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Assessment of activity energy expenditure during competitive golf: The effects of bag carrying, electric or manual trolleys

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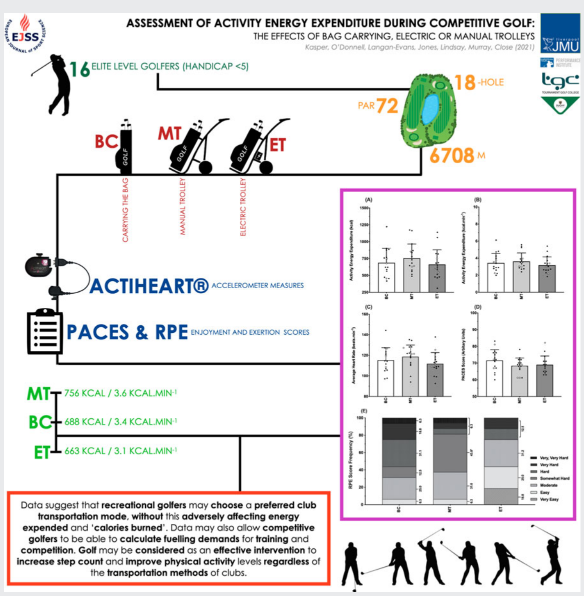
ABSTRACT
Golf is a sport played around the globe, with an estimated 42.6 million people playing within the United Kingdom and United States of America alone. To date, there is limited data on the energy expenditure of golf. The present study assessed the activity energy expenditure (AEE) of 16 high-standard (handicap under 5) golfers who completed three rounds of competitive golf either carrying the golf bag (BC), using a manual push trolley (MT) or an electric trolley (ET) (Stewart Golf, Gloucester, UK). Prior to each round, participants were fitted with an Actiheart® accelerometer (Camntech, Fenstanton, UK) to estimate AEE, whilst ratings of perceived exertion (RPE) and enjoyment were collected following each round. Data were analysed using a one-way repeated measures ANOVA, with Hedges g effect sizes (ES) calculated. Mean (SD) AEE was 688 ± 213 kcal for BC, 756 ± 210 kcal for MT and 663 ± 218 kcal for ET ($p = .05$) although these differences were deemed *small* or less. The ET condition resulted in the lowest mean heart rate, *moderate* or *very large* from BC or MT, respectively. There were no significant differences in enjoyment although perceived exertion was lowest in the ET condition. In summary, we report meaningful differences in AEE between the three conditions ($p = .05$), with perceived exertion and maximum HR being lowest when using the electric trolley. Golf may be considered as an effective intervention to increase step count and improve physical activity levels across the general population regardless of transportation methods of clubs.



KEYWORDS
Golf; physical activity; MET; nutrition

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Highlights

- Golf is played around the world both professionally and recreationally although to date research on the activity energy expenditure (AEE) of the sport is limited.
- We report that the AEE for a round of golf was 3.4, 3.6 and 3.2 kcal.min^{-1} for the bag carrying, manual trolley and electric trolley conditions, respectively.
- The mode of transporting the golf clubs had no meaningful differences in AEE although perceived exertion and maximum HR were lowest when using the electric trolley. Golf may be considered as an effective intervention to increase step count and improve physical activity levels across the general population regardless of the transportation methods of clubs.

Introduction

Golf is a sport played both recreationally and competitively around the globe, with an estimated 42.6 million people playing within the United Kingdom and United States of America alone (National Golf Foundation, 2021; The R&A, 2021). Golf courses vary in distance, with the shortest on the European tour as of 2021 being 6686 yards / 6.1 km (Himmerland Golf & Spa Resort, Himmerland, Denmark), and the longest being 7834 yards / 7.2 km (Gary Player Country Course Golf Club, Sun City, South Africa), with an average 7181 yards / 6.6 km across 34 courses. This is typically longer than the length of a course for recreational golf, which is closer to 6700 yards. Navigating these long distances can take players between ~3 and 5 h, dependent upon walking speed and course design (Parkkari et al., 2000). The best available literature highlights that golf can provide moderate intensity, health-enhancing physical activity for most persons (~4.8 METs) (Luscombe et al., 2017; Murray et al., 2017) having many positive impacts on both the physical and mental health of players (Kobriger et al., 2006; Murray et al., 2017; Parkkari et al., 2000; Zunzer et al., 2013).

