6.1 (1.0)	-5.3 (1.9)
Club direction (°)		-0.7 (1.3)	-0.4 (0.6)	0.0 (0.8)
Face angle (°)	Impact Location	0.4 (2.7)	0.8 (1.1)	-2.4 (0.8)
Face angle (°)	Geometric Centre	2.5 (3.5)	0.8 (1.1)	-2.4 (0.8)
Dynamic loft (°)	Impact Location	16.2 (2.0)	24.4 (1.2)	40.3 (1.6)
Dynamic loft (°)	Geometric Centre	16.1 (2.8)	24.4 (1.2)	40.3 (1.6)

Impact parameters

Results by parameter are shown in Table 3. Average clubhead velocity ranges (toe minus heel) across each clubface were 9.6, 7.7 and 7.8 mph respectively for the driver, 7-Iron and wedge. Furthermore, the clubface curvature meant the driver face angle differed on average by 2.1º between the impact location and the geometric centre and the curved clubhead COG trajectory caused a rapid pre-impact attack angle and dynamic loft rate of change (Table 4).

Table 4. Rate of change of attack angle and club direction by club

Club	Attack angle (°/msec)	Club direction (°/msec)
Driver	3.3	2.6
Iron	1.8	1.1
Wedge	1.8	0.9

Conclusions

Data quality analysis suggested good tracking. When compared to the SmartScope the GOM distance and angle measurements showed small differences (64 ± 62 microns and 0.11 ± 0.09º respectively). Frame-to-frame virtual ball centre fluctuations, when stationary on the tee, were small (<40 microns). As were changes in distance between points on the clubhead and the average deviations in distance from the clubhead surface mesh to the tracked points (<50 and <100 microns respectively). Subsequently demonstrated was how parameter values depend on when and what point on the club head is tracked. The study has future applications for evaluation of commercial launch monitors.

Keywords: Impact mechanics, clubhead speed, driver, iron, wedge

References

Betzler, N. F., Monk, S. A., Wallace, E. S. & Otto, S. R. (2014). The relationships between driver clubhead presentation characteristics, ball launch conditions and golf shot outcomes. *Journal of Sports Engineering and Technology*. 228(4). 242-249.

Ellis, K.L., Roberts, J.R. & Sanghera, J. (2010). Development of a method for monitoring clubhead path and orientation through impact. *Procedia Engineering,* 2(2), 2955–2960.

GOM. (2015). Available From: <http://www.gom.com/metrology-systems/3d-motion-analysis.html>. [14 January 2016].

A Case Series: The Body Swing Connection: Physical functional movement vs. Injuries and Kinematic Factors in Competitive Golfers

Xin Yi, Liew & Brady Tripp

Purpose

Overuse injuries due to the repetition and torque of the golf swing can lead to a decline in performance and injuries that result in time away from the game (McCarroll, Rettig & Shelbourne, 2000 & McHardy, Pollard & Luo, 2006). As golfers start to play at elite levels during youth, it is important to identify the relationship between physical abilities, injuries and kinematic factors. With evaluation of a functional movement screen, video and 3D kinematic analysis of the swing, the aim of this study was intended to identify the relationships between these three factors in competitive golfers.

Method

A total of 14 golfers (18-22 years old) were recruited for the study; eight females and six males. Seven females (Handicap: mean=+1; range=+4 to 0) were NCAA Division I Collegiate golfers (Elite Group); 1 female and 6 males (Handicap: mean=5.4; range=0-10) were from the University Club Golf Team

(Amateur Group). The golfers completed a health history questionnaire and were assessed with the Titleist Performance Institute (TPI) functional movement screen designed for golf by TPI Medical certified athletic trainers to identify physical limitations in mobility and stability related to the golf swing (Rose, 2013). An orthopedic assessment was performed by a certified athletic trainer (ATC) on any existing or previous injuries reported to eliminate participants who were unfit for the study. The video of golf swing was collected using the PerformPro golf simulator (aboutGolf Inc, Maumee, OH), capturing video from frontal (face-on) and sagittal (down the line) views, and was analyzed according to the TPI Big 12 Swing faults. The researchers also collected 3D kinematic data using the MotionMonitor (Innovative Sports Training Inc, Chicago, IL) with sensors on the jugular notch, L4 spinous process, deltoid tuberosity, mid-forearm and hand. The sensors were “flock of birds” from Ascension technology (Ascension Technology Corp, Shelburne, VT) and were attached on the body landmarks by securing with straps and connected to the monitor via wires. Thirty-one anatomical landmarks on body and five points on each golf club were digitized to create 3D model of the subject and the golf club for tracking at the rate of 144 times per second. All the captures were performed in the lab with PerformPro golf simulator. The participants took as many practice swings as needed prior to the data collection using their own clubs. Ten iron shots (7-iron) and 10 drives were recorded.

Analysis/Results

Both groups were similar in age (average=20.2±1.4), however only the Elite group participates in structured physical conditioning in addition to golf training. Regarding injury history, the Elite group reported chronic wrist (n=4) and shoulder (n=2) injuries. The Amateur group had more thoracic (n=3) and low back (n=5) injuries from acute events during golf. The TPI Functional Movement screen results showed similarity within the Elite group. The Elite group (7/7) demonstrated limitations in lower body stability but good mobility (6/7 had good flexibility and rotation range). The Amateur group demonstrated limitations in both stability and mobility, especially in the lower body including poor core control (7/7); limited in pelvic rotation (5/7) and an inability to toe touch bilaterally (2/7). Regarding video swing analysis, the Elite group demonstrated a common swing fault with 5/7 sliding towards target into downswing. The Amateur group displayed more swing faults and inconsistencies; 7/7 demonstrated sway and slide, 3/7 over-the-top, 2/7 casting and hanging-back through impact. Evaluating 3D kinematic factors, no participant (0/14) demonstrated an ideal kinematic sequence in the downswing (Tinmark, Hellstrom, Halvorsen & Thorstensson, 2010). The most common fault was observed where the velocities of thorax and lead arm peaked out of order when compared to the pelvis- thorax- lead arm-club kinematic sequence (Tinmark, Hellstrom, Halvorsen & Thorstensson, 2010). Observing the peak velocity values, both groups had similar kinematic data values that agree with previous literature for peak velocities of kinematic sequence (Callaway, Glaws, Mitchell, Scerbo, Voight & Sells, 2012).

Conclusion

The Elite group demonstrated good mobility and coordination scores with the TPI Functional movement screen but could improve in hip and core stability. The Amateur group demonstrated more inconsistencies, including limitations in both mobility and stability according to the TPI physical screen results, primarily noted in lower extremity rotation and balance. Overall, the Amateur group displayed more swing faults in the lower body and posture due to compensations from a lack of mobility and core stability. Some relationships between physical functional ability and swing faults were observed in this study, with the most common combination of 1) a lack of lower body stability and core stability identified with sliding during downswing and inefficiency in transferring energy from the thorax to arms during the downswing, 2) lack of pelvic rotation, core stability and balance identified with sway and slide, and 3) reverse spine angle and over-the-top. This case series could be a pilot study for future research in investigating the relationship between physical limitations, swing analysis, kinematic factors and performance among youth amateur golfers and identifying of subsets of functional movement screens for this population. Future studies could also identify the long-term effects of corrective exercises based on physical limitation and swing analysis on performance and injury prevention.

Keywords: Physical screen, functional movement, golf injury, kinematic sequence, golf biomechanics

References

Callaway S., Glaws K., Mitchell M., Scerbo H., Voight M. & Sells P. (2012) An analysis of peak pelvis rotation speed, gluteus maximum and medius strength in high versus low handicap golfers during the golf swing. International Journal of Sports Physical Therapy. 7(3): 288-295. Retrieved from PubMed Database.

McCarroll J.R., Rettig A.C. & Shelbourne K.D. (1990) Injuries in the amateur golfer. Phs Sports Med. 18: 122-126. Retrieved from PubMed Database.

McHardy A., Pollard H. & Luo K. (2006) Golf injuries: a review of the literature. Sports Med.. 36:171-187.

Retrieved from PubMed Database.

Rose G. (2013, May 28) Titleist Performance Institute (TPI) Screening Tool. TPI.com. Retrieved from http://www.mytpi.com/articles/screening.

Tinmark F. , Hellstrom J. , Halvorsen K. & Thorstensson A. (2010) Elite golfers' kinematic sequence in full-swing and partial-swing shots. Sports Biomechanics.. 9(4): 236-244. Retrieved from PubMed Database.

Lumbar and Thoracic Range of Motion in Skilled Golfers With and Without Low Back Pain

Scott Lynn, Scott Carver, Guillermo Noffal, Lee Brown & John Garner

Purpose

The lower back is a common site of golf-related injury [1]. This may be partially due to the required rotation of the trunk during the swing, as axial twisting has been shown to increase the risk of lower back pathology [2]. It has been suggested that the separation between the shoulders and hips (or X-factor) is important in creating a powerful golf swing [3]; however, the contribution of the lumbar and thoracic spines in producing the X-factor may determine a golfer's injury risk. Therefore, this study will investigate lumbar and thoracic spine range of motion (ROM) during the golf swing in those with golf related low back pain and those without pain.

Method

Participants were 21 male golfers with a handicap <10. Initially, all participants completed a pain questionnaire indicating how much back pain they typically experience at the end of a round of golf [4] and were then split into a No Pain group (NP, n=10, age=34.2±12.2 years, height=1.8±0.07 m, mass=79.5±14.6 kg, handicap=4.2±4.0) who reported no pain and a Low-Back Pain group (LBP, n=11, age=37.1±12.7 years, height=1.8±0.05 m, mass=86.2±16.3 kg, handicap=6.4±3.2) who reported clinically relevant levels of low back pain by marking more than 20 mm of pain on the 100 mm McGill visual analog pain scale [4]. Before testing, all participants had individual motion tracking markers placed on the skin at the spinous process of C7 & T12, right and left transverse processes of T1 & L1, bottom of the sternum just above the xyphoid process, top of the sternum on the manubrium. There was also a plate containing 4 markers strapped to the sacrum using a tensor bandage. A 9-camera Oqus 300 motion capture system (Qualisys, Gothenburg, Sweden) was used to record the motion of the retro-reflective markers at 240 Hz. Following their own normal warm up, participants were asked to hit balls with their own driver into a net for 5 trials with one minute rest between trials. Lumbar spine motion was then calculated in Visual 3D software (C-Motion Inc., Rockville, MD, USA) as the relative angle between the coordinate system created at the sacrum and the T12-L1-xyphoid markers, while thoracic spine motion was calculated the same way using T12-L1-xyphoid and then C7-T1-Manubrium markers. Only transverse plane angles were examined and the lumbar and thoracic ROMs during the swing were calculated for each swing and averaged together across the five trials for each subject. Dependent variables were the percentage of the total spinal rotation ROM coming from the lumbar spine (%LSROM) and the thoracic spine (%TSROM). T-tests were used to determine differences within and between groups.

Analysis/Results

In the NP group, 8/10 participants had the thoracic spine contributing a greater percentage to the total ROM as compared to the lumbar spine. In the LBP group, 7/11 participants had the lumbar spine contributing a greater percentage to the total ROM as compared to the thoracic spine. The NP group also had a greater percentage of their total ROM coming from their thoracic spine (%LSROM = 45.3±7.3%, %TSROM = 54.7±7.3%, $p<0.05$), while there was no difference in the LBP group (%LSROM = 47.0±11.3%, %TSROM = 53.0±11.3%, $p>0.05$).

Conclusions

The NP group, who can play golf pain free, produced the majority of their golf swing spinal rotational ROM from the thoracic spine. Rotating more through the thoracic spine and less through the lumbar spine during the golf swing may provide protection from injury as rotation in the lumbar spine has been shown to increase the propensity for disc herniation [2]. Future research should investigate swing strategies and exercise programs to determine if these ROMs can be altered in the golf swing. There was greater variability (larger standard deviations) in the LBP group and this may have been because we did not control for specific pathologies. Also, the cross sectional design of this study could not determine if some participants had adapted their golf swings over time to compensate for their pain. The sternal marker trajectories also had gaps in some participants due to the markers being blocked as the arm passed in front of them during the swing. Future research should attempt to use IMU technology to quantify these ROMs and avoid these methodological issues.

Keywords: *Biomechanics, Kinematics, Motion Capture, Injury prevention*

References

1. McHardy, et al. Golf injuries: a review of the literature. *Sports Med* 36: 171-87, 2006.

2. Marshall & McGill. The role of axial torque in disc herniation. *Clin Biomech 25*: 6-9, 2010.

3. Meister et al. Rotational biomechanics of the elite golf swing: Benchmark for Amateurs. *J Applied Biomech* 27: 242-251, 2011.

4. Melzack, R. The short-form McGill pain questionnaire. *Pain* 30: 191-197, 1987.

Impact of a Pressure Mat Intervention for Increasing Performance in Novice Golfers: A Pilot study

Dany MacDonald & Rachel Kays

Purpose

A person's balance has been suggested as a key component to a successful golf swing (Choi, Sim, & Mun, 2015). This assumption suggests that proper balance may result in better contact and increased performance. Recently, pressure mats which assess a player's weight distribution throughout the swing have been developed, however there has been a scarcity of research to investigate their effectiveness as a teaching tool. Therefore, the purpose of this pilot study was to investigate the effectiveness of a golf pressure mat as a teaching tool compared to a control group and individuals receiving instruction from a certified professional. The hypothesis was that compared to the control group, the pressure mat group would result in greater proficiency and produce results of similar magnitude to individuals obtaining instructions from a professional.

Method

Thirty novice golfers (20 males, 10 females) with an average age of 36.8 years (range: 19 – 68 years; SD = 14.7) participated in the study. For this study, novice was defined as playing less than two rounds per week. Individuals were also asked their handicap, however only five of the 30 participants reported a handicap (mean handicap = 13.8). Upon registering, participants were randomly assigned to one of the following conditions: control group, instruction group, or pressure mat group.

Following randomization, participants attended data collection sessions on four consecutive weeks at an indoor golf simulator. The collected data included: total distance, total distance carried, and dispersion (all in yards). At baseline (week 1), participants were asked to hit 40 shots. Ten shots were hit with each of the following clubs: 9 iron, 5 iron, 3 wood, and driver.

During the second, third, and fourth weeks of data collection, participants engaged in different activities based on the condition they were assigned. Participants in the control group were provided access to the simulator and given no more than 30 minutes to practice. No instruction or feedback was provided. Following this, participants completed the data collection process of hitting 40 shots as described above. Participants in the golf professional instruction group received a 30-minute lesson with an instructor. The instructor worked with the participants swing using traditional golf instruction methods. Following the session, participants hit the 40 shots described above. A similar process was used with participants in the pressure mat group. Rather than receiving a lesson from a professional, a pressure mat was used to teach optimal weight distribution and balance throughout the golf swing at key positions: address, transition, and impact. Suggested weight distribution for each position was described and served as the basis for each 30-minute session. Following the session, participants hit the 40 shots described above.

Analysis/Results

To assess differences between the groups, 3 x 4 (group by time) repeated measures ANOVAs were conducted on each of the clubs used. The dependent variable was termed 'shot value' and represented by total distance minus dispersion. To account for individual performance, shot value scores were normalized against the baseline values for each person. This created values that represent a person's change in performance over time. ANOVA analyses yielded non-significant results between groups ($p > .05$), but trends suggested that while the control group did not improve, individuals in the pressure mat and instruction groups increased of similar magnitudes (see Figure 1 for example). The analyses also revealed that effect sizes (partial eta squared) were very small throughout the study (E.S.: range: .04 - .16), along with the overall power of the analysis (power = 0.053).

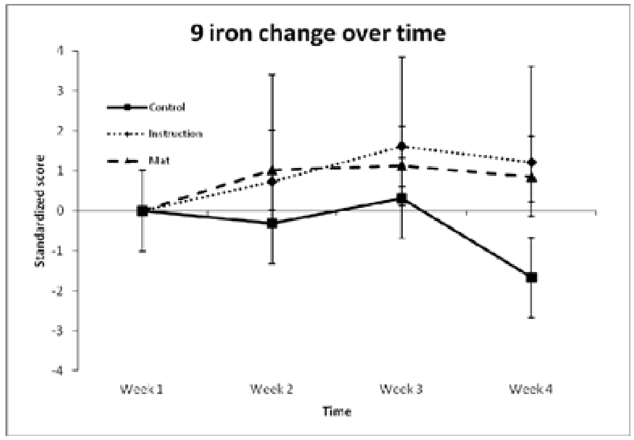

Figure 1. Average change scores over time by group for 9 iron.

Conclusions

The purpose of this pilot study was to investigate the effectiveness of a golf pressure mat as a teaching tool compared to a control group and a group of individuals receiving instruction from a certified professional. Although the results were non-significant, trends in the data suggest that the pressure mat and professional instruction conditions resulted in similar increases in performance compared to controls. The small effect sizes and small sample size were a limitation to the present study but current findings suggest that a larger study further investigating the use of pressure mats as a viable form of golf instruction is warranted. Follow-up studies should consider asking participants about any preconceived notions they have about pressure mat training as this may affect their willingness to implement changes into their golf swing. Implications of current findings will be discussed in light of what optimal pressure distribution during the golf swing should be along with pressure mats as a useful instrument to teaching golf.

References

Choi, A., Sim, T., & Mun, J.H. (2015). Improved determination of dynamic balance using the centre of mass and centre of pressure inclination variables in a complete golf swing cycle. Journal of Sports Sciences, 12, 1-9.

A Performance Comparison of Swing Weight Matched and Moment of Inertia Matched Golf Irons

Sasho MacKenzie, Keirsten Wilson, Daniel Boucher

Purpose

Individual golf irons have specific lengths and lofts to enable the golfer to hit the ball specific distances with the same swing. Iron's are 'matched' within a set by adjusting the mass of each club to account for differences in length, so that they all 'feel' the same to the golfer during the swing. Longer clubs are lighter. There are two currently existing methods for matching clubs within a set. The traditional swing weight (SW) method matches clubs based on static properties, while a more sophisticated approach gives each club the same moment of inertia (MOI) about an axis through the end of the grip (Cross & Nathan, 2009). Research has often theorized that MOI matching is superior (Budney & Bellow, 1982), but the impact of each matching method on performance has never been studied. This study conducted a performance comparison of SW matched and MOI matched golf irons.

Method

The impact of two iron matching methods on golf performance was compared using a balanced crossover study design. Participants (N=29) attended a familiarization day to determine personalized target distances for each of 3 clubs (pitching wedge, 7-iron, 4-iron). Each participant attended two testing sessions (SW and MOI). Each testing session consisted of 6 warm up shots and 36 test shots, taken 2 at a time in a randomly assigned club order. A FlightScope Doppler radar launch monitor was used to collect club data at impact and predict ball flight trajectories indoors. Participants' personal targets and ball flight paths were projected on a screen 10 m in front of them, providing feedback in real time. Three-way ANOVAs (set, club, swing) were used for each dependent variable (e.g., radial error) to test for statistical significance.

Analysis/Results

Three-way ANOVAs were done for each dependent variable, comparing Set (SW, MOI), Club (PW, 7-iron, 4-iron), and Swing (1st, 2nd). Radial error (RE) was considered the best indicator of overall golf performance, but total distance (TD), and clubhead speed (CHS) were also compared. ANOVAs for RE, TD, and CHS all showed no significant difference between the SW and MOI matched sets. The Set x Subject interaction for RE showed an overall significant difference between the two sets, $F(28,145)=2.0$, $p=.004$. An analyses of each golfer's RE data revealed that 14 golfers played better with the MOI set and 15 golfers played better with the SW set; however, single subject statistical analyses of RE showed a statistically significant difference in performance for only 3 of the 29 participants. We found no significant difference between a participant's first and second swing for a given club with either set. There was a main effect for Club, as was expected, due to the difficulty of hitting a shot with more distance.

Conclusions

There was no significant difference between the two existing methods of matching. Therefore, the older SW method of club matching may be as effective as the more complex MOI method. Any advantage of the MOI matched set may have been negated because virtually all golfers normally play with SW matched clubs. Our participants may have been more accustomed to SW matched clubs, and have tailored their swing to SW matched clubs over years of playing golf.

Keywords: Iron Matching, Swing Weight, Moment of Inertia

References

Budney, D. R., & Bellow, D. G. (1982). On the swing mechanics of a matched set of golf clubs. *Research Quarterly for Exercise and Sport*, 53(3), 185-192.

Cross, R., & Nathan, A. M. (2009). Performance versus moment of inertia of sporting implements. Sports Technology, 2, 7-15.

