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Improved physical health in middle-older aged golf caddies following 24-weeks of high-volume physical activity

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ABSTRACT

Background: The physical demands of golf caddying, including walking whilst carrying a golf bag, may potentially affect body composition, and markers of metabolic, cardiovascular, and musculoskeletal health. Therefore, this study examined the impact of 24-weeks of caddying on physical health in middle-older aged males.

Methods: Eleven full-time experienced male caddies (age: 59±8 years; caddying experience: 14±12 years) were recruited from a local golf course. The following were assessed at pre-season and after 24-weeks of caddying (March-September 2022): body composition, heart rate, blood pressure, blood lipids, and performance tests (static and dynamic balance, strength, and sub-maximal fitness). Physical activity levels were assessed at pre-season and at the mid-point of the caddying season. Across the caddying season, participants completed a monthly average of 24.0±3.8 rounds.

Results: Following the caddying season, improvements in static balance (Δ= 13.5s), dynamic balance (Δ= -1.8s), and lower-back absolute strength (Δ= 112.8N) and muscle quality (Δ= 2.0N/kg) were observed (all $p<0.05$). Additionally, blood lipids, including total cholesterol (Δ= -0.6mmol$\cdot$L^{-1}), high-density lipoprotein cholesterol (Δ= 0.14mmol$\cdot$L^{-1}), low-density lipoprotein cholesterol (Δ= -0.61mmol$\cdot$L^{-1}) (all $p<0.05$), and body composition, including body mass (Δ= -2.7kg), fat mass (Δ= -1.9kg), fat percentage (Δ= -1.4%), fat-to-muscle ratio (Δ= -0.03), and body mass index (Δ= -0.9kg$\cdot$m^{2}) (all $p<0.05$) improved. Caddying did not offer beneficial changes to cardiovascular variables or cardiorespiratory fitness ($p>0.05$), while coronary heart disease risk score decreased (Δ= -3.3%) ($p<0.05$). In relation to physical activity, light (Δ=

145min) and moderate (Δ= 71min) intensity physical activity, moderate-to-vigorous physical activity (Δ= 73min), and total physical activity (Δ= 218min) between pre-season and the mid-point of the caddying season increased, while sedentary time (Δ= -172min) decreased (all $p<0.05$).

Conclusion: Golf caddying can provide several physical health benefits such as improvements in various markers of cardiometabolic health, lower back absolute strength, and static and dynamic balance. The physical health improvements that caddying offers is likely contributed to by increased physical activity volume and intensity through walking on the golf course. Therefore, caddying may represent a feasible model for increasing physical activity volume and intensity and achieve physical health related benefits.

Introduction

Life expectancy in the United Kingdom (UK) has recently stabilised.[1] However, the number of older adults in the population (>60 years) is increasing,[2] with current estimates within the UK, that beyond this age, individuals can expect to live on average an additional 24 years.[3] This presents a challenge to enhance the proportion of life spent in good health, reported to be 79% and 77% from birth in males and females, respectively.[4] Therefore, strategies are necessary to promote healthy ageing and delay physical declines concomitant with chronological ageing. Physical activity (PA) is a viable possibility and an encouraged behaviour,[2] which may be realised through activities associated with the sport of golf, such as playing, and caddying.

Golf caddies are employed by various golf courses and are broadly responsible for carrying a golfer's clubs and providing advice.[5] At Carnoustie Golf Links in the United Kingdom, 67.4% of golf rounds completed by non-members in 2022/2023 were with a caddie (15,153 rounds of golf). This demand for golf caddies has increased from 57.4% (10,409 rounds) in 2018/2019.[6] Despite golf caddies' key role within the game, there is limited scientific literature surrounding the physical health-related impact of this role, which has led them to being identified as the 'forgotten worker'.[7]

Golf caddies walk on average 15,480 steps per day during caddying at the same golf course whilst carrying a bag weighing approximately 12 kg.[6] As a result of the physical demands of caddying, the golf caddies' role provides an opportunity to increase an individual's PA in an outdoor environment.[6,8] Caddying and playing golf share some similarities, in terms of walking and carrying clubs, with an important difference being that the caddie does not take golf shots. A recent systematic review highlighted that golf may be an effective method for improving aspects of physical health, across body composition, and metabolic, cardiovascular and musculoskeletal health domains.[9] However, the review highlighted a limited number of studies (N=2) related to caddies, whereas most studies (N=21) investigated golfers.[9] Therefore, it is possible that caddying may also facilitate reductions in risk factors for cardiovascular diseases, metabolic, and musculoskeletal health, which warrants further study.

Although limited, previous cross-sectional and longitudinal studies have displayed positive results in relation to the physical health of the golf caddie, from single golf courses within each study.[8,10] This includes greater Achilles tendon stiffness, and quadricep and grip strength in young-middle aged caddies when compared to age and sex-matched controls.[10] Furthermore, young to middle-aged caddies displayed improved bone mineral density and leg press strength following 12 months of caddying.[8] These findings are likely attributed to the extensive walking and load carrying required of caddies. Although these findings are important, further longitudinal research is required to better understand the long-term physical health effects from golf caddying, especially within a middle-older age category. As outlined, previous research has focused on young-middle aged caddies; however, the caddying population often extends to an older age category (≥60 years).[11,12]

Considering the PA that caddying offers, this presents the opportunity to determine the viability of caddies to act as a model for health benefits from high volume low and moderate intensity PA in middle-older aged adults.[6] This may be realised by establishing the demands and concomitant physical health responses to a season of caddying in middle-older age populations. Therefore, this study aimed to assess the impact that caddying throughout a 24-week period had on markers of body composition, and cardiovascular, metabolic, and musculoskeletal health in middle-older aged caddies. It was hypothesised that regular caddying throughout the course of a 24-week season would improve markers of physical health and function within these domains.