Despite exercise energy expenditure (EEE) being well documented within other sports (Bradley et al., 2015; Costello et al., 2018; Hannon et al., 2021; Smith et al., 2018; Wilson et al., 2018), limited research exists within the sport of golf, especially during competitive situations and using appropriate methodologies. It is crucial to have an accurate understanding of the energetic cost of sports and activities to assist with both exercise prescription (from a health perspective) and to efficiently fuel performance at the competitive level. The sparsity of investigations examining EEE within golf is limited by the wide array of methods to assess total energy expenditure (TEE), alongside few studies attempting to quantify activity energy expenditure (AEE) of the sport (Murray et al., 2017). For example, one study reported that the total mean EE for 18 holes for males and females was 926 ± 292 kcal and 556 ± 180 kcal, respectively (Zunzer et al., 2013). However, not only did this study use a commercially available Global Positioning System (GPS) watch to estimate TEE, the AEE of the exercise was not reported. Moreover, these data were collected on golfers with what could be classed as a recreational golfer handicap (males n = 38, Handicap = 22.6 ± 9.9 and females n = 15, Handicap = 27.9 ± 11.0) and it is therefore important to also assess the AEE of golfers with a superior playing standard using more accurate methodologies.

There are a growing number of studies in elite athletic populations that have assessed AEE using the Actiheart® monitor (Wilson et al., 2013), a device that has been validated against doubly labelled water in free-living and exercise conditions (Brage et al., 2015; Villars et al., 2012). The Actiheart® monitor has been proposed to have increased reliability versus stand-alone accelerometer and heart rate monitors (HRM), due to accounting for upper in addition to lower body movements, something that can often go unmeasured using hip based accelerometery. In addition, although HR may be correlated to physiological output, these may not be able to account for other factors within golf, such as stress levels (Crouter et al., 2008). Consequently, it is reasonable to suggest that independent of using doubly labelled water, which itself is limited to several days worth of expenditure rather than the typical duration of golf round (Westerterp, 2017), that a combination of both accelerometery and heart rate using the Actiheart® system may pose the most promising solution for estimation of AEE in free-living conditions (Brage et al., 2004). This suggestion is in agreement with research in the physical activity field, which suggests that the Actiheart® system provides a greater level of accuracy when estimating AEE vs. stand-alone devices (such as a pedometer), particularly within low to moderate activities (Thompson et al. 2006).

A further complexity in the understanding of AEE within golf involves the consideration of the various modes of transporting the playing equipment around the course, given that a typical golf bag with clubs will weigh approximately 12–15 kg. Whilst professional players often employ a "caddie" to carry the clubs, most amateur golfers either carry the clubs themselves, push them using a manual trolley, use an electronic trolley or use a golf cart (often referred to as a buggy). Indeed, in a 2015 survey by The Royal & Ancient (R&A) with an $n = 56,248$ across 112 counties, it was reported that the vast majority of respondents walked the course, with only 15.7% driving the course using a golf buggy. This figure was even less in Great Britain and Ireland or Continental Europe with only 2.2% and 6.5% using a golf buggy, respectively (The R&A, 2015). It is therefore important that research is performed to not only understand the AEE of golf but also assess the influence that the most common transportation methods of the equipment may pose whilst walking the golf course.

Therefore, the aims of the current study were to (1) investigate and quantify the AEE of experienced golfers over the course of an 18-hole round of golf under tournament conditions (2) compare the AEE of various transportation modes whilst walking the golf course (including the effects of the transportation method on enjoyment and ratings of perceived exertion), and (3) elucidate the main contributor to any differences in AEE (e.g. walking vs. transportation mode). It was hypothesised that carrying the golf bag would result in increased AEE when compared with both the electric and manual trolley transportation methods.