Is Golf a One-Sided Sport? Bilateral Demands of the Hip Joint During the Golf Swing

Nicole Marcione, Andrea Du Bois & George Salem

Purpose

The golf swing is a very complex movement, requiring powerful hip muscle control. Golf is a sport that, along with baseball and tennis, has been commonly viewed as a "unilateral" activity, with side-to-side differences in physical demands (McClanahan, et al., 2002). Golfers have been encouraged to incorporate bilateral training into their regimen. Our lab has discovered that hip joint kinetics are not as "one-sided" as once hypothesized. Past studies have investigated hip moments, rotational velocities, and hip range of motion in golfers (Gulgin & Armstrong, 2008; Gulgin, Armstrong, & Gribble, 2009). Limited research exists comparing the kinetic hip demands of golfer's lead and trail limbs during the golf swing (Foxworth, et al., 2013). This study compares peak power generation and mechanical energy expenditure of the hip joint, across multiple planes of both the lead and the trail limbs.

Method

Seven healthy, young male recreational golfers were recruited; 6 were right-handed (Age: 25.14±2.91, Height: 183.63±4.01cm, Mass: 78.62±7.42kg; Golf experience: 9.93±4.59yrs). On average, the golfers played 44 times per year. Lower extremity kinematics were measured using a marker set with a 10-camera Qualysis (Göteborg, SE) 3D motion capture system. Ground reaction forces (GRF) were measured with 2 AMTI force platforms (Newton, MA). DuraPro™Tuff- Turf™ was cut to the size of each force platform and secured to simulate a more realistic golf surface. Participants completed 5 golf swings with a 7 iron. The middle 3 golf swings were used for the analysis. Kinematics were collected at 250 Hz. GRFs were collected at 1500 Hz. Kinematics and kinetics were filtered using a 4th order Butterworth low-pass filter with a 12 Hz cutoff. Visual 3D (C-Motion Inc., Rockville, MD, USA) was used to calculate peak power generation (PPG) and a custom MatLab code calculated mechanical energy expenditure (MEE) for the hip joint in the lead and trail limbs during the swing, across all 3 planes.

PPG (the product of the hip net joint moment and angular velocity) and MEE (the integral of the absolute value of the power curves or total work) were calculated. Means and standard deviation (SD) were calculated across the 3 swings. Paired t-tests were used to assess differences between lead and trail limbs. A significance level of $p \leq 0.05$ was used. Cohen's d was calculated with G*Power to measure effect size. All statistics were calculated using PAWS Statistical Analysis software version 18 (SPSS, Inc., Chicago, IL).

Analysis/Results

Paired t-tests demonstrated no significant mean differences ($p>0.05$) between lead and trail limb PPG in the sagittal (Δ=0.76±2.63 W/kg), frontal (Δ=-0.10±0.57 W/kg), or transverse planes (Δ=- 0.36±0.79W/kg). Paired t-tests also demonstrated no significant mean differences ($p>0.05$) between lead and trail limb MEE in the sagittal (Δ=0.02±0.29 J/kg), frontal (Δ=-0.3±0.0.21J/kg), or transverse planes (Δ=-0.01±0.23 J/kg). All of the effect sizes were small <0.3, except for PPG in the transverse plane (0.43). Individual data analysis revealed that the majority of participants had >15% differences in all 3 planes (sagittal: 6/7, frontal: 5/7, transverse: 6/7) of PPG between limbs and the majority of participants had >15% differences in MEE (sagittal: 4/7, frontal: 5/7, transverse: 7/7) (Gouwanda, & Arosha-Senanayake, 2011; Rumpf, et al., 2014; Sadeghi, Allard, Prince, & Labelle, (2000).

Conclusions

These results demonstrate that, in this group, kinetic hip demands of lead and trail limbs during the golf swing are more symmetrical than previously thought. However, when analyzing individual data, the outcomes are very different than the group mean data. This highlights the importance of examining both group mean data, along with individual data, when analyzing golf symmetries.

These results also emphasize the need to understand bilateral limb demands in order to properly inform instructors and therapists when prescribing progressive golf activities for seniors and others that may be learning the game of golf or recovering from injury or surgery (e.g. hip or knee replacement). Thus, we plan to replicate these studies in older adults to evaluate if these conclusions continue to hold true.

Keywords: Golf, asymmetries, hip biomechanics

References

Foxworth, J. L., Millar, A. L., Long, B. L., Way, M., Vellucci, M. W., & Vogler, J. D. (2013). Hip joint torques during the golf swing of young and senior healthy males. *The Journal of Orthopaedic and Sports Physical Therapy, 43*(9), 660.

Gouwanda, D., & Arosha Senanayake, S. M. N. (2011). Identifying gait asymmetry using gyroscopes—A cross-correlation and normalized symmetry index approach. *Journal of Biomechanics, 44*(5), 972-978.

Gulgin, H. R., & Armstrong, C. W. (2008). Passive hip rotation range of motion in LPGA golfers. *Clinical Kinesiology: Journal of the American Kinesiotherapy Association, 62*(2), 9.

Gulgin, H., Armstrong, C., & Gribble, P. (2009). Hip rotational velocities during the full golf swing. *Journal of Sports Science & Medicine, 8*(2), 296-299.

Rumpf, M. C., Cronin, J. B., Mohamad, I. N., Mohamad, S., Oliver, J. L., & Hughes, M. G. (2014). Kinetic asymmetries during running in male youth. *Physical Therapy in Sport, 15*(1), 53-7.

Sadeghi, H., Allard, P., Prince, F., & Labelle, H. (2000). Symmetry and limb dominance in able- bodied gait: A review. *Gait & Posture, 12*(1), 34-45. doi:10.1016/S0966-6362(00)00070-9

Putting “Yips” and Jerking in Golf Novices

Christian Marquardt, Martin Strauss, Silvia Jakobi & Joachim Hermsdörfer

Purpose

Typically Yips is assigned to the occurrence of involuntary movement jerks, spasms or freezing while putting. Between 20% and 30% of golfers seem to be affected by Yips (Smith et al., 2003, Klämpfl et al., 2013). Yips has been described as an organic problem (dystonia), a psychological problem (choking), or a continuum between both (Smith et al. 2003). The co-contractions found in Yips resemble to task-specific dystonia (Adler et al. 2005). Marquardt (2009) suggested that Yips is the consequence of exaggerated self-perception and conscious control. This paper also points out, that the putting data collected with SAM PuttLab shows Yips symptoms also in beginners and high handicap golfers. It is speculated that these novices might bring in the movement problem from other racket sports such as tennis. In the two studies we present here we now investigated Yips symptoms in explicit golf novices who never played golf before, and in golf novices who regularly play tournament tennis.

Method

The data was collected in an indoor putting studio at the Technical University of Munich. The putts were registered and analyzed with the SAM PuttLab technology. The participants were not informed about the scope of the study. In both studies the test conditions varied in a random order. For each condition 7 putts had to be played to an artificial hole.

In the first study 31 (20 m, 11 f, average age 23 years) sports students (8.3h sports exercise per week) with no golf experience participated. The 9 test conditions were playing a 1m putt, a 3m putt, and putting without a ball, each with both hands, with the right hand only and with the left hand only.

In the second study two age and gender matched groups of right handed participants with no golf experience participated. The participants were recruited so that half of them (n=15, 8 m, 7 f) were playing tournament tennis (average 3.2 h/week, history of playing tennis 20.4 years) and half of them (n=15, 7 m, 8 f) were explicitly not playing any racket sports, but doing other sports. The 6 test conditions were playing 3m putts to the left (conventional) and to the right (using a left-hand putter), each with both hands, left hand only, or right hand only.

Analysis/Results

The results from the first study showed that in golf novices jerking similar to Yips symptoms occur. Seven of 31 participants (22.6%) could be identified who showed severe jerking indicated by an extremely high variability in the rotation rate at impact (average SD=30.6 deg/s), in particular if putting with the right hand only. This parameter has been found to be the most sensitive putting parameter to identify Yips in amateur golfers (average SD=22.6 deg/s; Marquardt, 2009). To more precisely quantify Yips and jerking a new parameter is proposed. A jerk corresponds to large oscillations of the acceleration signal. The Yips parameter AROT measures the range of rotational acceleration of the putter in a time window of +- 100 ms around impact. Using this parameter for putts with the right hand only it was possible to identify two sub-groups and to separate the 7 participants with jerking (AROT > 5000 deg/s²) from non-jerking participants (AROT < 2500 deg/s²). Comparing these two groups we found significant main effects for variability of Face Direction at Impact ($F(1.27)=16.3$, $p<0.001$), for variability of Total Rotation ($F(1.27)=12.7$, $p<0.01$) and for variability of Rotation Rate at Impact ($F(1.27)=185.6$, $p<0.001$).

In the second study significant differences were found between the tennis and the non-tennis group in many rotation parameters. The Yips parameter AROT was significantly higher for the tennis group, but only if playing a right forehand (3932 deg/s²). In all other conditions AROT was in the same range as for the non-tennis group (<1500 deg/s²). Variance analysis showed a significant interaction for AROT between group and test condition ($F(1.47,41.5)=3.85$, $p < 0.05$). Looking at individual performance AROT classified four of 15 subjects (26%) in the tennis group as Yippers (AROT > 7500 deg/², threshold=4000), but none of the subjects in the non-tennis group.

Conclusions

Both studies found jerking in golf novices very similar to Yips in golfers. The incidence of affected subjects (22.6% respectively 26.6% in the tennis group) matches to the numbers discussed for golfers. Evidence for transfer effects from other racket sports is supported by the fact that only the tennis players were affected by jerking. Our conclusions is that at least in golf novices, jerking is a general behavioral movement control problem connected to the accuracy demanded by the task, in this case putting. Additionally, the task dependency in the novices is surprisingly similar to golfers: Only putts to the left are affected, in particular if played with the right hand only, but not in any other condition. It is not plausible that novices suffer from dystonia or are affected by performance anxiety only in one putting condition but not in others. The astonishing similarity of the symptomatology suggest that Yips in golfers and jerking in golf novices might be based on the same mechanisms. In fact many golfers also overcome Yips problems by taking the right hand out of the game (claw grip) or by using a left-hand putter and putting to the right side. The right forehand might be mostly affected by jerking because it is the dominant hand and the palm is providing extensive sensory input which then can trigger inadequate motor strategies to control impact. Data collected from left-handed Yippers might help to better understand this directional dependency. For future studies the Yips parameter AROT is proposed as an objective measure to differentiate between Yips affected and normal putting. For golf novices putting with the left hand only the threshold was set to 4000 deg/s² , which is 2SD away from the average of non-affected putting.

Keywords: Yips, putting, movement analysis, dystonia, choking

References

Adler, C.H., Crews, D., Hentz, J.G., Smith, A.M., Caviness J.N. (2005). Abnormal co-contraction in yips-affected but not unaffected golfers: evidence for focal dystonia. Neurology, 64: 1813-1814.

Klämpfl, M. K., Lobinger, B. H., & Raab, M. (2013). How to detect the yips in golf. Human Movement Science, 32(6), 1270-1287.

Marquardt, C. (2009). The vicious circle involved in the development of the yips. International Journal of Sports Science and Coaching, 4 (Supplement 1), 67-88.

Smith, A.M., Adler C.H., Crews, D., et al. (2003). The “yips” in golf: a continuum between focal dystonia and chocking. Sports Medicine, 33: 13-31.

Developing Tactical Awareness and Strategic Thinking in Golf

Peter Mattsson & Paul Schempp

Purpose

A sport instruction model, Teaching Games for Understanding (TGFU) (Bunker & Thorpe, 1982), has been shown in previous research to improve participants tactical awareness and game play qualities (Butler, 2006). This study was designed to determine if a group of elite golfers became more aware of tactical conditions and less focused on skill execution during competitive play after a TGFU training program.

Method

Participants. 12 players, 6 men and 6 women, on the Swedish National Team (age 19-23 years, scoring avg. 70.58-77.2) participated in a specially designed training program over four days. The program was based on the progressive TGFU model. The program emphasized game appreciation, tactics, decision-making and individual skills using drills, and partner and small group activities. The program was conducted in practice areas and on a golf course.

Data Collection.

Think-aloud technique was used where the subjects wore a cordless microphone connected to an audio recorder. The participants were instructed to “think aloud” (i.e. to speak out loud) everything they thought in the shot preparation and execution phases of a golf shot. To make the players accustomed with the technique, there was a ‘rehearsal’ in putting where each player hit several shots and received feedback on the process. Pre- and posttests required the players to hit one shot from 170 yards (150 yards for women), with the goal to get closest to the bottom of the cup. In order to increase the pressure in the situation there was a public posting of the scores, giving the ranking 1-12 of the player’s results. There was also a reward for the player hitting the closest to the pin and a penalty for everyone missing the green. The audio recordings were later transcribed and analyzed.

“Characteristics of an elite golfer” was a checklist to determine where players ranked the important characteristics of an expert golfer. The players completed this checklist pre- and post training in order to establish if the players’ view on the characteristics on an expert golfer had changed as a result of the programme. The selected characteristics were ranked by the players from most to least important.

Program Evaluation required the players were to assess their preferences and responses to the TGFU activities.

Analysis/Results

Findings reveal a change in the players’ pre-shot thinking process that reflected greater tactical awareness. The players’ awareness of the concepts in the condition category increased slightly (48-52) together with the awareness of the goal concepts (21-28). The biggest changes were shown in the number of players deciding on what type of shot to hit (7-10) and where to place the shot (4-7). The awareness of action concepts decreased from 29 to 20. The order in what the players ranked the characteristics of an expert golfer did not change, although there was an increased emphasis on the importance of sound decision making with the preprogram rank averaging at 1.58 (SD 0.9) and post-program at 1.33 (SD 0.49) leaving an effect size of -0.51. Analysis of the think aloud protocol showed the players pre-shot decision making increased in strategic thinking. One player reported "I learned to think more about how to hit a shot (and) increase focus." Another player said they learned to "plan where to hit the shot, to land it and with which trajectory." Most of the players cited increased use of strategy in pre-shot routines including to identify new solutions, picture and visualize the shot, and different ways of hitting shots. Due to the small number of subject no further stats were conducted.

Conclusions

Based on the findings, it is likely that practice based on this model will increase both players' declarative and procedural knowledge in the game of golf. Players showing an increased awareness of the type of shot to hit and where to place the shot in the post-test may explain the increased emphasis on the sound decision making characteristic of an elite golfer. Whether this could further lead to an improved performance will however require more research although Cohn (1991) early showed that peak performance among other things was characterized by the golfers being highly focused and immersed in the task at hand.

*Keywords***:** *Golf, Teaching games for understanding, tactical awareness, practice*

References

Bunker, D. & Thorpe, R. (1982). A model for the teaching of games in secondary schools. *Bulletin of Physical Education, 18 (1)*, 5-8

Cohn, P. J. (1991). An exploratory study on peak performance in golf. *Sport Psychologist, 5 (1), 1-14.*

Butler, J. I. (2006). Curriculum constructions of ability: enhancing learning through Teaching Games for Understanding (TGfU) as a curriculum model. *Sport, Education and Society*, *11(3), 243-258.*

To Evaluate the Relative Influence of Coefficient of Friction on a Putted golf ball

Rory Mckenzie, Liam Eley, Iwan Griffiths & Paul Hurrion

Purpose

Numerous studies (Epperson & Gadsden, 1993; Flom & Beuche, 1959; Hubbard & Alaways, 1999) outline the principles of static and kinetic friction and how these have an effect on golf putting, however no research has looked at the effect the surface has on the rolling characteristics of a golf ball. It has been suggested (Weber, 1997) that stimpmeter readings can be used to measure the amount of friction that is present on the golf green. In critique of this method the stimpmeter only assesses the amount of rolling friction that is present on the green and does not take into account the initial skid phase that occurs at the start of the putt. Green reading has consistently been found to be the biggest contributor to overall putting performance (Epperson & Gadsden, 1993; Karlsen et al. 2008; Laws, 1990), however there are very few practical implications that golfers can use to enhance this area. This study aims to determine the coefficient of kinetic friction of varying types of surface, before analysing the effect that they each have on the ball roll characteristics of a putted golf ball (i.e. distance taken for the ball to reach true roll).

Method

Two different methods of collecting putting data were used during this study; a putting robot and a human subject (handicap = 8). This was done to allow for a comparison between how consistent a human was in relation to a robot. An Odyssey (Callaway Golf Europe Ltd., Surrey, UK) White Hot #3 putter (putter length - 34"), with a 69º lie and 2.5º loft, was used for both methods. Five different Titleist Pro V1 golf balls were used during the study. These golf balls had a spherically-tiled 352 tetrahedral dimple design. All golf balls had three small black dots embedded on the side of the ball to allow the camera to identify and track the ball during experimental trials (see figure 1). For each surface thirty valid putts were tracked for the first 40cm of their travel, namely; a putting mat, rubber, melamine faced chipboard (MFC) and compact carpet, via a high speed camera (360 frames per second). In order for a putt to be selected for analysis it had to meet the 'Quintic recommendations' for a 'valid putt' (see table 1). A numerical simulation was used to determine the mean coefficient of kinetic friction from each of the four surfaces. The simulation process used numerical integration of the equations of motion, solving for both the angular and linear speeds of the ball using guessed values for the coefficients of friction. The distance required to achieve true roll was obtained from the simulation. This was compared to the actual distance that true roll occurred for the putt that was being analysed, which was obtained from the experiment. If there was agreement to two decimal places, the coefficient of friction was recorded otherwise the coefficient was adjusted and the simulation run again.

Results

The highest coefficient of kinetic friction for the robot method was obtained using the rubber surface ($\bar{\mu}$ = .29, σ = .01), whilst the lowest was MFC ($\bar{\mu}$ = .11, σ =.01). The distance to zero skid reflected this with the respective surfaces generating distances of 6.00 and 16.77 inches. The highest coefficient of kinetic friction for the human method was obtained using the rubber surface ($\bar{\mu}$ = .31, σ = .01), whilst the lowest was MFC ($\bar{\mu}$ = .10, σ = .01). The distance to zero skid reflected this with the respective surfaces generating distances of 5.65 and 17.37 inches (table 2). Results would indicate that that the greater the coefficient of friction, the smaller the distance it takes for a golf ball to achieve pure rolling motion (i.e. a negative relationship). Results suggest that both methods (robot and human) of measuring the coefficient of kinetic friction of different surfaces are comparable (figure 2). For the human and the robot methods, 253 and 43 putts were found to be invalid respectively, and were therefore discarded from the experiment.

Conclusions

The use of the 'Quintic Ball Roll' system as a measuring tool may be used by coaches to replicate putting green characteristics away from the golf course for players to familiarise themselves with the conditions in order to prepare themselves for competition play. This method may also be of use to green keepers who are looking to measure green speed, and may be a more appropriate method when compared with the stimpmeter which eradicates the initial skid phase of the putt, suggesting it's inappropriateness as a measuring tool. Based on these suggestions it would be of interest for future research to investigate the relationship artificial surfaces, such as those used in this study, have with grass (outdoor golf greens). Manufacturing a number of artificial putting surfaces with diverse ranges of surface frictions would allow golfers and coaches to adapt their game, thus improving putting knowledge and performance. Results also suggest that the human in this method was far less consistent than the robot. It may be of interest for future research to analyse whether there is a relationship between the handicap of the player and the consistency of putting performance.

References

1. Epperson, B.P & Gadsden, E.T.: Golf. Birmingham, Ala. Pat. 5,383,664 (1993)

2. Flom, D.G., & Beuche, A.M.: Theory of rolling friction for spheres. Journal of Applied Physics, 10, pp.1725 -1730 (1959)

3. Hubbard, M., & Alaways.: Mechanical Interaction of the Golf Ball with Putting Greens. Science and Golf III: Proceedings of the World Scientific Congress of Golf, 54, pp.429 – 439 (1999)

4. Weber, A.: Green speed physics. USGA Green section record, 35(2), 12-15 (1997)

5. Karlsen, J., Smith, G., & Nilsson, J.: The stroke has only a minor influence on direction consistency in golf putting among elite players. Journal of Sports Sciences, 26(3), .243-250 (2008)

6. Laws, W.G.: Optimal golf swing kinetics and kinematics. Science and Golf I. Proceedings of the First World Scientific Congress of Golf; pp.3-13 (1990)

Appendix

Table 2. Putting parameters for the putting robot and human subject.

Putting parameters	Quintic putting robot	Human subject
Impact ball speed	3mph ± .25	3mph ± .25
Initial launch angle	2° ± .5°	0.75° - 2.5°
RPM cut or hook spin	0 - 20 rpm	0 – 20 rpm

Table 2. Ball roll characteristics of four different surfaces for the two methods. Data are mean ± SD.