Methods

Participants

Eleven males (aged: 59 ± 8 years (range: 42–70 years); height: 176.5 ± 3.7 cm; body mass 86.5 ± 11.9 kg) who were employed full-time as golf caddies at Carnoustie Golf Links volunteered to participate (caddying experience: 14 ± 12 years (range: 3-41 years)). On average participants were overweight (body mass index (BMI): 27.7 ± 3.0 $kg{\cdot}m^2$), grade 1 hypertensive[13] (systolic blood pressure (SBP): 147 ± 22 mmHg; diastolic blood pressure (DBP): 93 ± 16 mmHg) and had slightly elevated total cholesterol (TC) (5.63 ± 1.02 $mmol{\cdot}L^{-1}$). The inclusion criteria for this study were aged ≥40 years,[12,14,15] free from any musculoskeletal injuries at the time of testing, and completing caddying duties whilst walking the golf course. Two participants reported regular use of cardioactive medication (e.g., anti-hypertensives and Aspirin), with the same dosages at pre- and post-season. All participants completed a written consent form and a physical readiness questionnaire prior to participating. Ethical approval was granted from Abertay University, School of Applied Sciences.

Protocol

See Figure 1 for a schematic overview of the protocol. Prior to the 24-week caddying season (March 2022), physical activity data was recorded via accelerometery and then again mid-season (July 2022), while physical health data were collected pre-season and post-season (March-September 2022).

Course and Weather Details

Throughout the 24-week caddying season (April-September 2022), all caddying duties were completed on the 18-hole Championship Course at Carnoustie Golf Links, Angus, Scotland, United Kingdom (yardage: 6139; men's par: 70, women's par: 74; men's slope rating: 130, women's slope rating: 140; men's course rating: 71.5, women's course rating: 77.3 (data based on green tee position))[16]; total ascent (elevation gain): 40m; minimum elevation: 2m, maximum elevation: 10m. Elevation values were calculated using Google Earth Pro. Par is defined as the score a scratch golfer (defined as a handicap 0 golfer) is expected to score on a given golf course. The course rating and slope rating is the evaluation of the playing difficulty of the course for the scratch golfer and the bogey golfer (defined as a handicap 18 golfer) under normal playing conditions.[17] Additionally, Carnoustie weather data were collected using Visual Crossing,[18] and calculated to represent daylight hours between sunrise to sunset to the nearest hour for each individual day. This included average temperature, humidity, wind speed and ultraviolet index and the sum of precipitation. These daily values were then average from 4th April 2022 to 22nd September 2022.

Accelerometery

Firstly, participants were provided with an accelerometer (ActiGraph wGT3X-BT, Pensacola, FL, USA) to wear for 7 consecutive days, 2 weeks prior to the caddying season commencing. All accelerometery data were collected between mid-late March 2022. The accelerometer unit was attached to an elastic belt and worn on the participant's right hip. Participants were instructed to wear the accelerometer at all times, except during bathing activities (e.g., showering) and sleeping.[19] Throughout the 7-days of accelerometer data collection, participants were asked to maintain their habitual activity patterns. Participants were also asked to complete an activity log detailing the times the monitor was removed and replaced each day. Accelerometer data were then collected via the same process at the mid-point of the caddying season (July 2022).

ActiLife software (Version 6.13.4, ActiGraph) was used to analyse accelerometer data. All data were downloaded at 60 second epochs. Raw accelerometery data were presented in counts per minute (counts·min^{-1}). Non-wear time (90 consecutive minutes of zero counts·min^{-1})[20] was excluded from all analyses. PA intensities were determined using the cut points: light-intensity (≤2689 counts·min^{-1}), moderate-intensity (≤6166 counts·min^{-1}), and vigorous-intensity (>6167 counts·min^{-1}).[21] To determine time spent in moderate-to-vigorous PA (MVPA), the time engaged in moderate and vigorous PA were summed. Total PA time was calculated by summing the time spent engaged in light, moderate and vigorous PA. Sedentary behaviour was defined using the cut point ≤200 counts·min^{-1}.[22] Participant's data were only included for analyses if the following criteria were met: ≥10 hours of wear time per day, for a minimum of four days, including one weekend day.[23] Additionally, participants completed a monthly questionnaire to determine how many rounds they caddied each month (April - September). To determine the average number of steps per round during the mid-season, the steps per round for each individual was determined and then an overall average calculated from 87 rounds.

Passive Physical Health

Participants were asked to attend a physical testing session prior to and following the 24-week period of caddying. Participants were asked to avoid alcohol and caffeine for at least 12 hours, vigorous exercise for 24 hours, exercise on the day of the testing, and to be fasted for >6 hours.[24] All tests were performed in the same order, which is outlined below, and were conducted during the same part of the day (i.e., morning or afternoon).[25] Firstly, passive physical health measures were recorded, followed by active physical function and performance tests.

Body Composition

Body composition was assessed using bioelectrical impedance scales (manufacturer stated error ±2%) (Tanita, Tokyo, Japan). Participants were asked to void their bladder prior to standing on the scales. The scales automatically calculated: body mass, fat percentage, fat mass, fat free mass (FFM), muscle mass, total body water (TBW), TBW percentage, bone mass, basal metabolic rate (BMR), metabolic age, BMI, and degree of obesity. Fat-to-muscle ratio was calculated as fat mass divided by muscle mass.[26] Height was measured using a wall stadiometer (Secca, UK) with socks and shoes removed.

Blood Pressure and Heart Rate

Following a 10-minute supine rest in a quiet environment, heart rate and blood pressure were recorded 2 to 3 times, separated by 2-3 minutes, and then averaged. Heart rate was measured using a three-lead electrocardiogram (ECG), inherent to an ultrasound machine (Vivid iq, GE Healthcare, London). SBP and DBP were recorded using an automated sphygmomanometer placed around the right-sided upper arm (Omron, 705IT, Hoofddorp, Netherlands). Mean arterial pressure (MAP) was calculated as: $(SBP + 2 * DBP)/3$ and rate pressure product (RPP) as: heart rate x SBP.[27]

Abdominal and Quadricep Thicknesses

Ultrasound image acquisition was performed by the same sonographer for all measurements (AB), with gain, depth, focus points, and frame rate altered to obtain the clearest images possible with clear inter-muscular delineation. All ultrasound measures were performed using a two-dimensional B-mode ultrasound using a 12 MHz linear array transducer (12L-RS, GE Healthcare, London) and an ultrasound machine (Vivid iq, GE Healthcare, London). Minimal pressure was applied to the ultrasound probe to avoid manual compression of subcutaneous fat and muscular tissue. Images were analysed by AC, who was blinded to data collection and study time point. Images were measured using a calliper-tool on an offline software (EchoPac, version 204), and the average of three images was calculated.

