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Development of a Simulated Round of Golf

Philip R. Hayes, Kjell van Paridon, Duncan N. French, Kevin Thomas, and Dan A. Gordon

Purpose: The aim of this study was to develop a laboratory-based treadmill simulation of the on-course physiological demands of an 18-hole round of golf and to identify the underlying physiological responses. ***Methods:*** Eight amateur golfers completed a round of golf during which heart rate (HR), steps taken, and global positioning system (GPS) data were assessed. The GPS data were used to create a simulated discontinuous round on a treadmill. Steps taken and HR were recorded during the simulated round. ***Results:*** During the on-course round, players covered a mean (±SD) of 8,251 ± 450 m, taking 12,766 ± 1,530 steps. The mean exercise intensity during the on-course round was 31.4 ± 9.3% of age-predicted heart rate reserve (%HRR) or 55.6 ± 4.4% of age-predicted maximum HR (%HRmax). There were no significant differences between the simulated round and the on-course round for %HRR ($P = .537$) or %HR max ($P = .561$) over the entire round or for each individual hole. Furthermore, there were no significant differences between the two rounds for steps taken. Typical error values for steps taken, HR, %HRmax, and %HRR were 1,083 steps, ±7.6 $\mathrm{b{\cdot}min^{-1}}$, ±4.5%, and ±8.1%, respectively. ***Conclusion:*** Overall, the simulated round of golf successfully recreated the demands of an on-course round. This simulated round could be used as a research tool to assess the extent of fatigue during a round of golf or the impact of various interventions on golfers.

Keywords: walking, exercise intensity, physical activity, energy expenditure

Golf is a popular leisure-time and sporting activity.[1] Its popularity has led to the generation of a considerable amount of research that has focused primarily on the biomechanics and psychology associated with the game.[1] Given the popularity of the sport, and extent of the research into biomechanical and psychological factors, it is surprising that the physiological demands of golf have received comparatively little coverage.

Broman, Johnson, and Kaijser[2] characterized golf as consisting of three distinct phases: walking, standing, and shot making. These activities each contribute to the total physiological strain of playing golf but have different requirements. The

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physiological demands of golf have previously been investigated in terms of the overall demand. Ainsworth et al[3] classifies the energy cost of golf as 4.5 metabolic equivalents (METs). In comparison, normal walking is considered to be 3.5 METs. The characteristics of an individual golf course, including the total distance and amount of ascent and descent, and the weight of the golf bag and how it is transported around the golf course all contribute to the metabolic demand.[4]

An 18-hole round of golf takes approximately 4 h to complete.[5] On the basis of the duration and aerobic nature of a round, some studies have examined the long-term health benefits of regularly playing golf.[4,6] Other studies have considered the cardiovascular response to a round of golf in various age groups,[2] cardiac patients,[7,8] healthy adults,[7,9] and elite amateurs.[10]

Owing to the relatively low rate of energy expenditure compared with such sports as running, team games, and racquet sports,[3] golf is often viewed as nonfatiguing exercise. Given the duration of a round of golf, homeostasis could potentially be challenged through either hypoglycemia or dehydration. Reductions in either blood glucose or hydration status may result in impaired motor skill[11] or cognitive performance.[12] These could reduce golfing performance but are preventable with the correct nutritional strategy.

The environmental and shot-making aspects ensure that each round is unique, thereby precluding the use of field-based testing. At present, it has not been possible to determine the extent of fatigue, physical or cognitive, during a round of golf. Furthermore, it is not possible to evaluate the impact of an intervention on performance whether the intervention is psychological, nutritional, ergogenic, or physical training. To answer these questions, standardized conditions are required. The aims of this study were to identify the physiological demands of a round of golf and subsequently develop a simulated "round of golf" that has a demand similar to that of an actual round.

Materials and Methods

Participants

After institutional ethical approval of the study, eight male recreational golfers gave written informed consent and completed a medical questionnaire. Their mean ± SD age, stature, mass ,and body mass index (BMI) were 50 ± 19 y; 1.82 ± 0.04 m; 88.6 ± 10.7 kg, and 27.1 ± 3.9 $kg \cdot m^{-2}$. On average, they played 6 ± 4 rounds of golf per month. Their mean handicap was 12.5 ± 2.7.

Design

Each participant completed two rounds of golf. The first was completed in the field on a full length 18-hole golf course, whereas the second was a treadmill-based simulation of the field-based round and was completed under laboratory conditions.