Surface	Coefficient of Friction (µ) Mean ± SD	Coefficient of Friction (µ) Range	*Mean distance to true roll. Inches (metres)*
Robot			
Putt mat	.24 ± .01	.21 - .26	7.03 (.18)
Rubber	.29 ± .02	.27 - .34	6.00 (.15)
MFC	.11 ± .01	.09 - .13	16.77 (.43)
Carpet	.17 ± .01	.15 - .19	10.33 (.26)
Human			
Putt mat	.24 ± .01	.22 – .27	7.35 (.19)
Rubber	.31 ± .03	.28 – .37	5.65 (.14)
MFC	.10 ± .01	.09 – .12	17.59 (.45)
Carpet	.19 ± .01	.17 – .21	9.60 (.24)

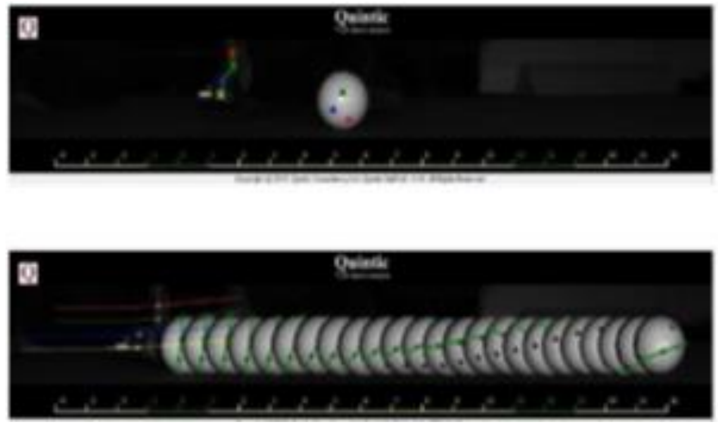

Fig. 1. A visual representation of how the golf ball is tracked during a putt

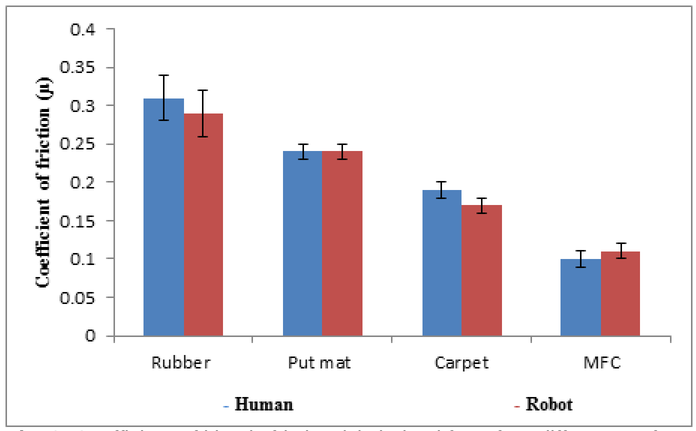

Fig. 2. Coefficient of kinetic friction (µ) derived from four different surfaces using the two different methods.

The Variability in Swing Kinematics and Carry in a Longitudinal Study of Elite Golfers

James Parker, John Hellström, Andreas Ivarsson, Urban Johnsson, M Charlotte Olsson

Purpose

Long drives with high accuracy are important in golf (Hellström et al., 2013). Biomechanical variables including thorax rotation speed and lead arm speed (LAS) seems associated with variance in club head speed (CHS) (Tinmark et al., 2010).However, the relationship between these biomechanical variables and driver performance over time it is not known. Thus, the aim of this study is to explore the relationship between peak speed of the pelvis, thorax, and lead upper arm and carry over time, investigating both within and between session variability in elite male golfers.

Method

Six elite male golfers (hcp -3 to - 0.5) (age range 21-23 years) were included in this study. The golfers were studied on four separate time periods over a year: (1) October; (2) February; (3) May; and (4) October. Tests were performed in an indoor studio hitting out. Each test occasion included a golf specific warm-up, then subjects hit five balls with their driver with a 'normal swing. Data on swing kinematics was collected using a four sensor electromagnetic motion capture system at 120Hz (Polhemus Inc. USA). Nine landmarks were digitized to define segment lengths, orientations and joint axes. The club sensor was secured directly below the grip on the shaft of the club. Club head speed and carry were collected using a launch monitor (Trackman 3e, v.3.2, Trackman, Denmark). Swing events were determined from sensors on the club; top of backswing was determined as the sample when the club changes direction from backswing to downswing. Impact was determined when the clubhead reaches the horizontal position equivalent to where it was at address. Thorax and pelvis rotation were calculated using the joint coordinate system method (Grood et al., 1983) and lead arm was calculated using the humerus joint coordinate system (first option) (Wu et al., 2005) in conjunction with advanced motion measurement software (AMM 3D, USA). IBM SPSS v.22 was used to analyse the data through hierarchical multilevel modelling (MLM)(Heck et al., 2010). First a baseline model without predictors was run, then MLM was repeated with predictors where the first level of the data contained carry and kinematic data from each shot (within session level). At the second level, the carry scores were nested within sessions and analysed between sessions. Lastly, at the third level, the sessions were nested within players (between players). Carry was used as the outcome variable and kinematics as predictor variables (p<0.05).

Analysis/Results

Initially MLM baseline model for carry only was tested without predictors. The results showed a statistical significant intercept (Estimate=226.24, *p*<.001). Intraclass correlations (ICC) suggested that 32.5% of variance in carry were present within sessions (level 1), whilst 38.0% were attributed to differences in carry between sessions (level 2). Results from second MLM generated an improved model fit (-2 LL & BIC) where peak speeds of the pelvis, thorax, and lead upper arm were included as fixed effect covariates on level 1. The result showed that peak lead arm speed (LAS) was a statistically significant predictor of carry (β=.17, p=.001) whereas peek speed of neither thorax (β=-.04, p=.364) nor pelvis (β=.02, p=.673) had any statistically significant relationship with carry.

Conclusions

This study found that 32.5% of the variation in shot consistency can be explained at the within session level (influenced by for example variance of impact location), and 38.0% of variation in shot consistency can be explained at the between session level (influenced by for example environmental factors). LAS was the only significant predictor of within session variance in carry. Our results indicated LAS as a predictor of within session variance in carry. This is partly supported by previous research showing that golfers with higher arm speed had higher ball velocity than golfers with lower arm speed (Healy et al., 2011). However, our results differ from previous studies reporting a relationship between peak thorax speed and driver performance (Joyce et al., 2013; Myers et al., 2008). The difference could be due to our results being based on longitudinal data at the intra-individual level, whereas previous studies used cross-sectional study designs, had larger sample sizes[JP[2], different analysis methods and reported at inter-individual level. In conclusion, our preliminary data show that LAS is a predictor of carry distance within session. Practitioners may consider training strategies to optimize arm speed to improve driving distance among elite golfers.

Keywords: Golf biomechanics, driving performance, Consistency, longitudinal, multi-level modelling

References

Grood, E. S., & Suntay, W. J. (1983). A joint coordinate system for the clinical description of three-dimensional motions: application to the knee. *Journal of biomechanical engineering, 105*(2), 136-144.

Healy, A., Moran, K. A., Dickson, J., Hurley, C., Smeaton, A. F., O'Connor, N. E., . . . Chockalingam, N. (2011). Analysis of the 5 iron golf swing when hitting for maximum distance. *J Sports Sci, 29*(10), 1079-1088.

Heck, H. R., Thomas, S. L., & Tabata, L. N. (2010). Introduction to Multilevel and Longitudianl Modeling with IBM SPSS. *Multilevel and Longitudinal Modeling with IBM SPSS*, 1-20.

Hellström, J., Nilsson, J., & Isberg, L. (2013). Drive for dough. PGA Tour golfers' tee shot functional accuracy, distance and hole score. *J Sports Sci*(ahead-of-print), 1-8.

Joyce, C., Burnett, A., Cochrane, J., & Ball, K. (2013). Three-dimensional trunk kinematics in golf: between-club differences and relationships to clubhead speed. *Sports Biomechanics, 12*(2), 108-120.

Myers, J., Lephart, S., Tsai, Y. S., Sell, T., Smoliga, J., & Jolly, J. (2008). The role of upper torso and pelvis rotation in driving performance during the golf swing. *J Sports Sci, 26*(2), 181-188.

Tinmark, F., Hellstrom, J., Halvorsen, K., & Thorstensson, A. (2010). Elite golfers' kinematic sequence in full-swing and partial-swing shots. *Sports Biomech, 9*(4), 236-244. doi: 10.1080/14763141.2010.535842

Wu, G., van der Helm, F. C. T., Veeger, H. E. J., Makhsous, M., Van Roy, P., Anglin, C., . . . Buchholz, B. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand. *J Biomech, 38*(5), 981-992. doi: 10.1016/j.jbiomech.2004.05.042

The rise of Professional Golf Players in Europe: An Efficiency comparison at the national level

Jesús Pastor, Javier Alcaraz, Francisco del Campo & Diego Pastor

Purpose

We revise 18 European nations considering three features judge as relevant for the emergence of professional golf players: number of golf courses, number of golf players and Gross Domestic Product (GDP). These three features should explain the number of each national professional players at the European Tour as well as the number of distinguished professional players identified as the subset of pro players that are classified for the Race to Dubai. In order to allow a direct comparison between all the nations we resort to ratio variables that eliminate the size effect and allow a constant returns to scale comparison. The well known output-oriented variable and constant returns to scale radial Data Envelopment Analysis (DEA) models are used.

Methodology

In a DEA framework, we are going to analyze the efficiency of eighteen European nations resorting to three inputs that are determinant to explain two outputs. The characteristics of the available 2014 data were used to select the sample of European nations to be analyzed. In fact we decided that, at the national level, the number of golf-courses in each nation (#GC) should be at least 50, and the number of national golf-players (#GP) should be at least 50.000. These data were obtained from the European Golf Association (EGA). The two remaining golf variables, the number of professional golf players playing at the European Tour (#PRO) and the selected number of them qualified for the Race to Dubai (#PROQ) were obtained directly from the European Tour Website. Finally, variables related to characteristics of the nation, such as GDP, expressed in thousands of millions of dollars, surface (SFC), expressed in thousands of square kilometers, and population (POP), expressed in millions of inhabitants, were obtained from Eurostat and from the World Bank. The main feature of our dataset is the big variation among nations.

Banker, Charnes and Cooper (1984) developed a couple of radial variable returns to scale (VRS) DEA models, namely the output-oriented and the input-oriented BCC models. We started solving a VRS output-oriented radial model, shortly BCC-OO, with three inputs (#GC, #GP, GDP) and two outputs (#PRO, #PROQ).

In order to enable a comparison of all the nations on an equal footing, we decided to eliminate the size effect by deriving three new ratio-inputs and two new ratio-outputs, defined as follows. Input 1, Golf-courses/Surface (#GC/SFC); Input 2, Golf-players/Population (#GP/POP); Input 3, GDP/Population (GDP/POP); Output 1, Professional golf-players at the European Tour/Population (#PRO/POP); and, finally, Output 2, Professional golf-players qualified for the Race to Dubai/Population (#PROQ/POP). Now, the model to be used is a constant returns to scale (CRS) output-oriented DEA model, known as CCR-OO model, developed by Charnes, Cooper and Rhodes (1978). The main feature of our ratio-dataset is, once more, the big variation among nations.

Analysis/Results

The BCC-OO model identifies 8 nations out of the sample of 18 nations as efficient, and another 3 as highly inefficient. On the other hand, the CCR-OO model with ratio-variables identifies just 5 nations as efficient, and 5 as highly inefficient. Each model allows us to classify the nations as efficient or inefficient and offer us benchmarks for future planning.

We further developed two similar models with the same three inputs and with a single output (#PRO for the BCC and #PRO/POP for the CCR). The new BCC-OO model identifies 7 nations as efficient, and 2 as highly inefficient, with similar efficiency scores for the whole sample. The new CCR-OO model identifies only 3 efficient nations and 5 as highly inefficient, and, again the corresponding efficiency scores are very similar to the CCR-OO model with two outputs.

The third exercise we performed is to consider Bounded CCR-OO models (Cooper et al., 2011, Pastor et al., 2013 and 2015). The obtained results are very similar to the corresponding CCR models without bounds.

Conclusions

We have developed several BCC-OO and CCR-OO models in order to classify each nation of our sample of 18 European Nations as efficient or inefficient, according to its ability to generate professional golf players for the European Tour. As by-products we measure how far each inefficient nation is for reaching efficiency and identify role models that can be used for the design of new golf strategies in order to improve the performance of inefficient nations.

References

Banker, R.D., Charnes, A. and Cooper, W.W. (1984), Management Science 30: 1078–1092.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978), European Journal of Operational Research 2/6: 429–444.

Cooper, W.W., Pastor, J.T., Borras, F., Aparicio, J. and Pastor, D. (2011), Journal of Productivity Analysis 35(2): 85–94.

Pastor, J.T., Borras, F., Aparicio, J., Monge, J.F. and Pastor, D. (2013), Journal of Productivity Analysis 40(3): 285–292.

Pastor, J.T., Aparicio, J., Alcaraz, J., Vidal, F. and Pastor, D. (20135), OMEGA 56: 16-24.

Development of a Virtual Random-Physics Putting Training System

Todd Pataky & Peter Lamb

Purpose

Putting machine precisely reproduce kinematics yet sink only ~80% of flat putts from distances of ~5 m (Kammerer et al. 2014, orally reported result). This implies that randomness in the uncontrolled ball-green interaction may represent an important source of variability in real golf putting. Since mental randomness training has been shown to improve reasoning regarding reality's probabilistic nature (Fong et al. 1986), and since virtual environment training can improve real performance (Holden et al. 1999), it is conceivable that *physical* randomness training can improve real golf putting performance through an acceptance of randomness. The ultimate purpose of this research is to test whether virtual random physics training can improve real putting performance in amateur golfers. The purpose of this specific study was to assess the effect of randomness magnitude on virtual putting performance.

Method

Eight university students participated in three computer-game sessions ("Training 1", "Training 2" and "Testing") on three consecutive days. The game (Fig.1) was developed using the Blender 2.76 real-time physics engine (Blender Foundation, Netherlands). Subjects moved the aiming target using the keyboard's arrow keys and launched the ball with the spacebar. In addition to gravity and green reaction forces external forces applied to the ball included:

- *Whole-green field force*: simulating sloped greens; randomly generated for each hole.

- *Impact force*: caused the ball to roll to the aiming target for a perfectly flat green.
- *Dynamic random forces* (DRF): caused subtle ball trajectory deviations (Fig.1). Each subject trained with one of eight randomly assigned DRF magnitudes, ranging from 0.05 to 0.2 m deviation per 3 m putt in equal (0.021 m) steps. All subjects were tested with the median DRF value (0.125 m) in the Test Session.

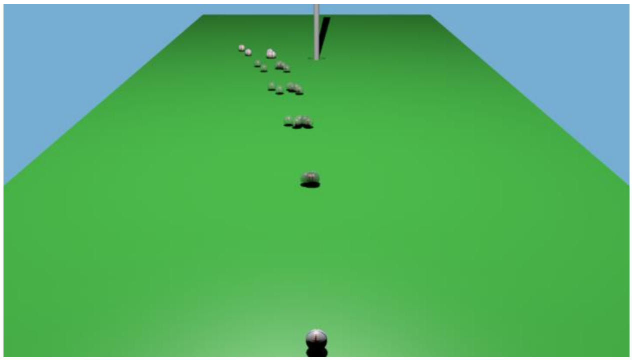

Figure 1. Random physics training system. The ball trajectories imply a right-to-left-sloping green. With non-random physics the ball trajectory would be constant and the task relatively easy. Small random forces retain a natural-looking ball roll but have non-trivial, unpredictable effects on final ball position.

Each session consisted of 18 holes and six consecutive putts per hole. The first putt was passive: with the target on the hole the ball was launched automatically and subjects were asked to watch its trajectory and to judge the green's slope. Subjects then actively performed the remaining five putts. Subjects were informed that there was some randomness in the game, so that consecutive putts to the same target would not necessarily yield identical outcomes.

Analysis/Results

In the Training sessions putting success (Fig.2a) and subject-selected target position variability (Fig.2c) were negatively and positively correlated with dynamic random force (DRF) magnitude, respectively ($r = -0.914$ and 0.612, respectively). Only the former reached statistical significance (p=0.002). In the Test session the correlation signs were opposite (Fig.2b&d; r=0.915 and r=−0.344, respectively), but again only the former reached significance (p=0.001). The putting success results indicate that DRF was directly related to task difficulty, but more importantly that subjects who trained in low-DRF conditions adapted poorly to the higher-DRF condition (Fig.2b, left side).

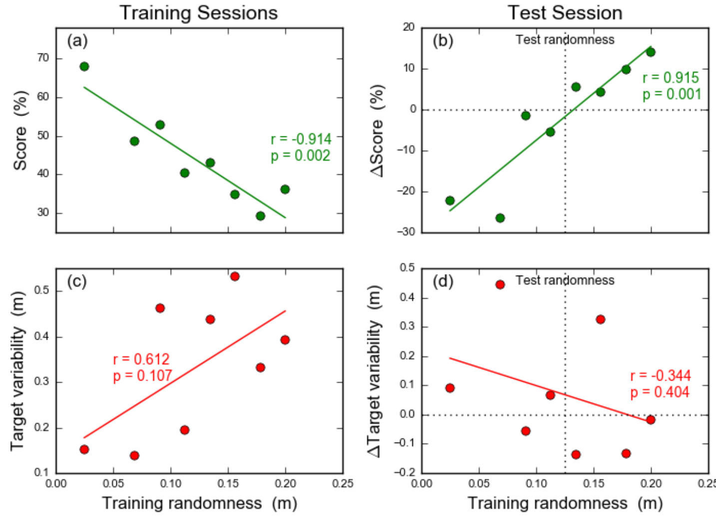

Figure 2. Effects of dynamic random forces on putting score and subject-selected target position variability. Each data point represents one subject.

Conclusions

This study's results parallel the task complexity (e.g. Rose et al. 1990) and virtual performance (e.g. Holden et al. 1999) motor control literatures and suggest that virtual putting success rate is easily manipulated through physics randomness. The underlying mechanism might be reduced target selection variability (Fig.2d) – or equivalently acceptance of the probabilistic nature of the putt – possibly secondary to forward probabilistic models of plausible outcomes (Dindo et al. 2011), but additional experiments involving more subjects, more sessions and/or more putts will be needed to clarify. Regardless of mechanism, it is possible that physics randomness training could instill in golfers an appreciation of real physical probability, which may concurrently improve putting performance by allowing golfers to more accurately separate the contributions of internal, kinematic variability and external, uncontrollable variability to individual putt outcomes. If these results can transfer to real putting in laboratory conditions, potential impacts on the field for randomness training are numerous. Coaches could use randomness training to: accelerate putt stroke learning in beginners, reduce putting kinematic variability in amateurs, and to coach mental toughness in all golfers.

Keywords: virtual reality, stochastic physics, virtual putting, putting kinematics, stroke variability

References

Dindo, H., Zambuto, D. & Pezzulo, G. (2011). Motor simulation via coupled internal models using sequential Monte Carlo. *IJCAI Proceedings-International Joint Conference on Artificial Intelligence* 22(3): 3.

Fong, G. T., Krantz, D. H., & Nisbett, R. E. (1986). The effects of statistical training on thinking about everyday problems. *Cognitive Psychology, 18,* 253–292.

Holden, M., Todorov, E., Callahan, J., & Bizzi, E. (1999). Virtual environment training improves motor performance in two patients with stroke: case report. *Journal of Neurologic Physical Therapy* 23(2), 57-67.

Kammerer, B. J., Menshik, A., Erlemann, L., & Lafortune, M.

(2014). Quantifying the performance metrics of a putter. *Golf Science: Abstracts of the 2014 World Scientific Congress of Golf*, 57; the cited result was orally presented but does not appear in the published manuscript.

Rose, D.J. & Christina, R. W. (1990). Attention demands of precision pistol-shooting as a function of skill level. Research Quarterly for Exercise and Sport. 61(1) 111–113.

Regulation of Angular Impulse to Control Golf Shot Distance Between the 9-Iron and Driver

Travis Peterson, Philip Requejo, Henryk Flashner, Rand Wilcox & Jill McNitt-Gray

Purpose

Golf players choose different clubs to regulate shot distance during the course of play. As required shot distance increases, angular impulse (AI) about the center of mass (CM) generated by reaction forces at the foot-surface interface is expected to increase (McNitt-Gray et al., 2013). Previous research indicated skilled players using a 6-iron modified shot distance by regulating the magnitude of the target and/or rear leg resultant horizontal reaction forces (RFh), with minimal changes in RFh-orientation relative to the target (McNitt-Gray et al., 2013). These results suggest that AI generated about the CM involves regulation of the RFh-magnitude. We tested this hypothesis by comparing the AI generated about the CM by each leg when players hit with a driver and 9-iron.

Method

Skilled players (n=10, handicap<5) volunteered in accordance with the institutional review board. Each player performed four to six shots towards a target with a 9-iron (9I) and a driver (D, TaylorMade). Players used their preferred address position with each foot fully supported by a force plate (Kistler, 1200Hz). The peak RFh-magnitude and RFh-angle (Figure 1) at the turf-plate interface and point of wrench application (PWA) were computed for each leg (Williams & Cavanagh, 1983). Moments about the CM were calculated as the cross-product of the RFhs and the CM-PWA vector for each leg when net AI was positive. Within-player statistical analysis was conducted using Cliff's analog of the Wilcoxon-Mann-Whitney test (Cliff, 1996). A modified, step-down Fisher-type method adjusted for multiple comparisons ($\alpha=0.05$, Wilcox & Clark, 2015).