Abdominal Subcutaneous Thickness

The transducer was positioned perpendicular to the skin in a transverse plane.[28] Participants lay supine with the transducers positioned 1 cm above the navel,[28] in line with the xiphoid process and approximately at the intersection to the waist circumference.[29] Subcutaneous fat was measured as the distance between the cutaneous boundary beneath the skin layer, and the linea alba as the superficial fascia of the rectus abdominis.[28,29]

Quadricep Muscle Thickness and Subcutaneous Fat

Remaining in the supine position, muscle thickness was assessed at the half distance between the greater trochanter and lateral femoral condyle to represent the mid-thigh of the femur.[30] The transducer was positioned perpendicular to the skin surface[30] in the transverse plane to maximise echogenicity for cross-sectional image acquisition. After initial placement, the probe was retracted until a thin layer of ultrasound conducting gel was visible and the rectus femoris appeared at its largest and least compressed.[30] Analysis of maximum thicknesses of the rectus femoris and vastus intermedius were determined separately, excluding the intramuscular fascia, and then summed to calculate the total muscle thickness. Rectus femoris thickness was determined as the widest point between the superficial fascia of the perimysium and deep fascia proximal to the vastus intermedius.[31] Second, vastus intermedius thickness was determined as the proximal fascia border to the anterior border of the femoral cortex.[30] Subcutaneous fat was recorded as the distance between the skin and superficial aspects of the fascia on the inferior border.[32] Relative muscle thickness was calculated as absolute thickness divided by body mass.[32]

Blood Lipids

Blood samples were collected using a disposable lancet (Accu-Chek, Roche Diagnostics Ltd., Sussex, UK), then 35 μL of whole blood was inserted into a capillary tube (Cholestech LDX Capillary Tube; Hayward, CA, USA). Blood samples were then dispensed into a lipid profile Cholestech LDX cassette before being placed in a Cholestech LDX Analyser (Cholestech Corp., Hayward, CA, USA) to provide measures of TC, high-density lipoprotein cholesterol (HDL), triglycerides (TRG), low-density lipoprotein cholesterol (LDL), non-LDL, LDL/HDL, glucose, and coronary heart disease (CHD) risk. CHD risk was measured using the Framingham algorithms, where the points were totalled to determine each participant's Framingham total score.[33]

Active Physical Function and Performance

Warm-up

Participants completed a 5-minute warm-up on a cycle ergometer (Monark Ergomedic 894E, Varberg, Sweden) at a pedal frequency of 60-70 rpm with 0.5 kilopond (kp) resistance.

Following the warm-up, participants were familiarised with each performance test prior to data collection commencing.

Dynamic Balance

Participants performed the Berg Balance Scale (BBS) test, designed to measure balance in older adults.[34] This test consists of a 14-item scale, measured from 0 to 4 scored subjectively by the rater.[35] Total scores of 0–20 demonstrate balance impairment, 21–40 represent suitable balance, and 41–56 show good balance.[34,35] The items comprise of mobility tasks, including: transfers, standing unsupported, sit-to-stand, tandem position, turning 360°, and single-leg position.[35] Participants then completed a timed up-and-go (TUG) test to measure dynamic balance. The time taken for participants to stand from sitting in a chair, walk 3m and then return to the seated position was recorded.[36]

Static Balance

Participants then performed the one leg stance (OLS) test, which is commonly used to measure static balance capabilities.[37] Each participant performed the test on their dominant leg, with their hands on their hips, their eyes open, and their non-dominant leg at the level of the shin.[37] The total time that participants remained in this position was recorded. The trial ended if the participant removed their hands from their hips, or the standing foot shifted or touched the non-dominant leg.[38] Each participant performed three trials, with 60-sec rest between trials, and the average over the three trials was calculated.[39]

Strength

Peak isometric knee extension force was measured using a handheld dynamometer (HHD) (MicroFET2, Hogan Health, UT, USA).[40,41] A "make test" method was used to measure leg strength due to its greater reliability when compared to the "break test".[42] In order to begin the "make test", participants were seated in an upright position with their knees at a 90° angle and hips secured to a chair with a seat belt.[41] The examiner's elbow was flexed at 90° and fixed against a wall, whilst the HHD was placed against the participant's lower leg, proximal to the talocrural joint. Peak force was measured for 5-sec on three separate trials, with 60-sec rest between trials,[40] and the average over the three trials was calculated.[10]

Peak isometric lower back strength was measured using a back and leg dynamometer (Takei, Analogue dynamometer, Japan).[43] Participants stood in an upright position on the base of the dynamometer with their arms straight and the lumbar spine flexed at 30° lumbar flexion.[44,45] Similar to the knee extension force, peak force was measured for 5-sec on three separate trials, with 60-sec rest between trials,[40,46] and the average over the three trials was calculated. The leg and lower back strength tests were expressed as absolute strength (N) and muscle quality (N/muscle mass in kg).

Sub-Maximal Cardiorespiratory Fitness Test

The Ekblom-Bak submaximal test was used to predict maximal oxygen uptake ($\dot{V}O_{2\max}$),[47] as an estimate of cardiorespiratory fitness (CRF). This test is a valid estimation of $\dot{V}O_{2\max}$ for the current study's participant age range (42–70 years).[47] Prior to the test, participants were fitted with a heart rate monitor (Polar H10, Kempele, Finland) and introduced to the Borg scale of perceived exertion.[47,48] The test procedure included 4-minutes of cycling on a cycle ergometer at a standardised low work rate of 0.5 kp at 60 rpm, followed by 4-minutes of cycling at a higher work rate chosen by the participant, based on their rating of perceived exertion. Average heart rate during the final minute of the high and low work rates were recorded.[47] The 2016 prediction equation was used to estimate $\dot{V}O_{2\max}$.[47]

Statistical Analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (IBM SPSS) (version: 28). Data were measured for normality using the Shapiro-Wilk test. For all parametric data, Paired Samples T-Tests were used to compare data pre and post caddying season. Non-parametric data were analysed using Wilcoxon Signed-Rank Tests. Hedges' g effect sizes were calculated and then interpreted using the following Cohen's thresholds: trivial (<0.2), small (0.2-0.6), moderate (0.6-1.2), large (1.2-2.0), very large (2.0-4.0) and extremely large (>4.0).[49,50] All data are presented as mean ± standard deviation (SD), p-value and effect sizes.