Methodology

Before both test sessions, the participants were instructed to avoid consuming a high-carbohydrate meal less than 12 h before both rounds of golf. They were also asked to consume their normal breakfast on each occasion. On the days of the trials, energy intake was controlled by providing the participants with a fixed amount of food after completing hole 9. They were instructed to drink on an ad libitum basis from the bottles of water provided; the volume consumed was recorded.

Before the start of each round, participants completed a competitive state anxiety inventory (CSAI-2)[13] to identify whether levels of cognitive or somatic anxiety differed between rounds, which could affect heart-rate responses. All participants provided urine and earlobe capillary blood (25 µL) samples before and after the round. These samples were used for the determination of blood glucose and urine specific gravity. An additional measure of blood glucose was obtained after hole 9.

During both rounds, each participant wore an electronic pedometer (Fastped 1, Cranlea and Company, Birmingham, UK) to record the number of steps taken. Time and cumulative steps taken were recorded between shots to distinguish between periods of shot preparation and putting. Heart rate (HR; $b\cdot min^{-1}$) was recorded every 5 s throughout each round (S720 Polar Electro OY, Kempele, Finland).

On-Course Round

The on-course round was conducted at the Cambridge National golf course near Toft-Comberton, Cambridgeshire, UK. The official course distance was 5710 m, with a standard scratch score of 70, and is typical of most courses in the UK. Statistics presented by the European Institute of Golf Course Architects found that 63.7% of courses in the United Kingdom and Ireland were between 5400 and 5669 m, with 91% below 6029 m.[14] The on-course round was played in groups of two or three using a modified version of the Texas scramble. This meant that each golfer teed off, but all subsequent shots were from the location of the best placed ball within that group of players. If a player's ball was not the best placed ball, then they retrieved their own ball before striking their next shot. This method was selected to ensure the round was representative, thus removing the possibility of an above- or below-normal performance. All participants had previously played the course at least once. The mean ambient temperature during the round was 16.4 ± 4.0°C, with a relative humidity of 70.3 ± 9.8%. All the golf clubs were transported using a golf cart to standardize conditions.

During the on-course round, a wide-area augmentation system (WAAS)-enabled global positioning system (GPS; E-trex Legend C, Garmin Ltd, Hampshire, UK) was used to continuously measure the position of the golfers. The GPS data provided the topographic course characteristics used to create a treadmill simulation of the golf course for the simulated round. During the on-course round, the best placed ball was constantly followed by a researcher who carried the GPS. This researcher walked with the golfer who had made the best shot to where their ball stopped. The other golfer(s) walked to the best placed ball after picking up their own ball. The GPS had a sampling rate of 3 s. The accuracy of a WAAS-enabled GPS is mainly influenced by the number of acquired satellites. Results of a pilot study to test the accuracy of the data acquisition showed that the GPS had a coefficient of variation of 0.91% in 400- and 800-m distances, with five to six available satellites.

Laboratory Measures

One week after the field test at approximately the same time of day, to avoid diurnal variation, the participants attended an environmentally controlled laboratory of mean ambient temperature 20.0 ± 0.5°C and relative humidity 61.3 ± 18.4%. A simulation of the walking parts of the on-course round was completed on an individual basis. This was based on the data from the GPS acquisition. From the GPS data, height and position were downloaded into Microsoft Excel. The downloaded data were filtered with a cutoff of 1.6 m horizontal displacement for each 3-s sample (a speed of ~2 $\mathrm{km \cdot h^{-1}}$). The remaining data were transformed into 12-s blocks from which the distances covered in relation to the change in height were derived. The 12-s blocks for each hole were rearranged to form a single downhill or combined uphill-flat section. The decision to arrange each hole into an uphill-flat and downhill component was made for two reasons. First, the treadmill response time for a change in gradient led to severe overlap of phases during gradient changes. Second, the transitions between uphill and downhill contours required the participants to dismount the treadmill while the direction of the belt of the treadmill was changed with each transition. This resulted in frequent stoppages that did not reflect the continuous nature of walking during the on-course round.

The distance of a hole during the simulated round was defined as the distance from the tee to the tee of the subsequent hole. For each hole, a mean speed was calculated from the GPS data. The modified course profile was imported into the treadmill operational software (Paragraphics, HP Cosmos version 1.31, Nussdorf-Traunstein, Germany). The simulated round was conducted on a motorized treadmill (HP Cosmos Quasar Medical treadmill) at a constant speed on each hole, derived from the GPS data.