Analysis/Results

Net AI significantly increased when swinging with a driver compared to a 9-iron for nine of ten players (Figure 1). Four players significantly increased rear leg AI, whereas six players significantly increased target leg AI. Swinging with the driver, nine players significantly increased the target leg peak RFh-magnitude and seven players increased target leg RFh-angle. Five players significantly increased rear leg RFh-magnitude with the driver. Individually, four players increased rear leg moment arm with the driver whereas three decreased and two increased target leg moment arm. Nine of ten players significantly increased stance width with the driver.

Conclusions

Angular impulse increased when swinging with a driver compared to the 9-iron. Target leg AI relied on increasing RFh-magnitude at an angle more parallel to the target line, contributing to a moment arm that was maintained or decreased in length. Rear leg AI increased RFh-magnitude for half of the players while maintaining RFh-angle, consistent with previous research (McNitt-Gray et al., 2013). Increasing stance width with the driver was anticipated to increase moment arms for the RFh-magnitude generated by both legs to assist in creating rotation. However, this was not true for all players. These results indicate multiple components of AI generation are consistently controlled by individual players across clubs to regulate rotation. Understanding how individual players regulate AI may lead to personalized coaching and training to utilize the mechanisms to increase golf shot distance.

Keywords biomechanics, angular impulse, leg coordination

References

Cliff, N. (1996). *Ordinal Methods for Behavioral Data Analysis*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc., Publishers.

McNitt-Gray, J. L., Munaretto, J., Zaferiou, A., et al. (2013). Regulation of reaction forces during the golf swing. *Sports Biomechanics*, *12*(2), 121–131.

Wilcox, R. (2012). *Modern Statistics for the Social and Behavioral Sciences: A Practical Introduction*. Boca Raton, FL: CRC Press Taylor & Francis Group.

Wilcox, R., & Clark, F. (2015). Robust Multiple Comparisons Based on Combined Probabilities From Independent Tests. *Journal of Data Science*, *13*(1), 1–11.

Williams, K., & Cavanagh, P. R. (1983). The mechanics of foot action during the golf swing and implications for shoe design. *Medicine and Science in Sports and Exercise*, *15*(3), 247–255.

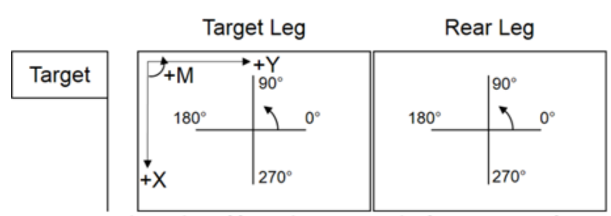

Figure 1: Top-down view of force plate setup and reference system for reaction force and angle orientation (above).

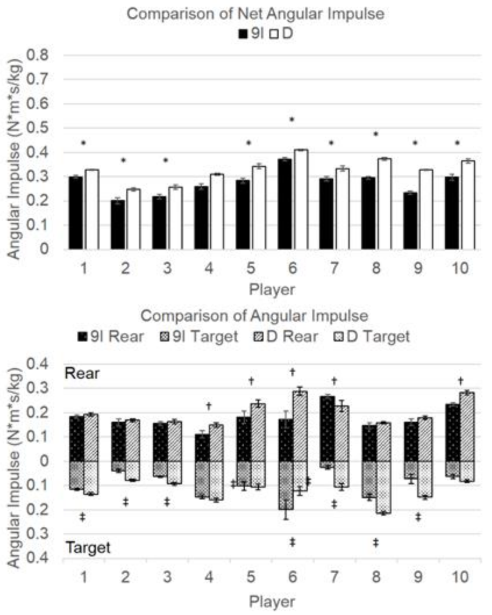

Figure 1: Mean (SD) of net (above), rear and target (below) angular impulse (normalized by body mass) of each players' golf swings with the 9-iron (9I) and driver (D) during the interval of interest. Positive values were plotted above and below zero for rear and target leg angular impulse (below). All significant differences were denoted when tested at α = .05 level when adjusted for multiple comparisons. * Net angular impulse, † rear angular impulse, ‡ target angular impulse.

The Role of the Caddie in Elite-level Golf

Jarred Pilgrim, Sam Robertson & Peter Kremer

Purpose

Golf is unique in comparison to other individual skill based sports, as golfers at the highest level usually compete with an assistant, known as the caddie, who plays a support role alongside the golfer (Carrick & Duno, 2002). Traditional duties commonly performed by the caddie to reduce the golfer's workload, such as carrying the golfer's bag, cleaning clubs and maintaining the course for play have been well documented (Aitken & Weigand, 2007; Bruce, 1998; Carrick & Duno, 2002; Lavallee, Bruce, & Gorely, 2004; Mackenzie, 1997). Furthermore, recent research has investigated the qualities that underpin an effective golfer-caddie partnership (Aitken & Weigand, 2007; Jowett & Zhong, 2014), the caddie's impact on the golfer's scoring outcomes (Coate & Toomey, 2014), and the basic structure of the caddie role (Aitken & Weigand, 2007; Lavallee et al., 2004). However, there remains a dearth in peer-reviewed evidence concerning the broader roles that caddies may play in adjusting psychological states, assisting in decision-making and in preparation for a competitive event. Thus, this study aimed to determine the nature of the caddie's role in the decision- making, psychological conditioning and tournament preparation of elite-level golfers.

Method

Purposeful sampling was used to recruit 17 golfers (15 male, 2 female; playing level = 2 rookie professionals, 15 elite amateurs; handicap index range = 0 to +4; age range = 17-24 years; M age = 20 years; M years of playing = 10 years) and 6 caddies (6 male; age range = 29-42 years; M age = 37 years; M years of caddying = 15 years; M number of golfers worked with = 19). The caddies recruited were all full-time employed in golf (1 tournament coaching consultant, 1 national coach, 3 PGA teaching professionals and 1 PGA professional trainee) and volunteered to caddie for Elite-level golfers as part of their capacity within these roles. The caddies and players recruited were not dyads and did not work together on a regular basis. Each golfer and caddie participated in semi-structured interviews designed to assess their experience in several areas relevant to the caddie role, including: background, playing/caddying experience, function of the caddie, the caddie's role in maintaining the golfer's mental state, communication and decision-making.

Analysis/Results

Interview recordings were transcribed verbatim and subjected to a six-step thematic analysis. The analysis produced four main findings: (1) the caddie's role in decision-making was to provide information, assist in shot selection and provide feedback on the golfer's club selection; (2) the caddie's role in psychological conditioning was to maintain the golfer's high performance state using a variety of cognitive and attentional strategies; (3) caddies assist in tournament preparation by 'mapping' to plan strategy and record the important characteristics of the course prior to a tournament; and, (4) although the benefits of caddies were recognised, golfers were dissatisfied with the quality of caddies available.

Conclusions

The findings of this study provide guidelines for the best practice of caddies working with elite amateur and rookie professional players. Additionally, the development of a prerequisite document or 'caddie contract' was proposed as an appropriate solution to the issue of golfer discontent in caddie quality in this cohort. This document would contain many of the components of an average employment contract; in particular, it would outline what the golfer expects of the caddie as an 'employee'. Golfers' specific preferences can vary considerably; therefore, it is important that the circulation of a generic contract be avoided. Contracts should be individualised to meet the golfer's unique requirements and developed based on the coach's recommendations. The application of this knowledge has implications for National Sporting Organisations, performance enhancement in the sport and the development of more effective working relationships between elite amateur golfers and their caddies.

References

Aitken, V., & Weigand, D. (2007). *Caddy-talk: Psychology of being a great golf caddy*. Milton Keynes: Dawvija Publishing.

Bruce, D. (1998). *Turn up, keep up & shut up: The role of a caddie in male professional golf in Australia* (Unpublished master's thesis). University of Queensland, Queensland, Australia.

Carrick, M., & Duno, S. (2002). *Caddie sense: Revelations of a PGA tour caddie on playing golf*: New York: St. Martin's Griffin.

Coate, D., & Toomey, M. (2014). Do professional golf tour caddies improve player scoring? *The Journal of*

Sports Economics, 15(3), 303-312.

Jowett, S., & Zhong, X. (2014). *Understanding the quality and functions of the golfer-caddie relationship* (Unpublished manuscript). Loughbourough University, UK.

Lavallee, D., Bruce, D., & Gorely, T. (2004). The golfer-caddie partnership: An exploratory investigation into the role of the caddie. *Athletic Insight: The Online Journal of Sport Psychology, 6*(1), 20-35. Mackenzie, R. (1997). *A wee nip at the 19th hole: A history of the St. Andrews caddie*. Ann Arbor: Sleeping Bear Press.

Elite Irish Golfers' Experiences of Transition From Amateur To Professional

Jussi Pitkanen & Martin Toms

Purpose

The purpose of this study was to establish and examine the factors behind elite amateur golfers' decisions to make the next career step and become professional athletes. The study relates to previous research in order to establish athletes' career progression to date and to compare their experiences as transitioning players. The research is intended to help future programmes in managing athlete transitions and career stages by governing bodies and organisations involved in talent development.

Method

Prior to the commencement of the study, ethical approval was sought from and approved by the University of Birmingham ethics committee. The participants were selected through a convenience sampling process, and all were contacted via email and telephone regarding participation in the study. The final participants in the study were four male professional golfers under the age of 30 years, who had transitioned from elite amateur over the previous four years. None of the contacted golfers have yet reached full European Tour status but had representative honours at junior and/or full amateur international level and won a major national tournament during their amateur career. Following initial contact, the athletes signed a consent form and participant information sheet detailing their involvement. All participants were allowed to choose their interview location, with two interviews conducted via Skype and the rest at a location convenient to the athletes. All interviews were recorded and transcribed verbatim following completion, after which they were sent to each participant for verification. A second round of brief follow up interviews, by phone or in person, were completed to clarify points from the initial data collection recordings. The data were collected using semi-structured interviews. To initiate the interview, each participant was asked to describe their personal experiences of the amateur-pro transition process and follow up questions were formulated based on the responses. An interpretive, constructivist stance was used in analysing the data emerging from the interviews and the interview transcripts were coded for linked themes using thematic analysis (Braun & Clarke, 2006), which was selected due to the 'essentialist or realist' nature of the methodology, which seeks to draw out participants' experiences of particular events, and allows for richer data to emerge. Open-ended questions were used to allow the participants to describe their journey in their own words and allow for richer data to emerge.

Analysis/Results

The main topics emerging from the player narratives were threefold:

1. Support; particularly the importance of family, friends and coaches and the necessity of elite performers to have a psychological and social support network in order to develop;
2. Financial implications of professional golf
3. The desire and motivation to pursue and succeed in a personal career.

The interview findings build on previous studies looking to uncover reasons for some elite athletes success (Hollings et al, 2014), and include demands and coping resources outlined in Stambulova's (1994) analytical athletic career model. Many of these in turn were linked to the junior-senior sport transition, yet were evident in the later amateur-professional phase in this study: family and federation support (junior-senior), implementation of psychological strategies in competition (junior-senior), self-reliance (amateur-pro) and selectiveness in support and social influences (amateur-pro). These in turns were equally matched by the demands placed on the athletes during their initial stages of professionalism, such as independence in training and practice (am-pro), reorganise one's lifestyle (junior-senior), and the search for an individual career path (junior-senior). The findings point towards a lack of a systematic approach to bio-psycho-social athlete development (Collins et al, 2012) and show a need to formalise holistic support mechanisms (Douglas & Carless, 2006; Mattson et al, 2007) available to elite amateur athletes in preparing for a career as a professional.

Conclusions

While a system of financial and service support exists for young professional golfers in Ireland (Team Ireland Golf Trust), the evidence from the study indicates a need for an inclusive talent development pathway, which incorporates and embraces professional players. The players identified psychological, logistical and emotional supports as key development areas and this opens an opportunity to create a career guidance service for elite players, who have in the past made the transition to the professional game without clear knowledge of the demands they will face. A possibility of a dual career for elite athletes should be explored considering previous findings into successful transition from junior to senior sport in Ireland (Cunningham, 2012).

Keywords: athlete career transitions, athlete support, bio-psycho-social

References

Braun, V., Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*. *3:2*: 77-101.

Collins, D., Bailey, R., Ford, P.A., MacNamara, A., Toms, M., Pearce, G. (2012). Three Worlds: new directions in participant development in sport and physical activity. *Sport, Education and Society*. *17:2*:225-243.

Cunningham, T. (2012). *Fund the sport or fund the athlete? The performance impact of high performance funding in Ireland.* Unpublished masters thesis, Université de Poiters, France.

Douglas, K., Carless, D. (2006). *Performance Environment Research*. UK Sport.

Hollings, S.C., Mallett, C.J., Hume, P.A. (2014). The transition from elite junior track-and-field athlete to successful senior athlete: Why some do, why others don't. *International Journal of Sports Science and Coaching. 9:3:* 457-471

Mattson, P., Hassmen, P., McCullick, B., Schempp, P. (2007). Swedish Golf Success: Its history and future. *Annual Review of Golf Coaching*. *2: S1*: 87-99.

Stambulova, N.B. (1994). Developmental sports career investigations in Russia: A post-perestroika analysis. *The Sports Psychologist*. *8*: 221-237

Conscious Processing of a Complex Motor Skill: An Investigation Into the Automaticity Paradigm of Full Golf Swing Execution

Noel Rousseau, Matthew Bridge & Ian Boardley

Purpose

Golf coaching has a cultural history of being highly explicit in the nature of its delivery. Given the potential complexity of the game this can easily lead to a situation of cognitive overload during practice and a debilitating reliance on conscious control (Masters and Maxwell, 2008, Wulf, 2013) during performance situations. The term 'paralysis by analysis' is one that is ever familiar to golfers and coaches alike. Of recent years there has been an overreaction to this pattern with researchers and sports psychologists offering the much used blanket advice of 'don't think about your swing' (Rotella, 1995, pg 40).

Noel Rousseau has examined factors that influence the propensity to, and the utility of, conscious processing during a complex motor skill. Prevalent theories of skill acquisition and automaticity view expert performance as best executed in the absence of conscious movement control. There is substantial evidence to support this claim for simple tasks but a lack of research for complex skills is apparent. In this study the role of conscious processing (reinvestment) is examined in relation to the full golf swing in baseline and anxiety conditions.

The early experiments in the study examined the effects of limiting conscious processing through a temporal restriction. Later experiments investigated individualistic elements of personality and cognitive 'make up,' that may affect the control structures of the golf swing.

Method

Throughout this study common methods are used and adjusted accordingly to fit the requirements of each experiment. In each of the 5 experiments, data were collected from highly skilled golfers (Handicap <5.4)(Exp1 n=26, Exp 2 n=13, Exp 3 n=26, Exp 4, n= 23, Exp 5 n=23). All participants hit 7 shots with a 5 iron in baseline and anxiety conditions. Anxiety was invoked via a competitive format based on shot performance in relation to a virtual target that consisted of different scoring zones. The results were displayed on site in view of all competitors. Participants paid £6.00 into a prize fund with £3.00 being used as a stake for each competition, which coincided with the anxiety trials. Both baseline and anxiety conditions were repeated pre and post temporal restriction intervention
(Figure 1). Measures of performance anxiety (Competitive State Anxiety Inventory-2R) and conscious processing (adjusted Movement Specific Reinvestment Scale) were administered immediately after each trial.
The intervention was designed to limit conscious processing via a 5 second temporal restriction. The time allocation was measured from commencement of their approach to the ball until they began their swing. The beginning of the swing was defined as the moment the club was swung away from the ball. In experiments 4 and 5, further measures of Processing Style (VVQ, Richardson, 1977) and Working Memory Capacity (AWMA, Alloway, 2007) were added to the common procedure.

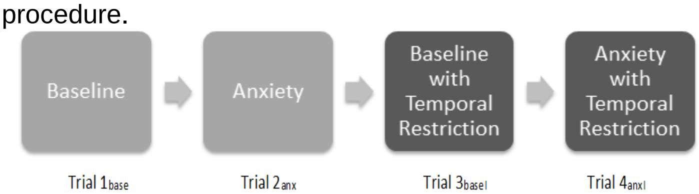

Figure 1 Experimental Conditions

Analysis/Results

For the analysis of the performance data, the accuracy value of the 7th ball of each trial was used, as this was deemed to be the shot with the most pressure. All comparisons were carried out using mixed factorial, repeated measures ANOVAs where the overall type I error rate for each analysis was set at $\alpha = .05$. In the later experiments, personality factors were correlated against performance and state reinvestment using Spearman's Rho correlation analysis.

Conclusions

The early experiments (1-3) examined the effects of limiting conscious processing through a temporal restriction. Mixed performance results were evident throughout, with no support being afforded to the complete automaticity of a complex skill. In a divergence to the reinvestment literature, the results from the later experiments indicate that conscious processing during task performance affects individuals differently, with mediating factors of processing style and working memory capacity. A high 'verbaliser' group deteriorated while 'visualisers' showed improvement during restricted conscious processing trials $F(1,14) = 8.4$, $p < .012$. Additionally, a positive correlation was indicated between working memory capacity and task performance during the temporally restricted trials $r_s = .54$, $p = .021$.
Overall, the results imply a positive role for conscious control in the golf swing. It is therefore suggested that a multifarious account of reinvestment would be more appropriate if it is to be applied to complex skill (Christensen et al., 2015).
The findings in this study are highly relevant to the applied setting, given the prevalent advice of psychologists and coaches is to 'not think about swing mechanics during task execution'. This study shows this position not to be universally applicable and raises further questions of 'what' to think about and how task focus can be refined.

Keywords: Reinvestment, Motor Learning, Automaticity, Conscious Processing, Working Memory

References
Alloway, T.P. (2007) "Automated Working Memory Assessment". Harcourt Assessment.

Christensen, W., Sutton, J. and McIlwain, D. (2015) Cognition in skilled action: Meshed control and the varieties of skill experience. Mind and Language. *Mind and Language (in press).*

Masters, R. and Maxwell, J. (2008) The theory of reinvestment. *International Review of Sport and Exercise Psychology*, 1: (2): 160-183.

Richardson, A. (1977) Verbalizer-visualizer: A cognitive style dimension. *Journal of Mental Imagery*.
Rotella, B. (1995) *Golf is Not a Game of Perfect*. Simon & Schuster.

Wulf, G. (2013) Attentional focus and motor learning: a review of 15 years. *International Review of Sport and Exercise Psychology*, 6: (1): 77-104.

The Effect of Address Club Face Position on Pelvic and Trunk Kinematics: A Constraints Based Approach

Terry Rowles, Will Wu & Scott Lynn

Purpose
Technology has revolutionized the level of detail with which we can view the golf swing. We can now obtain detailed analyses about the motions and forces occurring during the swing, but must not confuse analysis with instruction. According to the Constrained Action Hypothesis, the golf swing can be affected by the physical and mental abilities of the player, the environment in which the player is competing or practicing, and the golf task the player is required to execute[1]. Variables within each of these domains can serve as constraints that either enhance or hinder performance and learning. It has been shown that an abundance of information that is too complex can hinder skill learning[2]. These are examples of negative constraints within the golfer's environmental domain. When a coach provides the correct amount of instruction it becomes a positive constraint leading to enhanced performance and learning, and these should be maximized. This study provides a method in which coaches can structure the task constraint while providing very little instruction.
The purpose of this research was to demonstrate how the "task constraint" of simply closing or opening the clubface at address can be used to modify swing mechanics in order to square the clubface while providing little to no verbal instructions related to mechanics of the golf swing.

Method
Participants were 19 (15 male, 4 female) highly skilled golfers (age = 30.4±9.9yr, height = 1.77 ± 0.09m, mass = 78.9 ±12.5kg, handicap = 2.4 ±3.2). They were outfitted with an AMM 3D 12 sensor motion capture system collecting at 240 Hz. Subjects were allowed to hit as many shots as they needed to warm up and get used to the wires. Following their warm-up, they hit a total of 10 test shots with a 5-iron from two conditions in random order: (1) club face closed 20º, (2) club face open 20º. Once the subject was in their set-up position, they were asked to bring the club up in front of them and the leading edge of the club was placed on a large protractor that was being held by a research assistant. The subject was then instructed to loosen their grip and the research assistant twisted the club in their hands either 20º open or closed. The subject was then instructed to bring the club back down to the ball and without adjusting their grip or stance, attempt to hit a straight shot. A good trial was considered having a launch angle (as measured by Trackman) between +2º and -2º. If the launch angle was outside of this range, the trial was repeated. Kinematic variables for all five swings in each condition were averaged together for each subject. Paired sample t-tests determined differences between the Open and Close club face conditions.