To determine relationships between the total number of caddying rounds throughout the 24-week caddying season and all other variables, Pearson's Correlation Coefficients were conducted for all parametric data, whereas Spearman's Rank Correlations were conducted for non-parametric data. Correlation coefficients of 0–0.3 were categorised as negligible, 0.3–0.5 low, 0.5–0.7 moderate, 0.7–0.9 high, and 0.9–1 very high.[51] In all instances, $p<0.05$ was considered to be statistically significant.

Results

Descriptive statistics for PA levels, body composition, blood pressure, heart rate, blood lipids, and performance tests are presented in Tables 1–4. Total golf rounds completed by the caddies throughout the duration of the study (April–September) are presented in Figure 2. Throughout the caddying period, caddies completed an average of 24.0 ± 3.8 rounds per month and an overall average of 147 ± 36 rounds. Throughout the 24-week caddying period (April–September) the weather conditions were as follows: temperature: 14.21 ± 3.63 °C; humidity: 72.99 ± 10.64%; precipitation: 0.84 ± 2.25 mm; wind speed: 18.08 ± 6.87 km/h; and ultraviolet index: 2.44 ± 0.95. No injuries were reported that prevented caddies from completing the 24-week study (See Figure 2 for a full data set of complete rounds from all participants (n=11) each month)).

Accelerometery

When comparing PA levels prior to the caddying season commencing and the mid-point of the season, significant increases were observed for light- and moderate-intensity PA, MVPA, total PA, and steps ($p<0.05$). Sedentary time significantly reduced ($p<0.05$), whereas no significant difference was observed for vigorous-intensity PA ($p>0.05$) (Table 1). The golf caddies walked on average 11,101 ± 2,442 steps per round.

Passive Physical Health

Following the caddying season, significant improvements were observed for various body composition measures including body mass, fat percentage, fat mass, FFM, muscle mass, fat-to-muscle ratio, TBW, TBW %, BMR, BMI and degree of obesity ($p<0.05$). No significant differences were observed for bone mass and metabolic age ($p>0.05$). A significant reduction in absolute muscle thickness ($p<0.05$) of the quadriceps was observed following the caddying season. No significant differences were observed for muscle thickness relative to body mass, and thigh and abdominal subcutaneous fat thickness ($p>0.05$) (Table 2).

Significant improvements were observed in TC, HDL, LDL, non-LDL, LDL/HDL, and CHD risk ($p<0.05$). No significant differences were observed for TRG and glucose ($p>0.05$) (Table 3). In addition, no significant differences were observed for resting heart rate, SBP, DBP, MAP and RPP ($p>0.05$) (Table 3).

Active Physical Function and Performance

TUG, OLS, absolute lower back strength, and relative lower back muscle quality significantly improved following the caddying season ($p<0.05$). No significant differences were observed for all other active physical function and performance measures ($p>0.05$) (Table 3-4).

Associations between Caddying Rounds and Physical Health, Function and Performance

Total caddying rounds throughout the 24-week caddying season were significantly associated with body mass (r= -0.64, p=0.03), BMR (kj) (r= -0.66, p=0.03), BMR (kcal) (r= -0.66, p=0.03), metabolic age (r= -0.70, p=0.02), BMI (r= -0.63, p=0.04), degree of obesity (r= -0.63, p=0.04), absolute muscle thickness (r= -0.60, p=0.049), HDL (r= 0.80, p=0.01) and LDL/HDL (r= -0.83, p=0.42). No significant associations (p>0.05) were observed between caddying rounds and all other variables.

Table 1. Device-measured daily physical activity (PA), sedentary time, and step count of participants prior to the caddying season commencing (pre-season) and at the mid-season of the caddying season.

	Pre-Season	**Mid-Season**	**p-value**	**Effect size**
Sedentary (min)	437 ± 54	265 ± 22	**<0.001**	3.20
Light-intensity PA (min)	298 ± 53	443 ± 34	**<0.001**	2.59
Moderate-intensity PA (min)	96 ± 43	167 ± 29	**0.001**	1.79
Vigorous-intensity PA (min)	1 ± 1	3 ± 3	0.09	0.66
MVPA (min)	97 ± 44	170 ± 31	**<0.001**	1.84
Total PA (min)	395 ± 46	613 ± 45	**<0.001**	3.44
Steps (n)	12703 ± 3703	23707 ± 3148	**<0.001**	2.40

Data presented as mean ± SD (n=8). Bold values indicate statistical significance. Significance granted at $p<0.05$. PA- physical activity; MVPA- moderate-to-vigorous physical activity.

Table 2. Body composition of the study participants.

Measurements	**Pre-Season**	**Post-Season**	**p-value**	**Effect size**
Height (cm)	176.5 ± 3.7	176.5 ± 3.8	0.828	0.07
Body Mass (kg)	86.5 ± 11.9	83.8 ± 11.9	**<0.001**	1.45
Body Mass Index (kg·m^2)	27.7 ± 3.0	26.8 ± 3.2	**<0.001**	1.74
Fat Percentage (%)	27.0 ± 5.7	25.6 ± 6.0	**0.009**	0.94
Fat Mass (kg)	23.9 ± 8.3	22.0 ± 8.2	**0.005**	1.03
Fat Free Mass (kg)	62.6 ± 4.6	61.9 ± 5.0	**0.006**	1.02
Muscle Mass (kg)	59.5 ± 4.4	58.8 ± 4.7	**0.005**	1.03
Fat-to-Muscle Ratio	0.40 ± 0.12	0.37 ± 0.12	**0.011**	0.90
Total Body Water (kg)	43.4 ± 3.8	42.6 ± 4.0	**<0.001**	1.78
Total Body Water (%)	50.5 ± 3.1	51.2 ± 3.2	**0.02**	0.77
Bone Mass (kg)	3.1 ± 0.2	3.1 ± 0.2	0.19	0.41
Basal Metabolic Rate (kj)	7651 ± 653	7529 ± 691	**<0.001**	1.42
Basal Metabolic Rate (kcal)	1829 ± 156	1799 ± 165	**<0.001**	1.42
Metabolic Age (years)	59 ± 11	56 ± 12	0.08	0.57
Degree of Obesity (%)	25.9 ± 13.8	21.9 ± 14.3	**<0.001**	1.74
Muscle Thickness (cm)	3.8 ± 0.5	3.4 ± 0.6	**0.037**	0.70
Muscle Thickness (cm/kg)	0.04 ± 0.01	0.04 ± 0.01	0.092	0.54
Thigh Subcutaneous Fat Thickness (cm)	0.7 ± 0.2	0.7 ± 0.2	0.313	0.31
Abdominal Subcutaneous Fat Thickness (cm) (n=8)	3.0 ± 0.4	2.8 ± 0.4	0.206	0.47

Data presented as mean ± SD (n=11). Bold values indicate statistical significance. Significance granted at $p<0.05$.