Methods

Subjects

Sixteen high-standard male ($n = 13$) and female ($n = 3$) golfers with a handicap < 5 (mean ± SD: 1.5 ± 2.4) volunteered to participate in the study (age: 21.9 ± 7.0 years; height: 181.4 ± 10.7 cm; body mass: 77.0 ± 12.8 kg). All golfers were recruited from a specialist golf college based in Portugal (which accounts for the uneven gender split) and provided written consent after study details were fully explained. The study was approved by the Ethics Committee of Liverpool John Moores University (M21_SPS_1395).

Experimental design

In a randomised repeated measures design, players completed three rounds of competitive golf (18-hole, par 72) across separate days on the same championship course (O'Connor Jnr Championship Course, Amendoiera, Portugal) and under the following locomotor conditions: (1) carrying the golf bag (BC); (2) using a manual push trolley (MT) (Stewart Golf R1-S, Stewart Golf Ltd., Gloucester, UK); and (3) using a follow electric trolley (ET) (Stewart Golf X9 Follow, Stewart Golf Ltd., Gloucester, UK). All players used a lightweight carry bag with the same number of clubs and same bag contents for each round. Data were collected over an 8 week period with at least 7 days between trials. The weather conditions were consistent between trials (midday temperature: 17 ± 1°C; wind speed: 10.57 ± 4.08 mph), the tee-off time was always between 09:00 and 10:30am, the mean duration of the rounds were similar (BC: 3 h 22 min; MT: 3 h 29 min; ET: 3 h 27 min) and players followed the same dietary intake for each round. This included a self-selected pre-round breakfast, which was written down and repeated for each round. All players confirmed they had followed the same pre-round breakfast for each trial. No strenuous physical activity was permitted in the 48 h prior to data collection. The O'Connor Jnr Championship course measured 7336 yds / 6708 m for the men's course and 6168 yds / 5640 m for the women's course. Ratings of perceived exertion (RPE), enjoyment and AEE measures were collected for all rounds, as described in the subsequent sections.

Assessment of activity energy expenditure

Prior to each round, participants were fitted with an Actiheart® accelerometer (Actiheart 5®; dimensions: 39.7 × 30.3 × 9.25 mm; weight: 10.5 g) and chest HRM (Camntech, Fenstanton, UK). A signal test (10 min of wearing of the device) was completed to ensure the R wave of each participant was recorded adequately and to avoid inaccurate readings during measurement due to high noise level or low signal. Golfers proceeded to play a competitive round of golf. Immediately following each round, participants completed an enjoyment scale (previously used in Bartlett et al., 2011) and rate of perceived exertion questionnaire (previously used in Wilson and Jones, 1989). Participant HR and activity levels were recorded using 15 s epochs to estimate AEE for the duration of play. Estimates of AEE (kcal.min^{-1}) were calculated using a branch chain prediction equation detailed within the Actiheart® user manual (UK version; Cambridge Neurotechnology, 2020), which accounted for the removal of predicted resting metabolic rate (RMR) from the AEE estimation. Immediately following each round, the device was removed, and data downloaded for subsequent analysis.

Perceptual enjoyment and exertion

Immediately post-round, players reported their ratings of enjoyment according to the Physical Activity Enjoyment Scale Questionnaire (PACES) (Bartlett et al., 2011; Kendzierski and DeCarlo, 1991). Each element was rated on a 7-point bipolar scale with a score of 4 representing a neutral point (see Table 1). Participants also rated their perceived exertion using the modified Borg Scale (see Table 2) (Borg, 1982; Wilson and Jones, 1989), with a maximum value of 10.

Statistical analysis

Descriptive statistics are inclusive of mean ± SD for AEE (kcal.min^{-1}), HR (beats.min^{-1}) and PACES total, whereas ordinal responses for RPE were calculated into frequencies. Ratio and interval data were explored for outliers utilising box plots and normality was established via distribution of histograms and a Shapiro–Wilk test. Where data contained no outliers and was normally distributed, a one-way repeated-measures ANOVA was employed, with sphericity assessed via the Mauchly test and Bonferroni post hoc analysis used to examine pairwise comparisons, inclusive of 95% confidence intervals (95% CI). For data containing outliers and non-normal distribution, a non-parametric Friedman test was utilised with accompanying pairwise comparisons when the null hypothesis was rejected. Additionally, Hedges *g* effect sizes (ES) were also calculated utilising the following quantitative criteria to explain the practical significance of the findings: *trivial* <0.2, *small* 0.21–0.6, *moderate* 0.61–1.2, *large* 1.21–1.99, and *very large* ≥2.0 (Hopkins et al., 2009). Pearson's Chi-squared test was used to compare frequency percentages between RPE responses. All analyses were performed using SPSS (version 26 for Windows, SPSS Inc., Chicago, IL, USA) and the alpha level was set at $p \leq .05$.