Analysis/Results
Results are presented in Table 1. At both half down and impact, the closed face condition demonstrated greater pelvic sway and spine side bend than the open face position.

Table 1. Kinematic variables for the Open and Closed Clubface condition half down and at impact.

	Half Down		Impact	
	Closed	Open	Closed	Open
Pelvic Sway (cm)	**10.7(4.0)**	**8.7(3.7) ‡**	**12.1(4.3)**	**9.9(3.9)** ⁇
Pelvic Rotation (Degrees)	25.37(13.08)	24.39(10.75)	36.55(14.62)	36.87(12.51)
Spine Side Bend (Degrees)	**7.27(6.29)**	**1.01(9.63) ‡**	**19.19(7.01)**	**13.55(6.80)** ⁇
Spine Rotation (Degrees)	-22.39(12.26)	-21.85(11.64)	-14.02(11.58)	-13.28(10.83)
Thorax Rotation (Degrees)	1.65(6.98)	-0.89(7.50)	22.79(8.11)	20.91(8.26)

Note:
- Numbers presented as mean (SD)
- ‡ = significant difference ($p<0.05$) between closed and open conditions at Half Down.
- γ = significant difference ($p<0.05$) between closed and open conditions at Impact.
- Sign convention:
  - Pelvis sway = +ve towards and -ve away from target.
  - Pelvis rotation/Spine/Thorax Rotation = +ve open and –ve is closed.
  - Spine Side Bend = +ve is towards trail leg and –ve is towards lead leg.

Conclusions
This study demonstrates the utility of a task constraint based approach to modifying swing mechanics while reducing, or eliminating, the use of verbal instructions. With the advancement of technology, golf instruction has been greatly influenced by the influx of measurement technology. Due to these advancements, it is increasingly important to understand the difference between analysis and instruction. Once the two concepts are differentiated, instructors and players will then begin to effectively identify and structure learning environments that enhance performance and learning. The 3-D kinematics provided the analyses to observe the coordinated changes within the swing and the constraints based approach provided a Motor Control framework used to modify the swing based on orientation of the clubface without the need for verbal instructions or video demonstrations.
Future research should examine this approach in novice

golfers, determine how long golfers retain the changes in swing mechanics made using this approach, and examine the effectiveness of this approach as compared with verbal instruction.

Keywords: Motor learning, Motor Control, Practice, Biomechanics

References

1. Stergiou, N, (2004). Innovative analysis of human movement. Champaign, IL: Human Kinetics

2. Magill, R. A. (2011). *Motor Learning: Concepts and Applications* (9th edition). New York: McGraw-Hill.

Effects of Time of Day on Tee Shot Performance in Elite Amateur Golfers

Nicola Rowley, Luke Barblan & Alex Lindsay

Purpose

Effects of time of day (TOD) have been shown in numerous aspects of performance such as; strength, power, flexibility, coordination, reaction time and alertness (Drust, *et al.,* 1996). The aim of this study focused on a 'functional strength through the driver tee shot' to investigate whether there is an optimal TOD that golfers perform their best drives.

Method

Fifteen male golfers volunteered for the study (13 category one and two professionals mean±SD; age 19.8±1.9 years, height 180.6±9.6 cm, body mass 75.6±9.3 kg, handicap 1.6±3.1, playing year's 10±3 years). Each golfer completed a Morningness-Eveningness questionnaire (Horne & Östberg, 1976) and thereafter was tested on three occasions 07:30, 10:00 and 17:00 h, in a counterbalanced order of administration with at least 48 h between each of the 3 testing days where the average values at each time point was taken. At each session the golfers were asked to sit quietly for 1-min before a baseline heart rate was taken (Polar FT1 watch, T-31coded belt, Japan) as well as intra-aural (Ear) temperature (Instant Ear Thermometer Model UT-60, Japan). A standardized dynamic golf warm-up was executed on each occasion under supervision of the researcher in an indoor area and the heart rate and intra-aural temperature recorded immediately after and just before hitting the 3 tee shots. Flightscope (model: x2.2-C-WE) was used to track and record the key parameters of **1)** driving distance (yards), **2)** swing speed (miles per hour) and **3)** smash factor and dispersion of the shot (lateral landing in yards from target line) as a surrogate of accuracy, preformed 3 times. Data were analysed by ANOVA.

Analysis/Results

There was a time of day effect for temperature and resting heart rate with higher values in the evening than the morning ($p<0.0005$). The standardized warm-up significantly increased the heart rate and ear temperature at each time point during the day ($p<0.05$). A diurnal variation was found for tee shot swing speeds where late morning (10:00 h) and early evening (17:00 h) values were significantly greater than 07:30 h; hence swing speed increased during the day (07:30 h 107±1 mph; 10:00 h 108±1 mph; 17:00 h 109±1 mph, $p<0.03$). A time of day effect was also found for driving distance, where distance covered increased from 07:30 to 17:00 h (226.2 ± 6.3 yards to 233.3±4.2 yards, $p<0.05$). Although driving distance was not significant different of between 07:30 and 10:00 h (~0.6 yards) it was however significantly different between 10:00 h (227.6±11.3 yards) and 17:00 h values. This research supports previous research findings that strength and power peaks in the early evening (Drust et al., 2005). The difference between morning and early evening driving distance was 7.1 yards, which is the distance that separates the top 5 professional players in 2015 PGA driving distance statistics and also separates rank 5th to 17th.

At 10:00 h there was a significant greater smash factor and dispersion of the shot hence lateral landing in yards from target line on the tee shots compared to both 07:30 and 17:00 h (1.45±0.02 *vs* 1.43±0.01 and 1.44±0.01 respectively, $p<0.05$), this could reflect the golfers accuracy and co-ordination to execute the optimal technique at ball strike. However, there was no significant differences between the range of shots preformed at each time of day, nor the distance from the centre target line of where the ball landed ($p>0.05$). Further, there were 8 'Morning Type', 3 'Evening Type' and 4 'Neither' in the golfers used but there was no significant difference between the categories of 'Morning Type', 'Evening Type' and 'Neither' in any tee shot performance variable ($p>0.05$).

Conclusions

The results of the current study suggest that TOD has an effect on a golfer's tee shot performance with an increase of efficiency at impact (smash factor) late morning (10:00 h) and an increase in swing speed and driving distance throughout the day. This research provides valuable educative information for elite amateur and professional golfers about their daily variations in physiological function, and how this may relate to their performance on the course. Further research investigating the efficacy of intervention strategies within training sessions, to allow athletes to modulate the peak in their performance during the day is warranted and also investigations into other aspects of the golfing game such as iron play and putting..

Keywords: Diurnal variation Golf Performance, Chronotype.

References

Drust, B., Waterhouse, J., Atkinson, G., Edwards, B., Reilly, T. (2005), Circadian Rhythms in Sports Performance. *Chronobiology International: The Journal of Biological and Medical Rhythm Research,* 22(1): 21 – 44.

Horne, J. & Östberg, O.(1976) A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms*. International Journal of Chronobiology. 4*: 97-110.

Neuromuscular Fatigue over 2-day Tournament in Category One Golfer

Nicola Rowley, Alex Lindsay & Caroline Westwood

Purpose

Club head speed (CHS) is strongly correlated with golf handicap benefiting golf performance through increased driving distance (r = 0.95) (Fradkin et al., 2014). The importance of maintaining this explosive power movement over a 4hour period on consecutive days is critical for consistent driving and iron performance. Research into the effects of neuromuscular power throughout a 2-day golf tournament has not been previously documented in the literature. Qualitative measures of fatigue can be very subjective whilst objective measures through blood biochemical markers; can however be difficult to employ in an applied environment due to the cost, level of expertise required, and high degree of variability (Halson, 2014). Simple measure of muscle function (eg, jump height) can be used to establish explosive power and neuromuscular fatigue (NMF). The counter movement jump (CMJ) has been associated with fatigue (Gathercole et al., 2015; Taylor, 2012, Komi, 2000), as well as being related to golfer's CHS (Read et al.,2013). CMJ is short in duration involving the explosive movement through the lower and upper body which could link towards a field base marker of neuromuscular fatigue in elite golfers. Observing if CMJ values change over a golfing tournament may indicate NMF induced over the round and/or golf tournament.

Method

Twenty-eight category 1 male golfers from Tournament Golf College (mean±SD, body mass 75.4 ± 10.6 kg, height 179.9 ± 8.6 cm, resting heart rate 68 ± 7 bpm, golf handicap 1.96 ± 2.25, training hours 23 ± 5 hours per/week) consisting of golf practice, strength and conditioning, yoga and cross training. competed in the Algarve Professional Golf Tournament, Portugal. Each round was played on the O'Connor course with an average 18 hole playing time of 5hours 21min. One week prior to the tournament each golfer completed three separate baseline assessments of CMJ for height using arms (Non-ISO) and without using arms, placing them on the hips (ISO) using a portal Just Jump System. On each occasion the highest of three maximal CMJs was recorded and a mean taken and then used as the baseline marker for that individual. The CMJ ISO and NON-ISO were then taken prior to (1 hour before tee time) and concluding (immediately after) each 18 hole round of tournament played over 2 days in a quiet controlled area.

Analysis/Results

Baseline groups values showed the two techniques of CMJ to be NON-ISO CMJ 65.3 ± 4.5 cm with the ISO CMJ being significantly less 60.9 ± 3.4 cm, $p<0.01$. A paired-test (Minitab 17) was used to analyse differences in CMJ from baseline, and from pre to post round. There was no significant difference found from baseline CMJs values to post tournament CMJs values in both techniques. Also between pre to post rounds no significant difference between were found using a CMJ NON-ISO ($p>0.05$). However, there was a significant increase in CMJ ISO measurements pre to post round on both tournament days ($p<0.05$).

Conclusions

Golf is a low level although long duration activity consisting of short bursts of explosive power. The results have shown there is no decrease in CMJ, which can be related to NMF, immediately post competition, although the following day approximately 15 hours post round one, there is a decrease in CMJ values, although significant they are similar to the baseline CMJ on both techniques collected. On both tournament days an increase in ISO CMJ post 18 holes of tournament play which could be a lower body warm up effect after playing as shown in Read and colleagues (2013), where post-activation potentiation creates an acute enhancement in muscle function after activity increasing neural excitability (Hodgson et al., 2005). However, similar results were seen in CMJ protocols in a 2-day women's rugby sevens tournament which elicits substantial muscle damage; yet, little change in lower-body CMJ neuromuscular function (Clarke et al., 2015). The results found could also reflect on the fitness of the golfers used with training hours greater than 23 hours per week NMF may not be seen over a 2 day tournament and with research emerging showing a correlation between professional golfers CHS and squat jump performance which could support this theory that this method of field based assessment of fatigue may not be sensitive enough for this population (Turner, 2016). Further research should assess CMJ ISO over a longitudinal golf tournament season to establish baselines and post competition CMJs fluctuations. The findings of this study may have implications for training and on-course performance enhancement to demonstrate the importance of a pre-competition warm up to prepare the golfer for the first explosive power movement.

Keywords: Golf Fatigue Neuromuscular Warm Up

References

Clarke, A.C., Anson, J.M. and Pyne, D.B. (2015) 'Neuromuscular Fatgiue and Muscle Damage After a Women's Rugby Sevens Tournament', International Journal of Sports Physiology and Performance, 10 pp. 808-814.

Fradkin, AJ, Sherman, CA, and Finch, C. (2014) 'How well does golf club head speed correlate with golf handicaps?' Journal of Science and Medicine in Sport 7:pp. 465–472.

Gathercole, R.J., Sporer, B.C., Stellingwerff, T. and Sleivert, C.G. (2015) 'Comparison of the Capacity of Different Jump and Sprint Field Tests to Detect Neuromuscular Fatigue' Journal of Strength and Conditioning Research 29(9) pp. 2522-2531.

Halson, S.L (2014) 'Monitoring Training Load to Understand Fatigue in Athletes' Sports Medicine 44(Suppl 2): pp. 139–147.

Hodgson, M, Docherty, D, and Robbins, D. (2005) 'Post activation potentiation. Underlying physiology and implications for motor performance'. *Sports Medicine* 35: pp. 585–595.

Komi, P.V. (2000) 'Stretch-shortening cycle: a powerful model to study normal and fatigued muscle. Journal of Biomechanics. 33 pp. 1197–1206

Read, P. J., Miller, S.C. and Turner, A.N. (2013) 'The Effects of Postactivation Potentiation on Golf Club Head Speed' Journal of Strength and Conditioning Research, 27(6) pp. 1579-1582.

Taylor KL. Fatigue monitoring in high performance sport: a survey of current trends. J Austr Strength Cond. 2012;20(1): pp.12–23.

Turner, A.N. (2016) 'Determinants of Club Head Speed in PGA Professional Golfers' Journal of Strength and Conditioning Research (Ahead of print).

Finding Flow: Facilitators of Peak Golf Performance

Daniel Sachau, Luke Simmering, Bob Ono, Warren Ryan & Max Adler

Purpose

The first goal of this study was to assess how frequently recreational golfers experience flow. The second goal was to examine player perceptions of the extent to which a variety of on-course and environmental variables affect flow. Golfers use the phrase *in the zone* to refer to those moments when concentration is narrowed, everything clicks into place, and success feels effortless. Csikszentmihalyi (1975, 1990) labeled this experience *flow* and identified six primary characteristics of the state: (1) a narrow focus of concentration on the activity, (2) merging of action and awareness, (3) lack of self-consciousness, (4) heightened sense of personal control, (5) distortion of time, and (6) enjoyment. Csikszentmihalyi suggests that activities that produce flow are personally challenging, include clear goals, and provide immediate feedback about one's performance. Golf offers all of the prerequisites for flow. It can be challenging, goals are clear, and feedback is both immediate and unambiguous. Golf also includes variables that can take one out of flow. Golf provides distractions (looking for another player's golf ball, etc.), includes many opportunities to become self-aware (long walks between shots, waiting to hit, etc.), and reminds us that there are limits to our control (unlucky bounces, inconsistent swings, etc.). In the few studies that have been conducted on flow and golf, researchers have examined how psychological states before the round affected flow during the round. For instance, Cately and Duda (1997) found that *pre-round readiness* like confidence, positive thinking, and relaxation, all facilitated flow during a round. More recently, Swann used structured interviews of 13 elite golfers (Swan et al. 2012) and 37 professional golfers (Swann et al. 2015) and found, like other researchers, that that pre-round psychological variables had an effect on flow, but the authors also found that some environmental/situational variables could affect flow. For instance, poor weather or slow play could undermine flow. A caddie could help facilitate flow. The current study expands on the work of Swan et al. (2012, 2015) and focuses on the on-course variables that influence flow.

Method

Members of the Minnesota Golf Association (n = 2113) completed an online survey containing questions about the frequency with which they experienced flow. Participants also rated how 38 variables affect flow (1 = reduces the chance of being in the zone, 2 = has no effect, 3 = increases the chance of being in the zone). The typical participant played about 11 rounds per month, was male (85% were), was 55.0 years of age, and had solid golf skills (M = 12.8 handicap index).

Analysis/Results

A small percentage of golfers (7.5%) said they experience flow in 1 or more out of every 10 rounds. Just over 3% said they have never experienced flow when playing golf. The modal response was 1 time in 25 rounds. The variables that had the most positive effect on flow (were rated as increasing the chance of being in the zone) included playing well = 93%, vizualizing one's shots before hitting them = 86.2%, using a pre-shot routine = 79.2%, nice weather = 77.6%, not thinking – just swinging = 72.9%, thinking about making a good shot = 71%, competition = 62.1%, swinging at about ¾ strength = 56.7%, and focusing on the ball (rather than oneself) during the swing = 53.7%. The variables with the most negative effect on flow included playing poorly = 93.3%, swinging as hard as you can = 89.4%, slow play of others = 88.5%, thinking about avoiding a bad shot = 87.8%, worrying about something that is not golf-related = 84.9%, thinking about one's score = 77.4%, uncomfortable weather = 69.9%, someone providing swing advice = 66%, minor fatigue or pain = 62%, and focusing on swing mechanics during the swing = 59.2% (differences between percentages greater than 4 percentage points are significantly at $p < .01$). Finally, there was a negative correlation between handicap and flow frequency $r(2066) = -.23$, $p < .0001$. Better golfers experience flow more frequently than the less skilled.

Conclusions

The results of the study are consistent with studies on the effects of pre-round psychological states and course conditions on flow (Cately & Duda,1997; Swann et al., 2012). The main findings are that flow is a positive experience but is relatively rare on the golf course. Playing well is highly associated with flow. Good play might be both the cause and the effect of flow. Players who want to experience more flow should focus on the game (ball, course, flight path) rather than themselves when playing. Positive mental imagery will help facilitate flow and negative imagery (concern over avoiding bad shots) will undermine it. Competition facilitated flow for some golfers and undermined it for others. Flow is paradoxical, thinking about it eliminates it. This suggests a complicated model of focus involving moderate effort and positive expectations for performance without much self-reflection about one's role in that performance.

Keywords: Golf, Flow, Concentration, Performance

References

Cately, D. & Duda, J. (1997). Psychological antecedents of the frequency and intensity of flow in golfers. *International journal of Sport Psychology, 28*, 309 – 322.

Csikszentmihalyi, M. (1975). *Beyond boredom and anxiety*. San Francisco: Jossey-Bass.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper and Row.

Swann, C., Keegan, R., Piggott, D., Crust, L., & Smith, M. F. (2012). Exploring flow occurrence of elite athletes. *Athletic Insight, 4,* 2, 171-186.

Swann, C., Piggott, D., Crust, L., & Keegan, R., Hemmings, B. (2015). Exploring the interactions of underlying flow states: A connecting analysis of flow occurrence in European Tour golfers. *Psychology of Sport and Exercise, 16*, 3, 60 – 69.

What's in a Name? Brand Equity of Golf Drivers

Daniel Sachau, Eric Schinella & Luke Simmering

Purpose

Brand equity is the value of a product attributable to the product's brand name or logo. One measure of equity is the additional amount a person is willing to pay for a product simply because the brand name is associated with the product. Equity is affected by the extent to which consumers are aware of the brand, the positive or negative associations consumers make regarding the brand, perceptions of product quality, and brand loyalty (Washburn, Till, & Priluck, 2004). The purpose of this study was to examine brand equity for popular golf club manufactures.

Method

Participants (n = 3,340) were *active* golfers and members of a U.S. State Golf Association who responded to an on-line survey. The typical participant had been playing golf for 35 years, was 55 years old, had a 12 handicap, and had purchased 2 drivers (M = 2.5) over the last five years. Participants were asked to identify their favorite brand of driver among: Adams, Callaway, Cleveland, Cobra, Mizuno, Nike, Ping, TaylorMade & Titleist. Then participants were presented with an image and a description of new "longer hitting" driver (designed for this study) and asked how much they would be willing to pay for this innovative new driver from their favored company (their favored company logo auto-filled on the image). Participants were then presented with an image and description of an identical driver but with a generic label (USA Golf). Participants were asked how much more, if any, they would be willing to pay for the branded driver than the generic driver. Participants were also asked to identify which accessories they owned containing the logo of their favored brand (hats, golf shirt, golf bag, jacket, office decoration, auto decoration, glove). Finally, participants completed a 10-item brand attitude scale including questions about product quality, personal identification with the brand, and brand loyalty. Scores on these items were summed to create an Attitude Scale score (*alpha* = .84).

Analysis/Results

Because there were relatively few participants who chose Adams, Cleveland, or Nike as their favored driver, these brands were eliminated from further analysis. As Table 1 suggests, means for financial brand equity ranged between \$84 and \$117. Equity was negatively correlated with willingness to purchase an identical club labeled with a generic brand $r(2339) = -.50$, $p<.01$. The Attitude Scale score was modestly correlated with the measure of brand equity, $r(3158) = .22$, $p<.001$ and more meaningfully correlated with the number of similarly branded accessories a player owned $r(3158) = .40$, $p < .001$. The Attitude Scale was more highly correlated with brand equity $r(3158) = .22$, $p<.001$, than it was with brand price $r(3158) = .14$, $p<.001$, Diff Z = 3.29, $p<.002$.