Table 3. Blood lipids, blood pressure, heart rate and sub-maximal cardiorespiratory fitness of the study participants.

Measurements	Pre-Season	Post-Season	p-value	Effect size
TC ($mmol \cdot L^{-1}$)	5.63 ± 1.02	5.03 ± 0.77	**0.02**	0.82
HDL ($mmol \cdot L^{-1}$)	1.11 ± 0.23	1.25 ± 0.33	**0.03**	0.77
TRG ($mmol \cdot L^{-1}$)	1.56 ± 1.11	1.12 ± 0.69	0.21[a]	0.36
LDL ($mmol \cdot L^{-1}$) (n=8)	3.97 ± 0.96	3.36 ± 0.66	**0.02**[a]	0.98
Non-HDL ($mmol \cdot L^{-1}$) (n=6)	4.51 ± 1.05	3.55 ± 0.68	**0.02**	1.37
LDL/HDL (n=8)	3.80 ± 0.79	2.86 ± 0.85	**0.004**	1.42
Glucose ($mmol \cdot L^{-1}$)	5.42 ± 2.10	5.48 ± 1.20	0.58[a]	0.52
CHD Risk (%)	14.0 ± 6.1	10.7 ± 5.1	**0.03**[a]	0.85
Systolic blood pressure (mmHg)	147± 22	144 ± 20	0.38	0.28
Diastolic blood pressure (mmHg)	93 ± 16	89 ± 15	0.10	0.57
Mean arterial pressure (mmHg)	111 ± 18	107 ± 16	0.18	0.44
Resting heart rate ($beats \cdot min^{-1}$)	64 ± 12	58 ± 6	0.17	0.46
Rate pressure product ($beats \cdot min^{-1}$ mmHg)	9321 ± 2176	8413 ± 1600	0.15	0.48
Absolute $\dot{V}O_{2max}$ ($L \cdot min^{-1}$)	3.4 ± 0.3	3.5 ± 0.4	0.41	0.21
Relative $\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	40.2 ± 4.2	42.1 ± 4.9	0.07	0.61

Data presented as mean ± SD (n=10). Bold values indicate statistical significance. Significance granted at $p<0.05$. [a] Non-normally distributed analysis. TC- total cholesterol; HDL- high-density lipoprotein cholesterol; TRG- triglycerides; LDL- low-density lipoprotein cholesterol; CHD- coronary heart disease; $\dot{V}O_{2max}$- maximal oxygen uptake.

Table 4. Physical function and performance measures of the study participants.

Measurements	Pre-Season	Post-Season	p-value	Effect size
TUG (s)	10.7 ± 1.0	8.9 ± 0.9	**<0.001**	1.74
BBS	53 ± 2	54 ± 2	0.07[a]	0.60
One Leg Stance (s)	27.5 ± 24.3	41.0 ± 16.0	**0.03**[a]	0.77
Absolute Leg Strength (N)	266.1 ± 60.6	270.2 ± 39.6	0.67	0.13
Relative Leg Muscle Quality (N/kg)	4.5 ± 0.9	4.6 ± 0.7	0.43	0.25
Absolute Lower Back Strength (N)	945.0 ± 204.9	1057.8 ± 210.1	**<0.01**	2.03
Relative Lower Back Muscle Quality (N/kg)	15.9 ± 2.8	17.9 ± 2.6	**<0.01**	2.58

Data presented as mean ± SD (n=11). Bold values indicate statistical significance. Significance granted at $p<0.05$. [a] Non-normally distributed analysis. TUG- timed up-and-go test; BBS- Berg Balance Scale Test