For each simulated hole, the golfers teed off using the same club as during the on-course round using a soft, indoor airflow ball. This was followed by walking the uphill-flat phase. The players then dismounted the treadmill to play a lofted shot, before completing the downhill part of the simulation. After the downhill phase, the participants again dismounted the treadmill before putting a standard golf ball over a distance of 5 m. Between holes, there was a brief active recovery, and this approximated the mean time taken from green to tee on the course.

Data Analysis

CSAI-2. The score on the CSAI-2 was calculated according to the methods of Martens et al.[13] The scores were split into three subscales: cognitive anxiety, somatic anxiety, and confidence. Only somatic and cognitive anxiety scores were used, as confidence was not deemed relevant for the laboratory test. The scores were expressed as a mean and deviation from the mean scoring.

Time and Distances. Total distance and time taken to complete the on-course round were calculated from the GPS data. Both time and distance were subdivided into time taken or distance covered on the fairways, the greens, and between holes. The total number of steps between the conditions was compared.

Hydration. Hydration status was measured by use of urine specific gravity. This was determined with a precalibrated handheld refractometer (Eclipse IP65, Bellingham & Stanley Ltd, Tunbridge Wells, UK). Calibration was completed according to manufacturer's specifications. All measures were performed in triplicate.

Blood Glucose. After collection, capillary tubes were stored at 0°C and subsequently analyzed upon completion of the simulated round or in case of the on-course round within 5.5 h of collection. The samples were remixed and analyzed for glucose concentration using an Analox LM5 Champion Analyzer (Analox Instruments Ltd, London, UK). All samples were measured in triplicate. The Analox was calibrated according to the manufacturer's specifications (CV = 2.5%).

Heart Rate. Heart rate data were analyzed for each participant for the total period of activity, on every hole, and for the periods of walking and standing still in the simulation and on-course round. The intensity of exercise on the golf course was determined by transforming the heart rate into a percentage of the heart rate reserve (HRR; HR max – HR rest).[15] The age-predicted maximum heart rate (HR max) can be prone to large errors. To minimize this, we used the formula of Inbar et al[16]: HR max = 205.8 – (0.685 × age), which has a low reported standard error of estimate (6.4 $b \cdot min^{-1}$).

Statistical Analysis

Before statistical analyses, all data were checked for normal distribution using the Kolmogorov-Smirnov test and Q-Q plots and deemed to be normally distributed. All values were calculated and expressed as means and standard deviations. Statistical analyses were performed using SPSS version 13.0 for Windows (SPSS Inc., Chicago, IL, United States). Statistical significance was set at $P < .05$. Repeated-measures *t* tests were used to compare distances and times between laboratory and field settings. With the exception of the CSAI-2, which was analyzed using a Wilcoxon test, the remaining variables were compared using a fully repeated measures factorial ANOVA. A Bonferroni test was used to identify where significant differences occurred. The agreement between the on-course and simulated rounds was determined by using typical error.[17]

Results

Movement Variables

Figure 1 demonstrates the differences and similarities in the movement variables for both rounds. Total time for the simulated round was significantly shorter than the on-course round ($t = 10.14$; $df = 10$; $P < .001$); however, the time spent walking in excess of 2 $km \cdot h^{-1}$ was not significantly different ($t = 0.71$; $df = 6$; $P = .51$). The typical error for total time was ±41.8 min, whereas the typical error for movement time was only ±2.9 min. Standing time between the on-course round (2 h 20 min ± 3.3 min) and the simulated round (1 h 22 min ± 12.0 min) was significantly different ($t = 11.62$; $df = 6$; $P < .001$) (see Figure 1). The typical error for standing time was ±42.4 min.

The mean speed throughout the on-course round was 2.0 ± 0.1 $km \cdot h^{-1}$.When the walking aspect of the on-course round was considered in isolation, the mean walking speed was 4.9 ± 0.2 $km \cdot h^{-1}$. Throughout the simulated round, golfers walked at the same mean walking speed as the on-course round. The number of steps taken during the on-course and simulated rounds were 12,766 ± 1,530 and 11,835 ± 795, respectively. The typical error for the number of steps was 1,083. The mean distance covered for the on-course round was 8,251 ± 450 m.