Table 1

Equity for 5 Golf Driver Brands

	Favored Brand				
	TaylorMade	Callaway	Cobra	Ping	Titleist
N of participants who favored brand	1478	509	157	598	487
Mean price willing to pay for new driver	\$270.11$_a$	\$273.26$_a$	\$249.78	\$287.67	\$319.38
Equity or mean dollar value from answer to: How much more are you willing to pay for brand ____ than an identical generic?	\$84.32$_a$	\$85.91$_a$	\$88.50$_a$	\$103.68$_b$	\$117.00
Percent of participants within a brand who would **not** consider buying an identical but generic driver	22%$_a$	20%$_a$	25%$_b$	25%$_b$	30%
Mean Attitude Scale score	31.0$_a$	31.2$_a$	30.9$_a$	33.2$_b$	34.4
Mean number of similarly branded accessories players owned	1.7$_a$	2.4$_b$	1.0$_c$	2.1$_d$	3.0$_e$
USGA Handicap Index	12.45$_a$	13.91$_b$	15.58$_c$	11.7$_d$	7.91

*Means not sharing a subscript are significantly different at p < .05

Conclusion

There have been very few studies examining brand equity of golf manufactures. This study was one of the first. Brand equity for drivers could indeed be reduced to a dollar value and that value differed across brands. Interestingly, the most popular brands (in sales) were not necessarily the brands with the greatest brand equity. TaylorMade was favored nearly two to one over the other drivers, but it did not have the highest equity. Although the attitude and equity measures were correlated, the correlation was not as high as one might expect. Perhaps this was because attitudes towards any given brand were not very strong, and attitudes across brands were fairly similar. Drivers are thus easily substitutable. Nonetheless, attitude towards a brand was more highly related to the *extra* a golfer was willing to pay for a club (equity) than to the overall amount he or she was willing to pay for a club. This study opens the door for more research on ways to examine factors that shape golf brand equity.

Keywords: Golf Equipment, Brand Equity

References

Washburn, J. H., Till, B. D., & Priluck, R. (2004). Brand alliance and customer-based brand-equity effects. *Psychology & Marketing*, *21*(7), 487-508.

The Mentoring of Professional Golf Instructors

Paul Schempp, Bryan McCullick, Dawes Marlatt, Todd Sammons

Purpose

Research has consistently supported the notion that mentoring is amongst the most effective methods of socializing new members into a profession (Ragins, Cotton, & Miller, 2000). Mentoring has been shown to increase career mobility and opportunities (Allen & Poteet, 1999) as well as increased work-related satisfaction and success for both mentor and protégé (Hurst & Koplin-Baucum, 2003). Therefore, the purpose of this study was to investigate the impact of a mentor education program on golf professionals.

Method

Participants: Forty one PGA Class A professionals and apprentices who are or will be in a mentoring relationship volunteered to participate in this study. They were invited to participate in this study while attending a mentoring presentation at the 2016 PGA Education program at the annual PGA Show, Orlando, FL.

Procedures: The researchers planned and conducted two, one-hour mentoring presentations at the PGA Show, January 2016 in Orlando, FL, USA. One presentation provided content and activities on developing effect mentoring relationships and the second program focused on mentor roles, responsibilities and skills. At the conclusion of each course, participants completed an informed consent document and the Mentor Training Survey (for either Mentor or Protégé) (Fleming, et al., 2013). Six weeks later a link to the questionnaire was emailed to the participants. Out of the 41 participants, 27 completed the questionnaire (a 65% response rate).

Analysis: As the intend of the study was to assess the efficacy of a mentoring education program, descriptive statistics were calculated to determine any changes in mentoring quality or effectiveness.

Analysis/Results

Prior to the program, participants estimated the quality of their mentoring to be an average of 4.14 (SD=0.69) on a scale of 1-10, with 10 being the highest quality score. After the program, the PGA professionals believed the quality of the mentoring increased to 5.71 (SD=0.49). Further, the participants believed they increased the effectiveness in meeting the needs of their mentees (Pre-program M=4.29, SD= 1.11; Post-program M=5.57, SD=0.53). Finally, 86% of the participants reporting having made or planning to make changes in their mentoring as a result of this training.

Conclusions

This is the first study completed in the area of professional golf instructor mentoring. The findings will have import for both instructors seeking a quality mentoring experience and for professional associations designing and offering instruction to improve member mentoring. Based on the findings, it can be concluded that a mentoring education program that provides participants with information on developing effective mentoring relationships and essential mentoring skills appears to increase both the quality and effectiveness of golf professional mentoring.

Keywords: Golf Instructor Mentoring, Golf Instructor Development

References

Allen, T. D, & Poteet, M. L. (1999). Developing effective mentoring relationships: Strategies from the mentor's viewpoint. *Career Development Quarterly, 48*, 59.

Fleming, M., House, S., Hanson, V., Lu, L., Garbutt, J., McGee, R., Kroenke, K.,, Abedin, Z., & Rubio, D. (2013). The mentoring competency assessment: Validation of a new instrument to evaluate skills of research mentors. *Academic Medicine, 88*, 1002-1008.

Hurst, S., & Koplin-Baucum, S. (2003). Role acquisition, socialization, and retention: Unique aspects of a mentoring program. *Journal for Nurses in Staff Development, 19,* 176–181.

Ragins, B. R., Cotton, J. L., & Miller, J. S. (2000). Marginal mentoring: The effects of type of mentor, quality of relationship, and program design on work and career attitudes. *Academy of Management Journal, 43*, 1171-1194.

What the Research Says About Good Golf Instruction

Paul Schempp, Bryan McCullick, Collin Webster & Michael Breed

Purpose

The importance of good golf instruction has not escaped the notice of researchers in recent times. The research has, however, been scattered and isolated investigations have been the norm. The purpose of this paper is to summarize the research completed on golf instruction in the last two decades in order to offer golf instructors practical suggestions for improving instruction.

Method

Procedures: The authors undertook a literature review on golf instruction with a focus on a) golf instructor education, certification & development, b) characteristics and qualities of expert golf instructors, and c) the skills of expert golf instructors. The literature was conducted by entering keywords associated with the specific topics into the following databases: Education Research Complete, ERIC, Medline, Physical Education Index and Sport Discus. From the identified articles, articles were selected that met the all of the following criteria: a) data based research (quantitative or qualitative), b) participants were golf instructors, and c) articles published in the last 20 years. The authors recognize that the review includes research published only in English.

Analysis/Results

A total of 30 research publications were selected for inclusion in this review. From this body of scholarship, the authors attempted to group the articles to identify trends or themes in the research findings as they pertained to golf instruction. Five themes were identified: a) factors that contribute to effective golf instructor certification, b) strategies used for individual professional development, c) the impact of technology on golf instruction, d) effective instructional interactive behavior, e) communicative skills of expert golf instructors.

Conclusions

The current research on golf instruction and instructors reveals several patterns that can be adopted by a golf instructor to improve the quality of her or his teaching. First, it appears that the use of video analysis and computer assisted instruction can both benefit student learning. Second, expert teachers appear to talk less, listen more, observe longer and use more metaphors in explaining concepts during a lesson than less expert teachers. Consequently, when they do speak to students what they say is based on in-depth observations and tailored to what the students have told them. Third, expert teachers adapt their communication style to students' background, experiences, interests, and cognitive style. Fourth, teachers need to vary their instruction based on students' expertise and gender. Finally, when implementing a elite player training program, organization and structure are important factors.

*Keywords**:** Golf Instruction, Expert Golf Instruction, Communication, Golf Professional Certification*

An Investigation Into Golf Ball Speed at Hole Entry

Jonathon Sheppard, Paul Hurrion & Andrew Collinson

Purpose

Speed has a significant effect on putting results and should be considered an important factor when putting at any level (Pelz, 2000). Despite this, the ability to control speed can often be overlooked. The aim of this study was to investigate the effect of a 3° slope on ball kinematics. The primary objective was to identify differences in the speed of putts that finished 0.30 m past the hole and to determine any effect that this might have on the effective size of the hole. Previous research has identified the optimum speed of a putt should finish 9 inches (Aimpoint, 2013) and 17 inches (Pelz, 2000) past the hole. An intermediate of 0.30 m (1 ft) was chosen as this is also a common distance referred to by professional golfers.

Method

Twelve positions were located equally around a ghost hole in a clock face orientation, 1.20 m from the centre of the hole (Figure 1). The Perfect Putter (The Perfect Putter, USA), a putting ramp with exact release heights, allows for consistent speed and was used to perform three putts from each position. Each putt had to pass through the centre of the hole and stop on a ring marked 0.30 m from the back of the hole to count as a valid trial. A high speed camera (Quintic USB3 4MP) was positioned above the green and recorded the ball within the 30 cm ring at 200fps (800 x 800 pixels). Quintic Biomechanics software (Quintic Consultancy Ltd.) was used to automatically digitise each putt and subsequently ball velocity, distance travelled and time taken were calculated using X and Y co- ordinates. All variables were measured at five intervals (Figure 1). The protocol was repeated on two different surfaces; a Huxley putting green (Stimp 11) and a putting carpet (Stimp 10.5), both on a slope of 3°.

Analysis/Results

When putting directly up the slope from 6 o'clock, the average velocity at the front of the hole was 0.66 ms^{-1} ± 0.00 (Huxley) and 0.71 ms^{-1} ± 0.02 (Putting carpet). However, when putting directly down the slope from 12 o'clock, the average velocity was 0.29 ms^{-1} ± 0.04 and 0.25 ms^{-1} ± 0.04 respectively.

Putts directly up the slope were over two and a half times faster at the front of the hole compared to those directly downhill (Table 1), a total increase of 156%. Additionally, distance travelled to reach the line 0.30 m after the hole was on average 0.03 m greater when from the 4 and 8 o'clock positions (0.35 m ± 0.02) as opposed to 12 and 6 o'clock (0.32 m ± 0.03), due to the curvature of the path of the ball as it comes to rest. This was reduced to only 0.02 m greater from 10 and 2 o'clock positions (0.34 m ± 0.01), indicating that there is a more substantial break when putting up a slope (Table 2).

Conclusions

The results found help to highlight the importance of ball speed when putting. Holmes (1991) & Wesson (2008) described how the effective size of the hole is reduced when balls approach at high speeds due to an increased chance of either a lip out or by rolling straight over the hole. By comparing the results obtained from this study to their mathematical models, it can be determined that when putting directly up the slope, 0.66 – 0.71 ms^{-1}, the effective size was reduced by approximately 25% (Figure 2). However, when putting directly down the slope, 0.25 – 0.29 ms^{-1}, this resulted in an approximate decrease of only 5%. Equally, if a downhill putt travelling 0.71 ms^{-1} at the front of the hole actually missed, then this would leave an uphill putt of over 4 ft. This brings implications to players of all abilities and probes the question should golfers be more concerned with finishing a certain distance past the hole, or optimising the effective size of the hole to give them the best chance when putting. The uphill putt is often perceived by golfers as the easiest putt, however on a 3° slope with the ball finishing 1 ft past the effective size of the hole is reduced by 25%.

Keywords: putting; slope; speed; performance

References

Donaldson, J. (2013, March). Green Reading: Need for correct speed. Aimpoint Golf. Retrieved from https://aimpointgolf.wordpress.com/2013/03/01/need-for-correct-speed/

Holmes, B. W. (1991). Putting: How a golf ball and hole interact. American Journal of Physics, 59, 129-136.

Pelz, D. (2000). Dave Pelz's Putting Bible: The Complete Guide to Mastering the Green. New York: Doubleday.

Wesson, J. (2008). The Science of Golf. Oxford: Oxford University Press.

Appendix

Table 1. Mean velocity ± SD for each surface 30 cm prior to the front of the hole and at the front of the hole (m/s)

Surface	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock
	Velocity 30 cm from the front of the hole (m/s)											
Huxley	0.34 ± 0.03	0.40 ± 0.05	0.51 ± 0.00	0.64 ± 0.02	0.77 ± 0.00	0.84 ± 0.02	0.85 ± 0.00	0.71 ± 0.02	0.63 ± 0.02	0.44 ± 0.02	0.38 ± 0.01	0.39 ± 0.02
Putting Carpet	0.40 ± 0.01	0.43 ± 0.00	0.52 ± 0.01	0.67 ± 0.00	0.86 ± 0.09	0.90 ± 0.02	0.88 ± 0.01	0.80 ± 0.01	0.65 ± 0.03	0.54 ± 0.03	0.47 ± 0.03	0.38 ± 0.02
	Velocity at front of the Hole (m/s)											
Huxley	0.26 ± 0.03	0.30 ± 0.05	0.40 ± 0.01	0.50 ± 0.03	0.63 ± 0.01	0.66 ± 0.00	0.69 ± 0.01	0.53 ± 0.05	0.47 ± 0.01	0.33 ± 0.03	0.26 ± 0.01	0.29 ± 0.03
Putting Carpet	0.27 ± 0.01	0.30 ± 0.02	0.38 ± 0.02	0.50 ± 0.00	0.64 ± 0.03	0.71 ± 0.01	0.69 ± 0.01	0.63 ± 0.02	0.47 ± 0.03	0.38 ± 0.02	0.32 ± 0.01	0.25 ± 0.04

Table 2. Distance travelled past the back of the hole to reach the 0.30 m ring from each position (mean ± SD)

Surface	Distance from the back of the hole to reach the 0.30 m ring (m)											
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock
Huxley	0.32 ± 0.01	0.34 ± 0.02	0.36 ± 0.01	0.34 ± 0.00	0.33 ± 0.01	0.34 ± 0.01	0.34 ± 0.00	0.35 ± 0.01	0.37 ± 0.03	0.33 ± 0.00	0.33 ± 0.01	0.28 ± 0.03
Putting Carpet	0.32 ± 0.00	0.34 ± 0.01	0.37 ± 0.02	0.37 ± 0.00	0.32 ± 0.00	0.34 ± 0.01	0.35 ± 0.00	0.34 ± 0.01	0.35 ± 0.01	0.33 ± 0.00	0.31 ± 0.01	0.32 ± 0.01

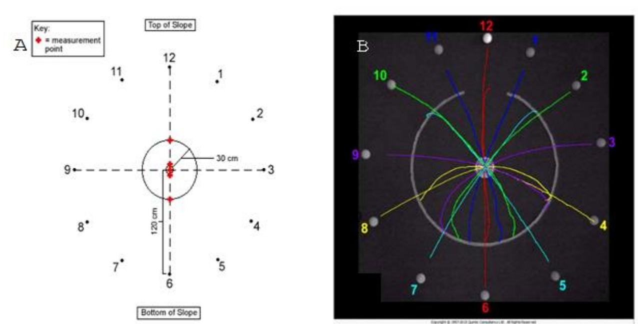

Figure 1. A = experiment set up including: slope orientation, distance of each putt and back of hole to ring; B = digitised traces from each position giving a visual representation of the path from each position.

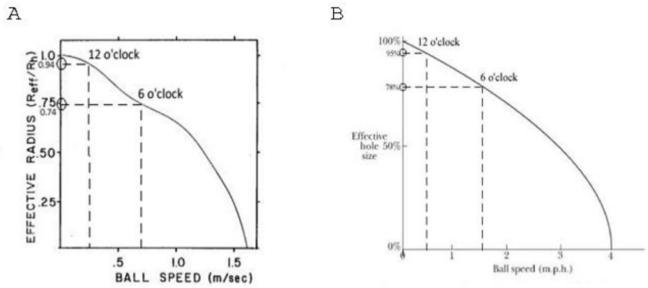

Figure 2. A = Holmes' (1991) representation of how the effective hole size changes relative to ball speed. The velocities obtained from 12 o'clock and 6 o'clock are marked with corresponding hole size (%); B = Wesson (2008) representation of effective hole size.

The Relevance of the 10k Hour Hypothesis in Golf

Christopher Smith

Purpose

The purpose was to assess the validity of the hypothesis that achieving world-class expertise in golf, previously attributed predominantly to innate talent, is largely a result of deliberate practice (a minimum of 10,000 hours or 10 years). Deliberate practice involves effortful activities designed to improve performance while negotiating motivational and external constraints (Ericsson, Krampe & Tesch-Romer, 1993).

Method

The validity of the hypothesis was examined in relation to the evidence found in the (a) research literature (including a meta-analysis and case studies); (b) a 2 ½ year case study conducted by the author; (c) personal accounts (anecdotal evidence); and (d) opinions of scholarly experts.

Analysis/Results

An analysis of expert performance (Ericsson et al. 1993) concluded that in most domains of expertise, individuals begin in their childhood a regimen of effortful activities designed to optimize improvement. Individual differences, even among elite performers, are positively related to the assessed amounts of deliberate practice. Many characteristics once believed to reflect innate talent are actually the result of intense practice extended for a minimum of 10 years, or 10,000 hours of deliberate practice.
A recent meta-analysis (Macnamara, Hambrick & Oswald, 2014), based on 66 studies, examined expertise of 11,135 participants in the areas of music, games, sports, professions and education where the relationship between practice and performance had been investigated. The analysis revealed that deliberate practice explained 26% of the variance in performance for games, 21% for music, 18% for sports, 4% for education, and less than 1% for professions.
David Epstein (2013), in the book titled "The Sports Gene," documented examples of high level athletes and performers who have achieved world class levels with far less than 10,000 hours of deliberate practice. Epstein quotes a South African researcher who said that "We've tested over ten thousand boys and I've never seen a boy who was slow become fast." His findings predominately do not support the 10k hour hypothesis.
The "Dan Plan" was a case study that tested the 10k hour hypothesis (GolfWeek, John Maginnes, 2012). In April of 2010, 32-year-old Dan McLaughlin started golf "from scratch" with the goal of attaining membership on the PGA Tour with 10,000 of deliberate practice. As of April 1, 2015, Mr. McLaughlin posted an index of 5.5. Dean Knuth (2013, Golf Digest), former senior director of the USGA handicap department, stated that most PGA Tour players would have an index of around +5.
Greg Norman began playing golf at 15 and within about 18 months went from a 27 index to a 0. He later spent 331 weeks became the #1 ranked golfer in the world. Norman's rapid progress from novice to scratch in approximately 18 months does not support the 10k hypothesis.
Larry Nelson didn't play golf as a child, which was unusual for a successful professional golfer. He began golf at the age of 21, broke 100 the first time he played and 70 within nine months. Nelson qualified for the PGA Tour at the age of 27, won 10 times on that Tour, including three major championships. Nelson's late entry into the game and accelerated development does not support the 10k hypothesis.
Calvin Peete began playing golf at the age of 23 and within six months of taking up the game was breaking 80; a year later he was breaking par. At the age of 32, he earned his PGA Tour membership, won 12 times on Tour including, and led the PGA Tour in driving accuracy for 10 straight years. Like Nelson, Peete's late start in the game and his expeditious ascent to an elite level does not support the 10k hypothesis.
Dr. Tucker and Dr. Ericsson's had a 2012 BBC World Service radio debate on the topic of "training vs. talent" or "The 10,000 hour vs genetic debate" (http://sportsscientists.com/2012/03/10000-hours-vs-training-debate/#.UM8vh7BVjD8.twitter). In one of Dr. Tucker's responses to Dr. Ericsson, he clearly stated that Ericsson's own studies had tried to explain performance level as a function of training, yet the research he had been involved in shows that only a very small part of performance can be explained by practice. Only 28% (incredibly low) of the variance in darts performance, for example, is explained by the number of hours practiced. The question begets, then: what then is the remaining 72% to be attributed to?

Conclusion

The evidence found does not conclusively support the 10,000 hour hypothesis that deliberate practice is the predominant determinant of world-class expertise in golf. Generalizing from the evidence found, deliberate practice, at best, appears to account for no more than 20% of one's expertise in golf.

References

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological *Review,* 1993, Volume 100, No. 3, 363-406.
http://projects.ict.usc.edu/itw/gel/EricssonDeliberatePracticePR93.pdf
http://www.smithsonianmag.com/smart-news/10000-hour-rule-not-real-180952410/?no-ist
Macnamara, B., Hambrick, D., & Oswald, F. (2014). Deliberate practice and performance in music, games, sports, education and professions: A meta-analysis. Psychological Science, 25, 1608-1618. doi: 10:1177/0956797614535810.
http://scottbarrykaufman.com/wp-

content/uploads/2014/07/Macnamara-et-al.-2014.pdf
Epstein, David (2013). *The Sports Gene: Inside the Science of Extraordinary Athletic Performance.* New York: Current (Penguin).
John Maginnes (2012). Maginnes On Tap: The Dan Plan. *GolfWeek.*
Dean Knuth (2013). *Golf Digest*.
http://thedanplan.com/
https://en.wikipedia.org/wiki/Greg_Norman
https://en.wikipedia.org/wiki/Larry_Nelson
https://en.wikipedia.org/wiki/Calvin_Peete
http://sportsscientists.com/2012/03/10000-hours-vs-training-debate/#.UM8vh7BVjD8.twitter

Age Related Differences in Lung Function between Female Recreational Golfers and Less Active Controls

Simon Brown, Dinesh Samuel, Sandra Agyapong-Badu, Isabel Herrick, Andrew Murray, Roger Hawkes & Maria Stokes

Purpose

Golf is associated with greater life expectancy in all socio-economic groups (Farahmand et al., 2009) and improves physical function, including aerobic performance, trunk muscle endurance and body composition (Pakkari et al., 2000), and balance (Gao et al., 2011). Regular physical activity decreases premature mortality by 30% and can help prevent and treat over 20 chronic diseases (Chief Medical Officer, Scotland, 2011). Improved strength of the respiratory muscles may play a role in the beneficial effects of physical activity in older people and this has yet to be examined for golf. The purpose of the present study was to determine whether playing recreational golf at a social level is associated with preserved lung function compared to sedentary controls in older females.