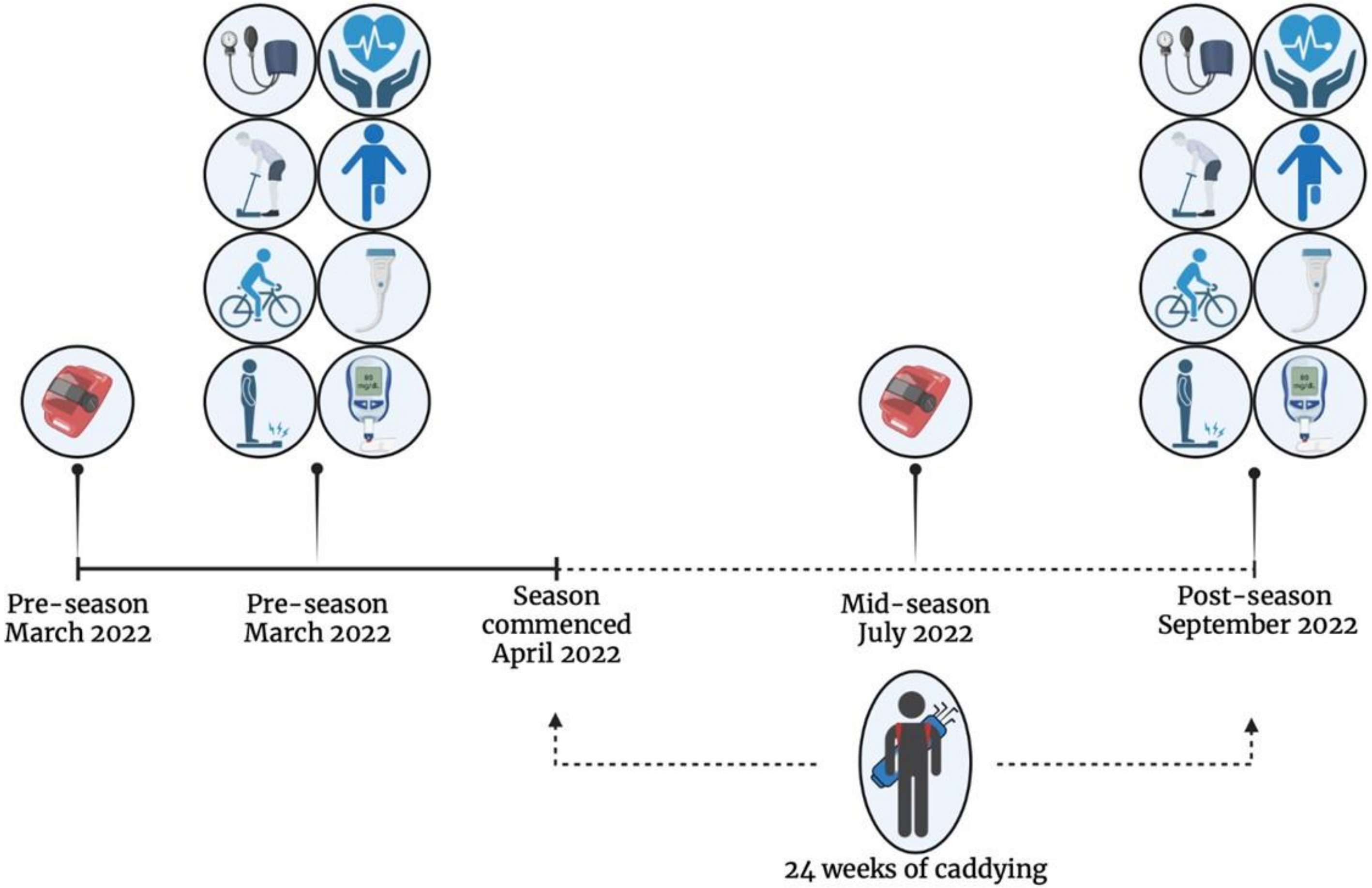

Figure 1. Schematic overview of the study protocol. Accelerometery data were collected before (March) the 24-week caddying season (April-September) commenced and then again mid-season (July). Outcome variables related to domains of body composition, cardiovascular, metabolic, and musculoskeletal health were collected pre- (March) and post-season (September).

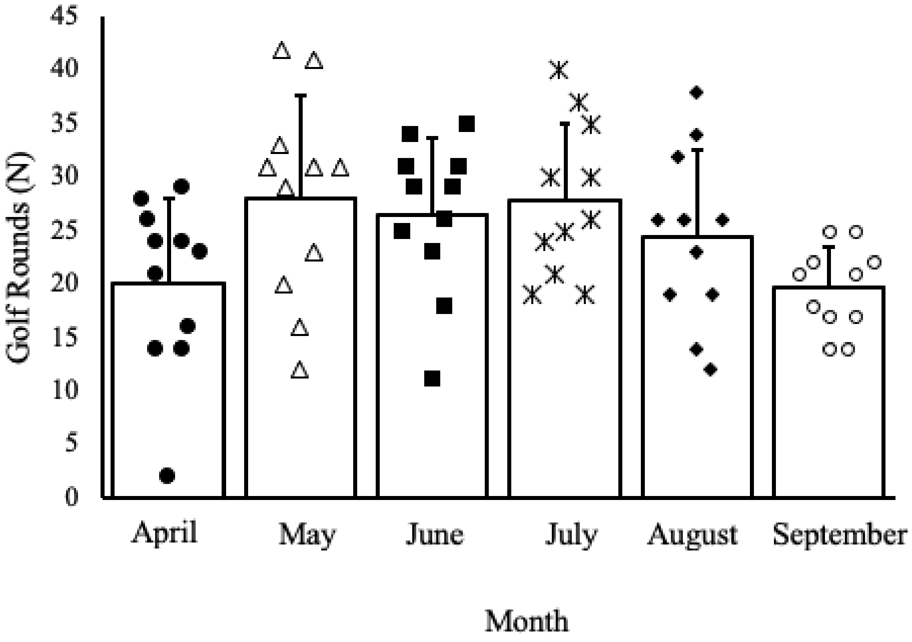

Figure 2: Number of golf rounds completed by the caddies throughout the duration of the study (April – September 2022) from 18-hole rounds. Data presented as mean ± SD with individual data overlayed (n=11).

Discussion

The aim of the study was to assess the impact of 24-weeks of golf caddying on markers of physical health in middle-older age caddies. The principal findings were that: (1) statistically significant improvements in multiple markers of cardiovascular and musculoskeletal health including: body mass, BMI, fat mass, TC, CHD risk score, balance, and absolute lower back strength and muscle quality were observed following the caddying season; 2) no statistically significant changes were observed in absolute leg strength and muscle quality, heart rate, blood pressure, or cardiorespiratory fitness following the caddying period.

The influence of caddying on cardiometabolic markers

In our study, following the caddying season global improvements were noted for markers of body composition, such as body mass, fat mass, fat percentage, fat-to-muscle ratio, BMI, and degree of obesity. BMI findings agree with a 20-week golf training study,[52] yet disagree with a 12-month observational study in caddies.[8] We studied caddies during the summer period of 6-months, while 12-months may have included periods of fluctuating frequencies in caddying. Previous studies have shown seasonal variation in PA in golfers,[53] therefore, during the winter months when PA is typically lower, it is not clear whether the improvements in body composition extend to the off-season for caddies. Moreover, in our study, the caddies performed on average more rounds (24.0 ± 3.8) and steps (23707 ± 3148) per month over the 24-weeks compared to Goto et al.[8] (18.2 ± 2.9 rounds, and 17970 ± 3434 steps, respectively), which may explain the differing study findings. Additionally, the total number of rounds within a condensed 6-month period was inversely associated with body mass, BMI, and degree of obesity in our study. This may suggest caddying, and by extension, PA volume is important for facilitating reductions in body mass. The overall reduction in fat mass exceeded the loss of whole-body muscle mass, reflecting improved (i.e., decreased) fat-to-muscle ratio. Previous research shows fat-to-muscle ratio is significantly associated with metabolic syndrome, hypertension, prediabetes, and type 2 diabetes,[54] with a lower fat-to-muscle ratio decreasing the risk of metabolic syndrome.[26] Together, these observations suggest that in a group of older males who are already active, additional benefits can be achieved by augmenting PA volumes. However, more research is needed to establish the effects on other measures that are associated with the metabolic syndrome, such as insulin resistance. Furthermore, our findings imply that caddying may improve body composition and aid muscular performance and balance. Therefore, collectively these benefits could reduce the likelihood of 'sarcopenic obesity', which has been associated with worsening physical function[55] in an ageing cohort of men.