Cardiovascular Measurements

The mean HR, the mean percentage age-predicted HR max (%HR max), and the mean percentage age-predicted HRR (%HRR) sustained throughout the on-course round were 94.8 ± 12.3 $b \cdot min^{-1}$, 55.2 ± 4.4%, and 31.1 ± 9.8%, respectively. During the simulated round, the same values were 91.6 ± 6.0 $b \cdot min^{-1}$, 53.7 ± 3.9%, and 28.1 ± 4.4% The mean HR ($t = 0.70$; $df = 5$; $P = .52$), mean %HR max ($t = 0.62$; $df = 5$; $P = .56$), and mean %HRR ($t = 0.66$; $df = 5$; $P = .54$) were not significantly different from the on-course round. The typical error was ±7.6 $b \cdot min^{-1}$, ±4.5%, and ±8.1% for HR, % HR max, and % HRR, respectively.

During the walking elements of the two rounds, the mean HR was not significantly different ($t = 0.70$; $df = 5$; $P = .52$). Similarly, for each individual hole, there were no significant differences in HR, %HR max, or %HRR between the on-course round and the simulated round. Figure 2 highlights the % HRR during both the on-course round and the simulated round.

Anxiety

There were no significant differences in cognitive anxiety ($z = 1.36$; $df = 6$; $P = .17$) and somatic anxiety ($z = 0.00$; $df = 6$; $P = 1.00$) between the simulated round and the on-course round.

Blood and Urine Measures

Blood glucose showed a significant main effect for time ($F = 5.45$, $df = 2, 12$; $P = .02$); however, between the two rounds, there was no significant difference ($F = 0.72$, $df = 1,6$; $P = .43$) (see Figure 3). The typical error values for pre-round, hole 9, and hole 18 were 1.1, 0.7, and 0.7 $mmol \cdot L^{-1}$, respectively.

The mean before and after urine specific gravity scores for the on-course round were 1.010 ± 0.005 $g \cdot mL^{-1}$ and 1.015 ± 0.005 $g \cdot mL^{-1}$, respectively. For the simulated round these values were 1.015 ± 0.005 $g \cdot mL^{-1}$ and 1.017 ± 0.005 $g \cdot mL^{-1}$. There were significant main effects for urine specific gravity between the two rounds ($F = 9.85$; $df = 1, 5$; $P = .03$) and over time ($F = 9.85$; $df = 1, 5$; $P = .03$). The typical error was 0.004 and 0.003 $g \cdot mL^{-1}$ for pre- and post-round, respectively. Participants consumed 624 ± 195 mL of water during the on-course round. This was not significantly different ($t = 1.12$; $df = 6$; $P = .31$) from the 513 ± 211 mL consumed during the simulated round.

Discussion

The aim of this study was to develop a laboratory simulation of a round of golf. The study demonstrated that the mean intensity of a round of golf was approximately 55% of age-predicted HR max or 31% of age-predicted HRR. There were no significant differences in HR, percentage age-predicted HR max, percentage age-predicted HRR, steps taken, time spent walking, blood glucose, or anxiety (somatic and cognitive) between the on-course round and the simulated round.

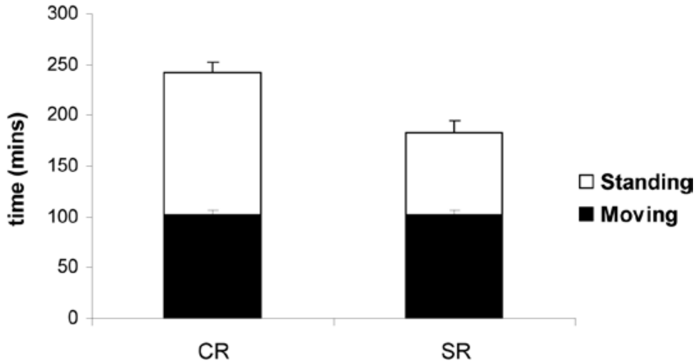

Figure 1 — Comparison of total time, time spent walking, and standing time for on-course (CR) and simulated (SR) rounds.