Method

Five groups of healthy females were recruited from golf clubs and the community in Hampshire (total n=132): (1) young sedentary (n=28, mean age 27.2 ± SD 4.8 years, range 19-35); (2) older golfers under 80 years (n=32, mean age 69.1, SD ± 3.4, range 65-77); (3) older non-golfers under 80 (n=33 aged 73.0 ±4.0, range 66-79); (4) golfers over 80 years (n=21, aged 82.9 ± 2.1, 80-87); (5) non-golfers over 80 years (n=18, mean age 83.0 ± 3.5, range 80-90). For inclusion, golfers had to be playing a minimum of one round/week (18 holes, walking between holes) for at least two years. Typically, golfers had played for over 30 years, 2-3 times/week. A subset of questions from the Physical Activity Scale of the Elderly (PASE) were used to ensure control participants were less active than golfers (Loland, 2002). Controlled medical conditions (e.g. diabetes, osteoarthritis) were permitted, to reflect the older population. Respiratory function was measured using a portable hand-held peak flow meter (PFM; Airmed, Mini-Wright). Peak flow was selected as the lung function variable, as it reflects respiratory muscle strength. The best of three maximal expiratory efforts, with the participant standing, was taken as Maximum Peak Expiratory Flow (PEFmax).

Analysis/Results

Data analysis: group means and standard deviations were calculated. A one-way ANOVA, with a Tukey HSD post-hoc test, examined for significant differences between groups.
Results: In the non-golfing groups, PEFmax declined significantly with age: from 388 ±80 l/min in 19-35 year olds to 319 ±59 in 65-79 yrs olds (p=0.001), and 263 ±77 in those over 80 years (p=0.036 vs 65-79 years). The PEF Max in golfers aged 65-79 (366 ±64) was not significantly different (p=0.722) from that in the younger (19-35) sedentary group, so had not declined, and was significantly greater than in their sedentary counterparts aged 65-79 years (p=0.033). In the over 80s golfers (299 ±43), PEF Max was no different to the 65-79 non-golfers (p=0.805).

Conclusions

Playing recreational golf regularly is associated with preserved lung function with ageing. These novel findings on respiratory function build on the existing evidence which suggests that encouraging participation in golf for all ages may have significant public health benefits. This cross-sectional study in self-selected groups merits further research involving prospective intervention studies, to substantiate the conclusion on slowing the rate of decline in lung function and also determine how reversible the loss of function is when golf is taken up in later life.

Keywords: Golf, Ageing, Lung function, Peak flow, Physical Activity

References

Annual Report of the Chief Medical Officer. Health in Scotland (2011). Transforming Scotland’s Health, pp13-15. www.scotland.gov.uk

Farahmand B, BromanG, de Faire U, Vagero D, Ahlbom A. (2009). Golf: a game of life and death – reduced mortality in Swedish golf players. *Scandinavian Journal of Medicine & Science in Sports, 19*, 419–424.

Gao K, Hui-Chan C and Tsang W. (2011). Golfers have better balance control and confidence than healthy controls. *European Journal of Applied Physiology, 111,* 2805-2812.

Loland, N. (2002). Reliability of the physical activity scale for the elderly (PASE). European Journal of Sport Science, 2(5), 1-12

Pakkari J, Natri A, Kannus P, Mänttäri A, Laukkanen R, Haapasalo H, Nenonen A, et al. (2000) A controlled trial of the health benefits of regular walking on a golf course. *American Journal of Medicine, 109*(2), 102-108.

Anterior Thigh Composition Using Ultrasound Imaging in Mature Female Recreational Golfers

Isabel Herrick, Simon Brown, Sandra Agyapong-Badu, Martin Warner, Sean Ewings, Dinesh Samuel & Maria Stokes

Purpose

Recreational golf is associated with better cardiovascular health and musculoskeletal function (Pakkari et al., 2000) and greater life expectancy (Farahmand et al., 2009). Regular physical activity decreases premature mortality by 30% and helps prevent and treat chronic diseases (CMO Scotland, 2011). The quadriceps muscle is important for mobility, particularly in older people. Differences in relative muscle thickness to subcutaneous fat were found between healthy sedentary young and older adults, suggesting that thigh composition may be a useful indicator of musculoskeletal health with ageing (Agyapong-Badu et al., 2014). The aims were to: 1) assess thigh composition in older female recreational golfers to see if they had greater relative quadriceps muscle and less subcutaneous fat than less active older females; 2) examine the feasibility of ultrasound imaging to make simple, rapid thigh thickness measurements in older females in a community setting.

Method

Thirty one recreational female golfers (mean age 69.1 years, range 65-77 years) were recruited. Scans from sedentary females (35 non-golfers, aged 73.4, 66-80 years) from a related study of up to 90 year olds (Agyapong-Badu et al., 2014) were reanalysed. The Physical Activity Scale for the Elderly (PASE; Loland, 2002), was used to ensure controls were less active than golfers, who had to play a minimum of one round (walking 18 holes) per week. Ultrasound Images of the dominant anterior thigh (all right dominant, so trail leg) were obtained using real-time B-mode ultrasound scanning (5-6.6 MHz curvilinear transducer), with the participant supine. Thickness of rectus femoris (RF), vastus intermedius (VI), subcutaneous fat and perimuscular fascia was measured off-line.

Analysis/Results

Tissue layer thicknesses were presented as means and standard deviations for each group and percentage contributions of each tissue layer were calculated. Data from golfers were compared with reanalyzed data from the sedentary group, in whom analysis of scans had previously excluded intermuscular (deep) fascia between RF and VI. The present study included the intermuscular fascia to provide a more rapid assessment technique (Aim 2), so required reanalysis of the data from sedentary group. Non-contractile tissue thickness included subcutaneous fat and superficial fascia.

Muscle thickness was significantly greater in golfers (2.8±0.7cm) than non-golfers (2.2±0.6cm); mean difference 0.6cm ($p<0.001$). Percentage contribution of muscle to anterior thigh thickness was 64±9 in golfers and 58±8 in non-golfers (mean difference 6%; $p=0.013$); and contribution of non-contractile tissue was 36±9 in golfers and 42±8 in non-golfers (mean difference 6%; $p=0.013$). Multiple linear regression analysis, controlling for age and BMI, showed that golfers had greater total anterior thickness (B = -0.984; CI, -1.64,-0.32; $p=0.004$) and greater muscle thickness (B = -0.619; CI -1.0, 0.29; $p=0.002$), compared to non-golfers. Golfers scored higher on the SF36 for physical parameters (Physical Function, Physical, General Health, less pain) but the two groups were similar for psychosocial parameters.

Conclusions

Moderately active older female golfers had greater relative muscle thickness and lower subcutaneous fat, and better physical function, than less active females. Their leaner thigh composition may indicate better musculoskeletal health. These findings could be used to inform further golf-specific studies, such as training effects on particular muscles. Simple, rapid, non-invasive ultrasound measurements of muscle size provide an indirect measure of strength, without reliance on voluntary effort and are potentially useful for monitoring effects of interventions in community settings.

Keywords: thigh composition, quadriceps muscle, ultrasound imaging, ageing, golf

References

Agyapong-Badu S, Warner M, Samuel D, Cooper C & Stokes M (2014) Anterior thigh composition using ultrasound imaging to quantify relative thickness of muscle and non-contractile tissue: a potential biomarker for musculoskeletal health. *Physiological Measurement*, *35*(10),2165-2175

Chief Medical Officer Annual Report. Health in Scotland. (2011): Transforming Scotland's Health, pp13-15. www.scotland.gov.uk

Farahmand B, BromanG, de Faire U, Vagero D, Ahlbom A. (2009). Golf: a game of life and death – reduced mortality in Swedish golf players. *Scandinavian Journal of Medicine & Science in Sports, 19*,419–424.

Loland, N. (2002). Reliability of the physical activity scale for the elderly (PASE). *European Journal of Sport Science*, *2*(5),1-12

Pakkari J, Natri A, Kannus P, Mänttäri A, Laukkanen R, Haapasalo H, Nenonen A, et al. (2000). A controlled trial of the health benefits of regular walking on a golf course. *American Journal of Medicine*, *109*(2),102-108.

Comparative Analysis of Iron and Driver Swing Dynamics Using High Resolution Motion Capture

Thomas Trueblood, Erik Henrikson & Paul Wood

Purpose

Due to the difference in length, lie angle, and head shape between an iron and a driver, most golfers will swing each club with different techniques and delivery dynamics. One club delivery parameter that has interested the coaching community is the clubface closing rotation rate at impact, or closure rate. The logical hypothesis is that a faster closure rate yields a lower probability of consistent face angle delivery and thus reduced driving accuracy (Cheetham, 2014), but recent advances in motion capture technology permit the scientific observation of these club delivery dynamics (Wright, 2008). Cheetham used electromagnetic motion capture to examine the relationship between driving accuracy and driver handle twist velocity (a component of closure rate) for tour professionals in 2014 and found no correlation. This study explores the large driver and iron datasets collected with the PING ENSO motion capture system in combination with PING's player testing database to explore the relationships of club delivery kinematics for a player's iron and driver swings and establish any correlation between closure rates and shot consistency for different handicap groups.

Method

PING operates an optical motion capture system called ENSO that tracks the precise motion of a golf club throughout a full swing. Each swing is run through a series of kinematic fitting algorithms to derive common club delivery dynamics such as attack angle and delivered loft. For this study, two tests were executed to capture the driver and iron swings from 110 players. In each test, players hit five shots in ENSO with a driver and 7-iron and recorded their current handicap and fitting information. Separately, PING's player testing database was mined to determine iron and driver shot consistency for players who regularly participate in player tests.

Analysis/Results

This dataset was first analyzed to establish the relationship between driver and iron closure rate on a per-player basis. The data was first sorted by handicap (HCP), which yielded 24 players with HCP<5, 40 players with 5≤HCP<14, and 46 players with HCP≥15. Table 1 shows the mean and standard deviation of HCP, driver and 7-iron speed, and driver and 7-iron closure rate for the three handicap groups. A least-squares regression analysis between iron and driver closure rates demonstrated a moderate positive correlation for the low and mid HCP groups but very weak correlation for the high HCP group, as shown in Figure 1.

		HCP		Driver Speed (mph)		7-Iron Speed (mph)		Driver Closure Rate (deg/sec)		7-Iron Closu Rate (deg/se	
	# Players	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low Group (HCP < 5)	24	0.8	2.4	103.6	6.9	86.7	6.6	2474	396	2411	31
Mid Group (5 = HCP < 15)	40	9.6	2.8	99.3	7.3	82.7	5.7	2660	560	2435	43
High Group (HCP > 15)	46	22.9	7.5	87.1	11.5	73.2	10.8	2442	512	2296	51
All Players	**110**	**13.2**	**10.2**	**95.1**	**11.5**	**79.6**	**10.1**	**2528**	**513**	**2371**	**45**

Table 1. Mean and standard deviation of key metrics for different handicap groups.

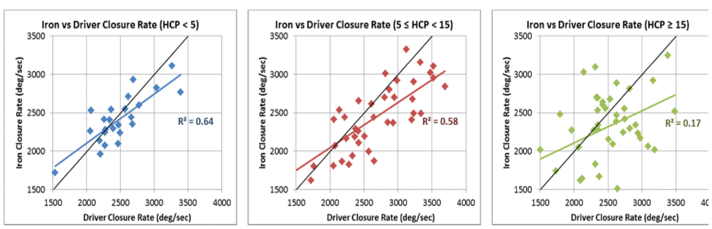

Figure 1. Correlation scatterplots comparing 7-iron and driver closure rate for different handicap groups.

The second phase of analysis involved querying PING's player testing database to ascertain each player's shot consistency for 7-iron and driver using a weighted sum of the standard deviations of carry distance, offline distance, launch angle, and spin rate for the player's most recent five player tests. Least- squares regression analysis with this merged dataset showed no correlation between closure rate and iron or driver consistency for any HCP group, with all R^2 values below 0.1.

Conclusions

Initial results show moderate correlation between driver and iron closure rates for players with HCP<15 but are relatively uncorrelated for players with HCP≥15, likely due to wider variation in club delivery kinematics for the high HCP group. No correlation between closure rate and shot consistency was found in any group, however the mean driver closure rate of the low HCP group was significantly lower than the mid HCP group despite a higher mean driver speed. This suggests that lower closure rates for a given club head speed appear to be a characteristic of lower handicap golfers. More in-depth study is required to analyze this hypothesis.

References

Cheetham, P.J. (2014). *The Relationship of Club Handle Twist Velocity to Selected Biomechanical Characteristics of the Golf Drive* (Doctoral Dissertation). Retrieved from http://www.philcheetham.com/media/Phillip-Cheetham-Doctoral-Dissertation-2014.pdf

Wright, I. (2008). Motion capture in golf. *International Journal of Sports Science & Coaching, 3,* 161-182. doi:10.1260/174795408785024351

The Sequencing of Segment Velocity During Golf Pitching

Tim Vernon & Robert Mackay

Purpose

Proximal to distal sequencing has been observed and implicated as a factor in successful golf swings (Sprigings and Neal, 2000 and Cheetham *et al.*, 2001; Lindsay *et al.*, 2008) and as one of the major differences between the swings of professional and amateur golfers (Cheetham *et al.*, 2008). All have concluded that the most effective method of swinging a golf club involves the use of a sequence of segmental motion whereby the downswing is started by the pelvis, with the thorax, arms and finally the club following. Each segment's peak velocity should be faster and marginally later than that of the preceding, more proximal segment.

The majority of this research has investigated full shots with the driver. More recently, Tinmark et al., (2010) investigated the transverse plane rotations of the upper and lower body during partial and full swing shots. The results showed a significant proximal to distal sequence of segment motion and a concomitant successive increase in maximum segment angular speed for all shots.

Study of the golf swing has been largely group based with their findings an attempt to characterise the 'perfect golf swing'. This shows a lack of regard for the individual nature of the golf swing, leading to the coaching of techniques that may or may not be of benefit to the individual golfer.

The purpose of this study was to investigate the strategies employed by elite amateur golfers in hitting a pitch shot to three targets of increasing distance.

Method

Ten elite amateur male golfers (mean ± SD; age 41 ± 20 years, mass 91 ± 15 kg, stature 181 ± 5 cm, handicap 2 ± 3) volunteered to participate in the study.

Following a self-directed warm up, each player performed ten golf pitch shots with their own pitching wedge to target flags at 120, 100 and 80 yards, the five closest shots within a 5m radius were chosen for analysis. Three-dimensional data were collected using a Polhemus Liberty electromagnetic tracking system (Polhemus Liberty., Colchester, VT, USA), sampling at 240 Hz, into Golf Biodynamics Ultimate System software (v11.0.5, Golf

Biodynamics Pty, Australia).

Five sensors were attached to each participant to measure the motion of the pelvis, thorax, lead upper arm, lead hand and club, and as per manufacturer's instructions, segment geometries were defined using an electromagnetic pointer to digitise anatomical landmarks.

Analysis/Results

The angular velocity of pelvis, thorax, lead arm, lead hand and club were exported from the data capture software using customised Matlab script (The Mathworks Inc, Natick). The magnitude and timing of peak segment angular velocities was calculated using customised Microsoft Excel software (Microsoft Corp, 2010) and assessed for statistical differences using repeated measures ANOVAs performed using SPSS 17.0 (SPSS, Inc., Chicago, IL, USA).

As per the findings of Tinmark et al., (2010), group findings showed a significant ($p<0.05$) successive increase in peak segment angular velocity, which increased as target distance increased (Figure 1).

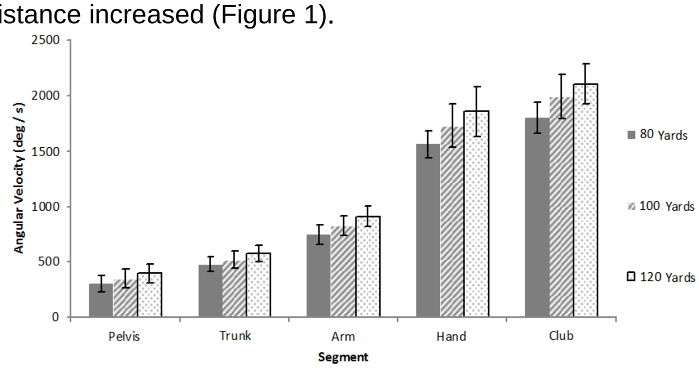

Figure 1. Group mean ± SD segment Angular Velocity During Pitch Shots to 80, 100 And 120 Yards.

Group analysis of the timing and sequencing of peak segment velocity (Table 1), suggests a shift away from the expected proximal to distal sequence for the pitch shot to 80 yards with large standard deviations in timing prompting further individual analysis. Three distinct strategies were observed as player's increased shot distance.

	P-T	T-A	A-H	H-C
80 Yds	97.6	57.2	72.4	19.4
SD	*28.2*	*30.6*	*14.9*	*10.2*
100 Yds	98.6	71.4	68.5	20.3
SD	*30.1*	*27.0*	*13.2*	*11.5*
120 Yds	94.3	68.0	66.2	23.1
SD	*28.0*	*31.4*	*21.6*	*7.5*

Table 1. Group Mean ± SD Time (ms) Between Segment Peak Velocity During Pitch Shots To 80, 100 And 120 Yards.
(P) Pelvis; (T) Thorax; (A) Arm; (H) Hand; (C) Club

Group 1 (n = 4) exhibited a proximal to distal sequence and successive increase in peak segment velocity when pitching to all distances. Group 2 (n = 3) altered their sequencing between the three conditions, with shots to 120 yards exhibiting a proximal to distal sequence but those to 80 and 100 yards having the velocity of the arm and hand segment peaking before the pelvis and thorax. The final group (n = 3) decreased the club head speed at impact for shots to 120 yards compared to those to 100 yards. It is suggested that they were de-lofting the club at impact to enable them to hit the ball further.

Conclusions

The group findings of this study, comply with those of others in that there is a concomitant increase in segment velocity as pitching distance increases, however, individual analysis suggests the presence of three movement strategies for pitching to increasing distances.

These movement characteristics are individual and can produce the same successful outcome (Glazier, 2011), this motor equivalence is a reflection of the fact that based upon past experience and individual, task and environmental constraints, people develop different strategies to the same problem.
The implications to the golfer and coach are that not everyone will conform to the same model of swinging a golf club and care should be taken to ensure feedback and coaching direction is appropriate to the individual. Further research is required examining these different strategies, to identify any common clusters, and to develop idiosyncratic strategies to maximise coaching effectiveness.

Keywords: Pitching, Kinematics, Segment Velocity, Proximal to Distal Sequence, Movement Strategies

References

Sprigings, E. J. and Neal, R. J. (2000). An insight into the importance of wrist torque in driving the golf ball : A simulation study. Journal of Applied Biomechanics, 16 (4), 356–366.

Cheetham, P., Martin, P., Mottram, R. and Laurent, B. (2001). The importance of stretching the "X-Factor" in the downswing of golf : The "X-Factor Stretch". In: Thomas, P.R. Optimising performance in golf. Australia: Australian Academic Press.

Cheetham, P. J., Rose, G. A., Hinrichs, R. N., Neal, R. J., Mottram, R, E., Hurrion, P. D., & Vint, P. F. (2008). Comparison of Kinematic Sequence Parameters between Amateur and Professional Golfers. In D. Crews & R. Lutz (Eds.), Science and Golf V (pp. 30-36). Mesa, Arizona: Energy in Motion.

Lindsay, D. M., Mantrop, S. and Vandervoort, A. A. (2008). A review of biomechanical differences between golfers of varied skill levels. International Journal of Sports Science and Coaching, 3 (S1), 187 – 197.

Glazier, P.S. (2011). Movement variability in the golf swing: Theoretical, methodological and practical issues. Research Quarterly for Exercise and Sport, 82, 157-161

Tinmark, F., Hellstrom, J., Halvorsen, K. and Thorstensson, A. (2010). Elite golfers' kinematic sequence in full-swing and partial-swing shots. Sports Biomechanics, 9 (4), 236 – 244.

Hip Moments in the Golf Swing: Relationship to Overhead Deep Squat & Early Extension

Casey Ward, Scott Lynn, Robert Dudley, James Charles, Guillermo Noffal & Lee Brown

Purpose

Within the past fifteen years, there has been a notable shift in the player development model for golfers, specifically the recognition of the importance of physical conditioning. Certain physical limitations have been linked to specific undesirable swing characteristics. One of the most common swing faults among amateur golfers is known as early extension (Gulgin, Schulte, & Crawley, 2014). Early extension is characterized as loss of posture in the downswing, and occurs when the hips and spine extend prematurely. It has been reported that limitations in performing an overhead (OH) deep squat are related to early extension in the golf swing (Gulgin et al., 2014). The purpose of this study was to examine the relationship between sagittal plane hip moments in the golf swing and OH deep squat, as well as to examine the differences in hip moments between golfers who present with early extension (EE) in the golf swing, and those who do not (NEE).