Favourable improvements in blood lipid profile were found, including reduced TC and LDL, and increased HDL. Acute physiological responses following low intensity, high-volume golf have demonstrated improved lipid profiles compared to lower volume Nordic walking and walking.[56] These findings support observations in this study, and may provide some explanation for our chronic adaptations. These findings also agree with improved HDL following golf training of varying durations (1-20 weeks),[52,57] yet we extend these previous findings by showing improved lipid profiles are also possible in caddies, after 24-weeks. Moreover, improved HDL would have contributed to the reduction in 10-year CHD Framingham risk score, since HDL is inversely associated with CHD.[58] Such changes are of clinical importance since 25% of all mortalities in the UK are caused by heart and circulatory disease.[59] Indeed, we observed a reduction of 3.3 percent points in CHD risk score, which reflects an improvement given the association between CHD and mortality.[59] Although these improvements are positive, the Framingham risk score may over-estimate CHD[60] and risk fluctuates throughout the year, therefore, this must be considered when interpreting our findings.[61] While our caddies walked the course, it is not known whether the golf bags were carried predominantly with a single or double strap. Golf bag carrying method has been shown to alter the acute metabolic cost of walking with a 12.5 kg bag in golfers,[62] with greater demand from single strap load carriage. This may be important for determining the repetitive acute physiological responses and thus, chronic cardiometabolic adaptations over a sustained period of caddying and warrants further study.

The influence of caddying on balance and musculoskeletal properties

Improvements were observed in the TUG and OLS tasks, which together suggests that caddying imparts a positive influence on dynamic and static balance. Although no changes were observed in the BBS test, a ceiling effect may have been present with the caddie group being categorised within the good balance category at pre-season [41-56],[34,35] and considered an independent group who are able to walk without an aid [≥49-56].[63] The positive findings regarding dynamic and static balance may be due to increased total volume of PA, including the amount of moderate-intensity PA, as well as continuous walking on uneven ground on the golf course, with an asymmetric load. Similarly, previous research demonstrated positive changes in dynamic balance following PA training programmes, which included walking,[64,65] and golf training.[66] Specifically, Du Bois et al.[66] reported a 13.3% improvement in the TUG test following a 12-week golf training programme, which included progressive golf play. These findings corroborate the 16.8% improvement reported within the current study, following 24 weeks of caddying. Furthermore, at pre-season, the TUG test score (10.7 seconds) was comparable to the sarcopenia predictor cut-off point of 10.85 seconds,[67] which improved to 8.9 seconds after the caddying season. Since the TUG test represents a measure of physical function,[68] an improvement of 1.8 seconds is indicative of superior functional ability in our group of middle-older age men following caddying. These findings are of practical importance since older adults suffer the most falls that lead to mortality,[69] and the TUG test is an important predictor of falls in seniors.[70] The improvements in dynamic and static balance, may provide support for encouragement to participate in activities to improve balance, which could contribute towards achieving UK PA guidelines for improved physical function.[71] However, our experienced caddies were physically capable of the high volume PA, whilst carrying golf bags, and more research is needed to determine whether smaller dosages of activity in those with compromised balance and physical capacities elicit similar adaptations. These results regarding balance are of significant clinical relevance since falls are the second leading cause of unintentional mortality,[69] and are suggested to contribute to rapid deteriorations in overall health, requiring frequent care.[72] The financial burden of fragility fractures is estimated to be an annual £4.4 billion in the UK National Health Service (NHS).[73] It is likely that these improvements in balance are reflective of the muscular strengthening and balance enhancing PA that caddying provides, which we recently reported during isolated rounds,[6] alongside the improved absolute back strength and muscle quality observed in the current study.

Augmented back strength following 24-weeks of caddying may be a result of the continual lifting and carrying of golf bags during repetitive rounds, which we observed to weigh on average 12 kg.[6] This is of particular importance since back muscle strength and quality of life are positively associated in older adults,[74] and with the former a contributor to the Geriatric Locomotive Function scale, a measure of locomotive syndrome.[75] While absolute lower back strength improved following the caddying season, absolute leg strength remained unchanged, which contrasts the improvements noted by Goto et al.[8] after 12-months of caddying. Methodological differences in strength tests used may be explanatory, with Goto et al.[8] utilising a leg press test, which requires substantial gluteal muscle activation.[76] Moreover, we noted improved lower back muscle quality, albeit calculated based on whole body muscle mass. Indeed, muscle quality is an indicator of muscle function in the elderly[77] and may be used as a supplementary tool for the assessment of functional decline in association with sarcopenia.[78] Within the current study, absolute muscle thickness reduced, which contrasts with cross-sectional work reporting larger muscle thickness in elderly female golfers compared to non-golfers.[32] However, it must be noted that Herrick et al.[32] recruited golfers who were significantly younger than non-golfers, which may have contributed to their greater muscle thickness. Without a control group in this study, it is difficult to draw a direct comparison, however, since we employed a longitudinal design, it is important to interpret the changes in muscle thickness within the context of reduced body mass after caddying. Relative muscle thickness did not significantly change from pre-season to post-season. This suggest caddying was neither advantageous nor deleterious for leg muscle thickness relative to body mass, however, further investigation is needed with an age-matched control group and longitudinal observation.

The influence of caddying on cardiovascular parameters and cardiorespiratory fitness

Caddying did not offer beneficial statistically significant changes to cardiovascular (heart rate and blood pressure) variables or cardiorespiratory fitness. Our observations contrast the reduced SBP and DBP following one-week of golf,[79] however, these participants were on vacation as opposed to our caddies, where it is their occupation. Moreover, Parkkari et al.[52] found through a longer golf training study (20-weeks) that those with the highest blood pressure reduced DBP by 3 mmHg. Since our group of older men represented a hypertensive cohort,[80,81] it is unexpected that blood pressure did not reduce, as others have also shown hypertensives yield the greatest exercise-induced reductions in SBP.[52] We noted increased time in MVPA, but not vigorous-intensity PA which may be of importance to the lack of changes, since others have shown reduced SBP following 6-weeks of high-intensity interval training in ageing men.[82] Likewise, Molmen et al.[83] observed 12% reductions in SBP following 12-weeks of aerobic interval training in older men with similar baseline blood pressure (145 ± 17 mmHg) to our group (147 ± 22 mmHg), therefore, exercise intensity may be an important factor. External factors beyond PA intensity could also have contributed to a maintenance of blood pressure, such as diet, sleep quality, and alcohol intake,[84,85] which are known to influence blood pressure but were not assessed in this study.