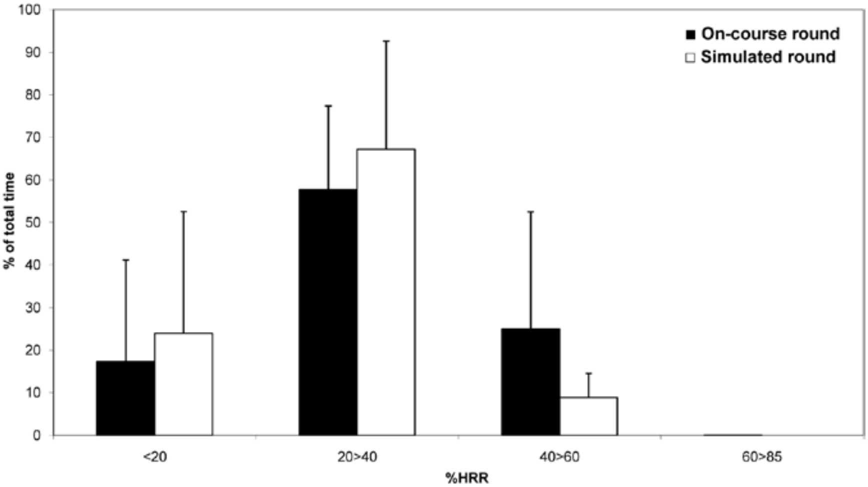

Figure 2 — Comparison of time spent in different heart rate reserve zones for the on-course (CR) and simulated (SR) rounds.

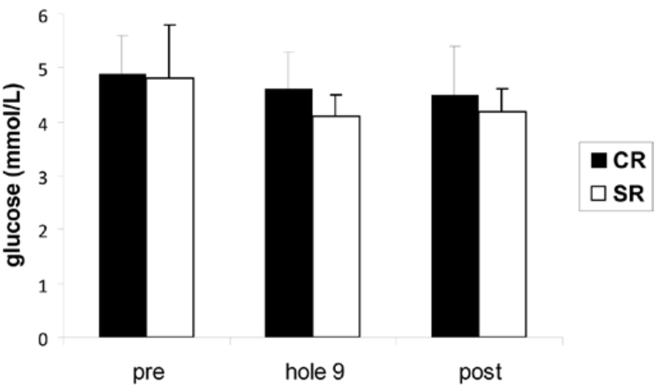

Figure 3 — Blood glucose responses during the on-course and simulated rounds.

Movement Patterns

The on-course round took just over 4 h to complete, during which time the players covered approximately 8 km. This is similar to the distance described by Parkkari and colleagues[4] but less than by Duncan et al,[10] who reported that players covered more than 10 km. To cover the 8 km during the on-course round, our players walked just over 12,500 steps, a value similar to that of Kobriger et al.[18] The differences are likely due to variation in golf course terrain among the studies.

To the best of our knowledge, this study is the first to simulate the physiological demands of a round of golf in a laboratory setting. The total duration of the simulated round was approximately 1 h shorter than the on-course round; however, the time spent walking was similar (see Figure 1). This discrepancy in total time can be primarily explained by the removal of time spent waiting for the other player(s) to complete their shots. Furthermore, there was less time spent in the shot-making phase of the game, in particular the putting aspect. The typical error values support this explanation. During the simulated round, players were asked to play shots; however, with no performance measure the time spent deliberating shots was reduced. This could also account for the 7% fewer steps during the simulated round, as players spent less time moving around lining up shots, especially when putting.

Cardiovascular Demands

The cardiovascular strain of a round of golf as demonstrated by the mean HR, %HR max, and %HRR was not significantly different between the two conditions. The low typical error scores for HR, %HR max, and %HRR support this view. There were no indications in either round that heart rate was affected by psychological factors. Scores on the CSAI-2 were low and not significantly different between rounds, indicating no elevated levels of cognitive or somatic anxiety that could increase heart rate.[19] Collectively, these findings show that the simulated round provided a cardiovascular strain similar to that of the on-course round.

The cardiovascular demands of both the simulated and on-course rounds are similar to previously reported on-course values. In elite amateur players, Duncan et al (2006)[10] found a mean %HR max of 52.8 ± 2.8% and 60.4 ± 3.1% for flat and hilly courses, respectively. Our results are similar to those of Duncan et al.[10] The elite amateur golfers in the study of Duncan et al[10] walked further (10,005 m vs 8,251 m) and faster (2.5 $\text{km}\cdot\text{h}^{-1}$ vs 2.05 $\text{km}\cdot\text{h}^{-1}$) than our golfers although at a similar cardiovascular strain, probably because of their superior conditioning.