Method

A total of 30 male and female golfers were tested (19 males, 11 females; age = 26.5 ± 8.1 years old; weight = 77.45 ± 14.72 kg; height = 1.78 ± 0.10 m; handicap = 6.87 ± 8.61). Participants were fitted with full-body retro-reflective markers. All kinematic data were collected using a 9-camera Qualisys (Gothenburg, Sweden) motion capture system. Force plate data was collected simultaneously using two AMTI (Watertown, MA) force plates. Each participant performed three OH deep squats, followed by five golf shots with a 5-iron. Visual3D software (C Motion Inc., Rockville, MD, USA) was used to process all kinematic and kinetic data. Hip moments were calculated using inverse dynamics and normalized to body weight (Nm/kg). Early extension was assessed quantitatively using a measure of pelvic displacement towards/away from the ball (thrust) at the half-down position. All variables were averaged across trials for each participant.

Analysis/Results

Participants within the sample were ranked according to the average magnitude of pelvic thrust, and subsequently the sample was divided into thirds based on these values. The third with the lowest pelvic thrust was defined as the non-early extension (NEE) group, while the third with the highest pelvic thrust was defined as the early extension (EE) group.

Independent samples t-tests were used to assess differences in pelvic thrust, hip moments, and relative timing of the peak moments in the golf swing, between the NEE and EE groups. Additionally, all participants were grouped together and bivariate correlations were performed between all dependent variables.

There was a moderate positive ($r = 0.389$, $p < 0.05$) correlation between lead hip peak flexion moment in the OH squat and the trail hip peak flexion moment in the downswing. There was also a moderate positive ($r = 0.385$, $p < 0.05$) correlation between lead hip peak flexion in the OH squat and the trail hip flexion moment experienced at half down.

There was a moderate negative ($r = -0.429$, $p < 0.05$) correlation between pelvic thrust at half down and the trail hip flexion moment at top of the backswing.

There were strong negative correlations between the magnitude of the trail hip flexion moment at the top and the timings of the lead hip peak extension moment ($r = -0.770$) and trail hip peak flexion moment ($r = -0.553$), respectively ($p < 0.05$). Likewise, there were strong negative correlations between the magnitude of the lead hip extension moment at the top and the timings of the lead hip peak extension moment ($r = -0.743$) and trail hip peak flexion moment ($r = -0.665$), respectively ($p < 0.05$).

No correlations were found between hip moments in the squat and pelvic thrust. The EE and NEE groups only differed in terms of the trail hip flexion moment at the top of the swing (EE = -0.55±0.24 Nm/kg; NEE = -0.91±0.32 Nm/kg, $p = 0.011$).

Conclusions

This study suggests a possible relationship between the mechanical strategies employed in the OH deep squat and the golf swing, specifically pertaining to hip loading. Sufficient training of movement patterns that develop strength and neuromuscular control of the hip extensors, and ultimately improve squatting ability, may enhance hip loading capacity in the golf swing.

Though hip range of motion is much greater in the squat, the peak flexion moments produced in the golf swing are nearly twice those experienced in the squat. As a physical screen for EE, the magnitude of hip loading in a body weight squat may not be sufficient to represent a critical factor in predicting pelvic thrust. Future studies should consider other characteristics of squat form and their relationship to EE, as well as the influence of hip extensor strength.

It was shown that greater hip moments at the top of the backswing were strongly correlated to earlier peak moments in the downswing, these results may be indicative of more efficient swing kinematics. Previous research has revealed greater sagittal plane hip moments are associated with improved pelvic kinematics, which are linked to more desirable ball flight characteristics (Lynn et al., 2013; Myers et al., 2008; Ward et al., 2014). The direct relationship between hip loading and ball flight characteristics should be further examined.

Keywords: hip moments, early extension, squat, golf

References

Gulgin, H.R., Schulte, B.C., & Crawley, A.A. (2014). Correlation of Titleist Performance Institute (TPI) level 1 movement screens and golf swing faults. *Journal of Strength and Conditioning Research, 28* (2), 524-539.

Lynn, S.K., Frazier, B.S., New, K.N., Wu, W.F.W., Cheetham, P.J., & Noffal, G.J. (2013). Rotational kinematics of the pelvis during the golf swing:

Skill level differences and relationship to club and ball impact conditions. *International Journal of Golf Science*, 2, 116-125.

Myers, J., Lephart, S., Tsai, Y., Sell, T., Smoliga, J., & Jolly, J. (2008). The role of upper torso and pelvis rotation in driving performance during the golf swing. *Journal of Sports Sciences, 26*(2), 181-188.

Ward, C.E., Charles, J.M., Lynn, S.K., Frazier, B.S., New, K.N., & Noffal, G.J. (2014, September). *Difference in hip moments in the downswing between skill levels and relationship to pelvic kinematics.* Paper presented at the World Scientific Congress of Golf, Gold Coast, Australia.

Relationships Between Vertical Ground Reaction Force Variables and Clubhead Speed in Highly Skilled Golfers

Wells, J.E.T, Mitchell, A.C.S., Charalambous, L. and Fletcher, I.M.

Purpose

The ability to generate high levels of clubhead speed (CHS) is considered to be an important impact parameter linked with successful performance within the game of golf (Cochran and Stobbs, 1999). The modern day golf swing is characterised as a stretch-shortening cycle (SSC) (Hume, Keogh & Reid, 2005), with the initiation of the downswing occurring from the ground-up (Nesbit and Serrano, 2005). This notion is supported by electromyographic analysis indicating that the quadriceps, gluteals and hamstrings are highly active during the downswing (McHardy and Pollard, 2005). Vertical jumps and isometric assessments are often employed by strength and conditioning specialists due to their ability to measure musculotendinous unit (MTU) function of the lower body. While research has highlighted significant relationships between CHS when modelled against one-repetition maximum strength and vertical jump performance (Hellström et al., 2008), these procedures are unable to establish biomechanical data such as peak force (PF), rate of force development (RFD), impulse, take-off velocity (TV) and eccentric velocity (EV). Consequently, the purpose of this study was to assess the correlations between golfers' clubhead speed and vertical ground reaction forces (VGRF).

Method

Twenty-seven highly skilled golfers (handicap < 5) engaged in a familiarisation session which was subsequently followed by a lab testing and CHS testing protocol.

Lab testing: Each participant performed three squat jumps (SJ), countermovement jumps (CMJ), drop jumps (DJ) and isometric mid-thigh pull's (IMTP) on dual Kistler force platforms (Kistler 9281, Kistler Instruments, Winterthur, Switzerland) sampling at 2000 Hz. This followed previously used procedures by Thomas et al., (2015). Positive impulse was measured from each of the vertical jumps. PF and RFD at time integrals of 0-50 ms, 0-100 ms, 0-150 ms and 0-200 ms were measured during the IMTP. The TV and EV of the centre of mass (COM) were measured using participants' CMJ. All data was smoothed using a low pass 4th order Butterworth filter as described by Winter (2009).

CHS testing: Each participant executed ten maximal golf shots using their own custom fit driver. CHS was captured using a TrackMan launch monitor (Interactive Sports Games, Denmark), which the authors have found to exhibit excellent test-retest reliability (coefficient of variation = 0.81% 95% CI: 0.71-0.9).

Analysis/Results

Pearson's correlation analyses were employed to measure the strength and the direction of the relationship. Findings reveal that there were significant correlations between golfers' peak CHS when compared to CMJ impulse ($r = .788$, $p<.001$), SJ impulse ($r = .711$, $p<.001$), DJ impulse ($r = .561$, $p<.01$), IMTP PF ($r = .482$, $p<.01$), RFD from 0-150 ms ($r = .343$, $p<.05$) and RFD from 0-200 ms ($r = .398$, $p<.05$). All variables presented excellent test-retest reliability apart from each of the RFD time integrals. All other variables failed to reach statistical significance.

Conclusions

The findings from this investigation indicate that activities less constrained by time (i.e. CMJ, SJ and IMTP) appear to have the greatest relationship with golfers' CHS. Slow contraction velocity exercises are able to generate greater levels of force production (i.e. the force-velocity relationship) due to increased time available for cross-bridge cycling rate, thus suggesting that the contractile element (i.e. cross-bridges) of the MTU appear to be an important component related to golfers' CHS. Since elite level golfers have been suggested to work at slower rates than less skilled golfers during the start of the downswing (Nesbit and Serrano, 2005) this appears conceivable.

Keywords: clubhead speed, stretch shortening cycle, peak force, rate of force development, impulse

References

Cochran, A & Stobbs, J. (1999). *Search for the Perfect Swing*. (6th ed.). Chicago: Triumph Books.

Hellström, J. (2008). The relation between physical tests, measures, and clubhead speed in elite golfers. *Annual Review of Golf Coaching*, 3(1), 85-92.

Hume, P.A, Keogh, J & Reid, D. (2005). The role of biomechanics in maximising distance and accuracy of golf shots. *Sports Medicine*, 35(5), 429-449.

Mchardy, A & Pollard, H. (2005). Muscle activity during the golf swing. *British Journal of Sports Medicine*, 39, 520-533.

Nesbit, S.M & Serrano, M. (2005). Work and power analysis of the golf swing. *Journal of Sports Science and Medicine*, 4(0), 520-533.

Winter, D.A. (2009). *Biomechanics and motor control of human movement*. (4th ed.). New Jersey: John Wiley and Sons Inc. Thomas et al. (2015). An investigation into the relationship between maximum isometric strength and vertical jump performance. *Journal of Strength and Conditioning Research*, 29(8), 2176-2185.

Acute effects of power based resistance training upon biomechanical parameters associated with club head velocity

Caroline Westwood, Joe Layden, Nicola Rowley & Chelsea Starbuck

Purpose

It is clear that the development of physical strength and power improves balance, enhances swing mechanics, optimises performance, and reduces injuries in golf and that more golfers are incorporating strength training into their programme (Read & Lloyd, 2014). However, no studies have considered how an acute power based resistance training session, and associated fatigue, effects golf swing dynamics. Fatigue following resistance training is associated with a decline in muscle force (Barry & Enoka, 2007) and affects interaction between muscles when generating force (Higham et al., 2008). Therefore, fatigue will effect parameters that may be critical to golf swing performance, most notably club head velocity (CHV; Hume et al., 2005). Such factors include the associated X-factor angle, maximal trunk axial rotation velocity (MTARV) and weight transfer (Hume et al., 2005). As such fatigue following an acute power training stimulus may impact on golf swing mechanics during a subsequent golf specific training session. Therefore, the purpose of this study was to exam the acute effects of a power based resistance training (PBRT) session on golf swing mechanics.

Methods

Eight male golfers (height 177.15±4.50cm, weight 77.82±10.71kg, handicap ≤3, deadlift 1RM 112±12kg), accustomed to strength training, volunteered for this study. Golf swing mechanics were assessed prior to and 120 minutes following a power training stimulus. The PBRT session included the following exercises: push press, jump shrugs and snatch high pulls from hang position, each performed at 75% 1RM for 3 sets of 4 reps. To assess fatigue, the maximum height of three counter movement jumps (CMJ) were recorded pre and post the PBRT stimulus. Kinematic and force data were collected for eight golf swings (seven iron club). Pelvis and trunk rotations were calculated to identify magnitude and occurrence times for X-factor angle and MTARV. Weight transfer parameters were established (range of transfer, maximal weight transfer, weight distribution at ball contact and weight transfer velocity during the downswing), according to Ball and Best (2007). Paired sample t-tests were conducted to identify differences between conditions.

Results

No significant ($P>0.05$) changes to CMJ height were revealed following the PBRT stimulus. No significant differences were observed between conditions for X-factor angle and angle occurrence time ($P>0.05$). However, the MTARV were significantly lower ($P<0.05$) following the power training stimulus (217.05±49.27°/s) compared to the baseline data (270.58±45.12°/s). Although, no significance was observed for the occurrence time of the MTARV, 6 out of 8 participants demonstrated an earlier occurrence (0.06s) following the power training stimulus compared to baseline data. Weight transfer parameters remained similar between conditions ($P>0.05$).

Conclusion

Although, X-factor angle and weight transfer measures remained similar following the PBRT stimulus, a significant reduction in MTARV was observed. Fatigue associated with PBRT may affect the coordination and force development of the trunk muscles during the downswing, thus reducing MTARV. which may impede golfers' performance (Hume et al., 2005). These preliminary findings demonstrate an impact on golf performance following PBRT and consideration of this when programming the training week should be given. Future research should examine the coordination of the trunk muscle activation on golf performance following PBRT and 24 hours post. In addition as it is known that upper body kinematics strongly determines CHV (Hume et al., 2005; Myers et al., 2008), therefore future work should also consider this factor.

References

Ball, K. A., & Best, R. J. (2007). Different centre of pressure patterns within the golf stroke II: Group-based analysis. *Journal of Sports Sciences*, *25*(7), 771–779.

Barry, B. K., & Enoka, R. M. (2007). The neurobiology of muscle fatigue: 15 years later. *Integrative and Comparative Biology*, *47*(4), 465–73.

Higham, T. E., Biewener, A. A., & Wakeling, J. M. (2008). Functional diversification within and between muscle synergists during locomotion. *Biology Letters*, *4*(1), 41–4.

Hume, P. a., Keogh, J., & Reid, D. (2005). The role of biomechanics in maximising distance and accuracy of golf shots. *Sports Medicine*, *35*(5), 429–449.

Myers, J., Lephart, S., Tsai, Y.-S., Sell, T., Smoliga, J., & Jolly, J. (2008). The role of upper torso and pelvis rotation in driving performance during the golf swing. *Journal of Sports Sciences*, *26*(2), 181–188.

Read, P. J., & Lloyd, R. S. (2014). Strength and conditioning considerations for golf. *National Strength and Conditioning Association*, *36*(5), 24–33.

Golf and Sustainable Development: Opportunities from Theory to Practice

Rehema White, Iain Matthews & Erik Lundkvist

Purpose

Sustainable development (SD) has been an internationally supported concept since the Brundtland report defined it as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED,1987). Since then, many definitions of SD have been explored (e.g. Kates et al 2005; Redclift, 2005) and a range of theoretical models has been applied. The *three pillars* model of sustainable development, balancing environmental, economic and social aspects of sustainable development, has been widely used in practice but more recently critiqued as a 'weak model' of sustainability (Dresner, 2002). Alternative models include *strong sustainability*, in which natural capital cannot always be exchanged for financial or other forms (Dietz and Neumayer, 2007), or *wider framings* such as “action into the meaning, making and maintenance of Life in the long term” (Ferraro et al., 2010). In this paper we ask what these theoretical models could bring to the concept and practice of golf.

Method

Three theoretical models for sustainable development were applied to assess understandings of golf and practices of golf: ‘three pillars’, ‘strong sustainability’ and ‘integration of humans and nature’. Firstly, a literature search for peer reviewed literature on ‘golf and sustainable development / sustainability’ was undertaken using JSTOR and Web of Science. Secondly, a review of websites of major organizations and significant golf sector reports (including R&A, USGA, PGA, GEO, WGF) captured grey literature and practice recommendations. Thirdly, we engaged with the golf sector through attending and speaking at conferences, discussions with key informants and working with practitioners throughout a three year period. Finally, values and indicators of the theoretical models were mapped across ways in which golf was framed and practised and some practical recommendations derived.

Analysis/Results

The peer reviewed literature identified focused primarily on golf and economic development or environmental management. Whilst the ‘three pillars’ model was explicitly mentioned in some golf sector mainstream sites, sustainability was often confined to golf course management. Some cases maintained a holistic focus on sustainable development, others embedded sustainability within areas of practice. There was little evidence of ‘strong sustainability’ in discourse or practice, and regional differences. Some excellent projects going beyond environmental management were identified. Engagement within the golf sector demonstrated wider framings of sustainability, with willingness to explore access, participation and management norms for financial, reputational and value based reasons.

Conclusions

Advances in theoretical models of sustainable development have not yet had a significant impact on concepts and practices in the golf sector, although there are some encouraging examples such as supporting local deprived communities, enhancing access, diversification and event carbon accounting and procurement. Golf could benefit from a wider conceptual analysis, potentially leading to an improved role of golf in biodiversity conservation, resource (including carbon) management, physical activity and health, community development and economic outcomes. Practices to promote include local community support, multi-functionality and diversity of golf courses, access programs and rigorous sustainable golf course design and management across all world regions.

Keywords: Sustainability, Sustainable Development, Theory and practice

References

Dietz, S. & Neumayer, E. 2007. Weak and strong sustainability in the SEEA: Concepts and measurement. *Ecological Economics,* 61, 617-626.

Dresner, S. 2002. *The principles of sustainability,* London, Earthscan Ltd.

Ferraro, E., White, R. M., Cox, E., Bebbington, K. J. & Wilson, S. 2010. Craft and sustainable development: reflections on Scottish craft and pathways to sustainability. *Craft + Design Enquiry,* 3, 1-26.

Kates W. Robert , Thomas M. Parris & Anthony A. Leiserowitz, 2005. What is Sustainable Development? Goals, Indicators, Values, and Practice, Environment: Science and Policy for Sustainable Development, 47:3, 8-21, DOI: 10.1080/00139157.2005.10524444

Redclift, M. 2005. Sustainable development (1987-2005): An oxymoron comes of age. *Sustainable Development,* 13, 212-227.

World Commission on Environment and Development, 1987. Our common future. *Published as Annex to General Assembly document A/42/427, Development and International Co-operation: Environment.*

The German Golf League – Sport Economic Considerations for the Construction of a New Competition System

Timo Zimmermann

Purpose

In 2013, the German Golf Association (GGA) introduced the German Golf League (GGL). It represents a central element of the GGA’s “Vision Gold” with regard to the Olympic Games in 2020. To turn the vision into reality youth and talent promotion and the repositioning of the image of golf from a recreational sport for elderly people towards a high-performance sport is required. It was expected that the introduction of an attractive club league system would enhance this organizational change and develop new marketing opportunities for golf in general and for the golf clubs in particular. The case of the GGL offers the opportunity to explore the rarely observed process of establishing a new league system. This paper aims to investigate the construction of a newly introduced league competition from an economic perspective. Moreover, the current problem areas of the GGL and their possible solutions will be discussed based on the results of a stakeholder survey.

Method

Literature dealing with the economics of (professional) team sports (e.g. Drewes, 2003; Noll, 2003; Szymanski, 2003) provides theoretical references for analysing the league construction of the GGL. According to this, structures and rules of leagues have to be designed optimally to ensure a sporty attractiveness of the competition and to maximize marketing opportunities. These characters and league rules comprise for example scheduling the season, promotion and relegation rules, participation requirements or governance structures. Based on these aspects the paper will answer the following question: *“Which league design was selected by the*

GGA and *what compromises did the GGA have to make?"*. Additionally, results of an online survey of the GGL stakeholders, like athletes (n=628), clubs (n=143), coaches (n=93), regional golf associations (n=39) and club sponsors (n=44), conducted after the first season (2013), will be presented. The stakeholders of the GGL were asked about their expectations, goals and satisfaction concerning aspects of the league design, the local match day organization, essential competition rules as well as framework conditions of the league. The data were analysed by statistical methods. It was carried out descriptive evaluations and diversity tests between the stakeholders. In addition, interviews and group discussions with representatives of the golf associations (n=5) and clubs (n=10) were conducted to discuss problems of the GGL and their possible solutions after the first and second season (2014). To analyse the interviews a qualitative content analysis based on Mayring (2015) was conducted.

Analysis/Results

The results point out a wide acceptance of the league system and its management by the governing body GGA. There is a generally high level (mean >3 on 5 point likert scale) of support of the league objectives, the match day organization, the team classification, the promotion of young talents and the interaction with individual championships by the clubs, athletes, coaches and regional golf associations. But also a need for improvement was identified for some competition rules (e.g. promotion and relegation rules), the financing of the team's budgets and the event character of match days.

Conclusions

The GGA has already responded to the problems partially, for instance, by giving recommendations in order to achieve more attractive match days as events or to strengthen the marketing activities of the clubs. Structural changes of the league design will be provided in 2016, e.g. introduction of a relegation, easing the rules for professionals or authorization of two teams per club at various levels of the league. There will also a GGL-forum be established for a better and uncomplicated communication between the GGA and the clubs.

To sum up, the GGL is well on its way to become an attractive club competition in order to promote talents and to change the image of golf in Germany.

Keywords: German Golf League, Competition System, Sport Economic

References

Drewes, M. (2003). Competition and efficiency in professional sports leagues. *European Sport Management Quarterly, 3* (4), 240-252.

Mayring, P. (2015). *Qualitative Inhaltsanalyse: Grundlagen und Techniken* (12. vollständig überarbeitete Auflage). Weinheim: Beltz.

Noll, R.G. (2003). The Organization of Sports Leagues. *Oxford Review of Economic Policy, 19* (4), 530-551.

Szymanski, S. (2003). The Economic Design of Sporting Contests. *Journal of Economic Literature, 41* (4), 1137-118.