Cardiorespiratory fitness ($\dot{V}O_{2\max}$) did not change after caddying, which aligns with other longitudinal work in golfers.[52] It is likely that the exercise stimulus was not sufficient to induce central or peripheral adaptions, therefore maintaining absolute $\dot{V}O_{2\max}$. Maintained $\dot{V}O_{2\max}$ could be due to CRF (3.4 ± 0.3 $L.min^{-1}$) in our middle-older aged caddies (59 ± 8 years) pre-season being directly comparable to age-related normative values reported in the HUNT study (50-59 years, 3.7 $L.min^{-1}$; 60-69 years, 3.3 $L.min^{-1}$).[86] Therefore, a stronger exercise stimulus may be required during caddying to further improve CRF to surpass the age-predicted estimates. Moreover, we observed a trend towards greater relative $\dot{V}O_{2\mathrm{max}}$, therefore, a larger cohort may produce statistically significant results. Still, this change likely reflects reduced body mass as opposed to improved absolute CRF. Nevertheless, these findings do indicate that physical health improvements are possible without the necessity for altered CRF through low and moderate intensity, high volume PA.

Practical Implications

Using an interdisciplinary approach, the findings from this study can be applied to the golf caddying community and generalised to the ageing population. The number of individuals >60 years of age is continually increasing,[87] which presents a key challenge to implement non-pharmacological strategies to promote healthy ageing, and well-being in older age through the maintenance and augmentation of functional ability.[2] Our cohort of men represent a middle-older age group (59 ± 8 years),[12,14,15] and we report the benefits that caddying may offer as a model for increasing PA through walking, while achieving the UK PA aerobic activity guidelines[71] through caddying. While caddying may involve some technical requirements, such as offering advice and determining yardage, the role also involves non-technical/sport specific knowledge such as carrying golf bags,[5,88] which has been reported to be approximately 12 kg.[6,7] Therefore, caddying represents an activity capable of eliciting a high volume of PA through occupational walking,[6] which general populations may participate in. It is feasible to suggest that opportunities to increase high volume PA through caddying may grow in future years due to the continuing rise in golf participation following the COVID-19 pandemic.[89] Nevertheless, golf bag carriage style can influence the biomechanical demands of the lower extremity,[90] which must be considered before undertaking the role of a golf caddie. While we did not investigate caddie-related injuries beyond those that prevented participants from caddying, previous cross-sectional research has demonstrated that golf caddies reported higher prevalence of musculoskeletal pain compared to non-caddies;[11] Therefore, inactive individuals wishing to enhance their PA through a model of high volume exercise, which may include increased walking volumes and/or carrying a heavy load, should take caution to prevent injury occurrence. Nevertheless, walking has been shown through meta-analyses to provide a wide range of positive health outcomes.[91] Through findings that high volume activity, including the carrying of weight, provides physical health benefits, this knowledge may be extrapolated to those beyond golfing communities. We observed improvements in experienced caddies with relatively high PA, and normative aerobic capacity before the 24-weeks. This is promising for those who are already active to still gain physical health improvements, but also for sedentary individuals, since the largest cardiovascular benefits are seen in those with the lowest initial activity.[92]

Limitations and Future Directions

The current study provides valuable insights in the physical health of golf caddying; however, some limitations warrant consideration. Whilst positive findings were reported in relation to body composition, it should be noted that these measures were estimated using Tanita bioelectrical impedance analysis. In terms of body composition measurements, techniques such as dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI) have greater accuracy.[93] Previous research has, however, demonstrated that using Tanita bioelectrical impedance analysis is valid when measuring variables such as body fat %.[94] Additionally, Tanita provides good absolute (no significant difference in mean scores) and relative (r^2 = 0.44, $p<0.001$) agreement with DXA scans for body mass % when testing overweight and obese men.[95] Moreover, we indirectly estimated $\dot{V}O_{2\mathrm{max}}$, which may have reduced the sensitivity for detecting change, however, this approach was taken due to the constraints of field-based testing. Furthermore, static balance was assessed using the total standing duration during the OLS task. To detect sensitive changes in balance, centre of pressure measures via a force platform may be more advantageous.[96]

We used an observational study design without a control group to explore the impact that a 24-week season of golf caddying had on the physical health in a small sample of experienced male golf caddies (14 ± 12 years of caddying (range: 3–41 years)). Although we only included 11 participants, post hoc power calculations suggested an achieved power of 64% (TC) and 100% (TUG and BMI) for key variables of interest. Nevertheless, future work is also needed in larger samples and in varying populations such as, females and different age groups. To determine whether any lack of change was potentially due to a high pre-season PA, and by extension physical health qualities in the caddies, future studies may wish to include a matched control group. While we studied trained caddies, future research would benefit from a randomised controlled trial to determine the influence of the physical demands of caddying in those without previous exposure to caddying. Additionally, the current study assessed golf caddying during the standard golf season in the UK; however, golf seasons may differ between courses both within the UK and other countries. Additionally, research is needed to replicate this study using different golf course profiles, which may elicit higher PA demands and intensities through caddying in middle-older age.[97] In turn, caddies working on the professional tour who caddie at different courses throughout the season may be affected differently than those regularly working at the same golf course, in terms of PA volumes, intensities and potentially the resultant impact on PA health markers.

Conclusion

Golf caddying provided several physical health benefits in middle-older age caddies following a 24-week season. Improvements were noted in balance, body composition, lower back strength and muscle quality, and blood lipid profile, while cardiorespiratory fitness, leg strength and muscle quality, muscle thickness, and blood pressure were maintained. The physical health improvements occurred concomitantly with elevated levels of PA volume and intensity, which may suggest that caddying provides a useful high-volume model for concomitant PA and health related improvements. Still, future studies with larger samples of caddies and a matched control group are needed to establish causal inferences.

Declarations

Competing Interests: Graeme G. Sorbie, Ashley K. Williams, Sophie E. Carter, Amy K. Campbell, Jonathan Glen, David Lavallee, Nicholas Sculthorpe, Alexander J. Beaumont declare that they have no competing interests. Andrew Murray is a consultant to The R&A (a global governing body for golf).

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Authors' contributions: GS, AW, JG, AB were involved in the data collection process. SC analysed the accelerometery data. AC analysed the muscle thickness data. GS and AB analysed all other data and interpreted the data. GS and AB were major contributors in writing the manuscript. All authors read and approved the final manuscript.

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