Although the mean HR response was similar for the two conditions, there was a greater difference in the HR response between the walking and standing aspects of each round: 7 $\text{b}\cdot\text{min}^{-1}$ compared with 2 $\text{b}\cdot\text{min}^{-1}$ in the simulated and on-course rounds, respectively. The walking phase of the simulation was based on all the periods on the golf course where a speed faster than 2 $\text{km}\cdot\text{h}^{-1}$ was registered. In the simulation, the undulating nature of the course could not be reproduced because of the time taken to adjust the speed, gradient, and direction of the treadmill belt. Each hole was therefore simplified into two phases: a level/uphill and a downhill phase. In between these phases were periods of relatively little movement or stepping off the treadmill to play a shot. By contrast during the on-course round, participants alternated shorter periods of walking, with standing still and –moving at a speed below 2 $\text{km}\cdot\text{h}^{-1}$. This “minimal activity” on the course was primarily inactivity in the simulated round. The minimal activity probably contributed to the negligible difference in HR between the walking and shot-making phases in the field. Furthermore, during the simulated round, there was no real cognitive challenge when playing the shots, whereas on the golf course the shot-making element is fundamental to successful performance. An increase in arousal associated with shot making[19] could offset an increase in HR from inactivity; our CSAI-2 scores, however, do not support this. In more competitive or pressurized rounds of golf, HR could be influenced by anxiety.

There were significant main effects in urine specific gravity for both time and round. The difference between the two rounds was low, and similarly the pre- and post-round difference was low. The mean urine specific gravity values in both rounds and at both points in time fall into the euhydrated category.[20] No participant had a score in either round, pre- or post-round, that would be classified as hypohydrated.[20] While significant main effects exist, given that none of the participants became hypohydrated and the magnitude of change within each round was low, we feel that the simulated round is a reasonable reproduction of the on-course round. To some extent, the magnitudes of change over time were offset by the consumption of fluids during the rounds. Whether a round of golf in a temperate environment is sufficient to induce hypohydration when fluids are not consumed is yet to be determined.

There was a significant main effect for blood glucose over time but no significant differences between the rounds. This drop in blood glucose was essentially over the first nine holes, with little or no change in the last nine holes. At hole 9, the participants were given a standard snack, which presumably attenuated any further drop in blood glucose. Whether blood glucose would have continued to decline over the final nine holes had food not been consumed is unknown and warrants further research.

The typical error for resting blood glucose was 1.1 $\text{mmol}\cdot\text{L}^{-1}$. This is slightly higher than laboratory studies that have given a set breakfast to participants before exercise (typical error = 0.8 $\text{mmol}\cdot\text{L}^{-1}$; E. J. Stevenson, personal communication). Participants recorded their food consumption before the on-course round and were asked to replicate this, both in terms of food consumed and timing of consumption before the simulated round. The typical error is higher than in laboratory studies; however, given the field-based conditions we consider this to be an acceptable level of error. The typical error at holes 9 and 18 was low (0.7 $\text{mmol}\cdot\text{L}^{-1}$). This suggests that even though the durations of the round were different the simulated round is a good representation of the blood glucose response to an on-course round.

The aims of this study were to identify the physiological demands of a round of golf and to replicate these in a laboratory environment. There were no differences between the two rounds for blood glucose, movement variables, or cardiovascular responses. There was a significant difference between rounds for urine specific gravity; however, all subjects remained euhydrated. Both blood glucose and urine specific gravity showed changes over the course of a round.

Practical Applications

This study has demonstrated that it is possible to simulate the physiological demands of a round of golf in a laboratory setting. The simulated protocol provides a model for future research; this could include nutritional interventions or the increased physiological strain resulting from the carrying of a golf bag. To address these issues, a direct assessment of the reliability of the simulated round is required so as to ascertain the sample sizes that would be needed and to ensure repeatability of the protocol.

Acknowledgments

Congress presentation: Hayes PR, Van Paridon K, Thomas K, Gordon, DA. The physiological demands of golf: development of a laboratory simulated round. World Scientific Congress of Golf, Phoenix, Arizona, 26th March 2008. A copy of the data file used in the simulated treadmill round can be accessed at http://www.anglia.ac.uk/ruskin/en/home/faculties/fst/departments/lifesciences/research.html

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