Table 1. The Physical Activity Enjoyment Scale questionnaire (Kendzierski and DeCarlo, 1991).

*I enjoy it	1	2	3	4	5	6	7	I hate it
I feel bored	1	2	3	4	5	6	7	I feel interested
I feel bored	1	2	3	4	5	6	7	I like it
*I find it pleasurable	1	2	3	4	5	6	7	I don't find it pleasurable
*I am very absorbed in this activity	1	2	3	4	5	6	7	I am not at all absorbed in this activity
It's no fun at all	1	2	3	4	5	6	7	It's a lot of fun
*I find it energising	1	2	3	4	5	6	7	I find it tiring
It makes me depressed	1	2	3	4	5	6	7	It makes me happy
*It's very pleasant	1	2	3	4	5	6	7	It's very unpleasant
* I feel physically good whilst doing it	1	2	3	4	5	6	7	I feel bad whilst physically doing it
* It's very invigorating	1	2	3	4	5	6	7	It's not at all invigorating
I am very frustrated by it	1	2	3	4	5	6	7	I am not at all frustrated by it
* It's very gratifying	1	2	3	4	5	6	7	It's not at all gratifying
* It's very exhilarating	1	2	3	4	5	6	7	It's not at all exhilarating
It's not at all stimulating	1	2	3	4	5	6	7	It's very stimulating
* It gives me a strong sense of accomplishment	1	2	3	4	5	6	7	It doesn't give me a strong sense of accomplishment
* It's very refreshing	1	2	3	4	5	6	7	It's not at all refreshing
I felt as through as I would rather be doing something else	1	2	3	4	5	6	7	I felt as though there is nothing else I would rather be doing

Note: *Denotes reversal when scoring.

Results

Estimated activity energy expenditure

Round times and total AEE for BC (201.75 ± 17.91 min; 688 ± 213 kcal), MT (208.94 ± 17.04 min; 756 ± 210 kcal) and ET (207.31 ± 17.02 min; 663 ± 218 kcal) can be seen in Figure 1(A). Whilst there was a significant difference in AEE across conditions ($p = .05$), with ET being 25 kcal lower than BC ($p = 1.00$; ES = 0.11; 95% CI = −102.64 to 52.51) and 93 kcal lower than MT ($p = .07$; ES = 0.42; 95% CI = −191.05 to −4.97) and a 68 kcal difference between BC and MT ($p = .43$; ES = 0.41; 95% CI = −186.78 to 50.83), these resulted in *trivial* and *small* effects, respectively.

There was also a significant difference in AEE when expressed as kcal per minute between the transportation modes ($p = .03$). Use of the ET resulted in 0.3 kcal·min^{-1} less than BC ($p = .02$; ES = 0.14) and 0.5 kcal·min^{-1} less than using a MT ($p = .03$; ES = 0.24), yet again these differences resulted in *trivial* and *small* effects (Figure 1(B)). There was also a 0.2 kcal·min^{-1} difference between BC and MT rounds; however, this was non-significant and *trivial* in effect size ($p = .79$; ES = 0.19).

Heart rate

HR during the round of golf ranged from 97 to 144 beats.min^{-1} in the BC condition, 92–138 beats.min^{-1} in the ET condition and 94–135 beats.min^{-1} using the MT (Figure 1(C)). There was a significant difference in HR across conditions ($p = .04$), with mean HR during the ET round being 3 beats.min^{-1} lower than the BC ($p = .02$;

Table 2. The modified Borg Scale (Borg, 1982).

Rating	Descriptor
0	Nothing at all (not noticeable)
0.5	Very very easy
1	Very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	–
7	Very hard
8	–
9	Near maximal
10	Maximal

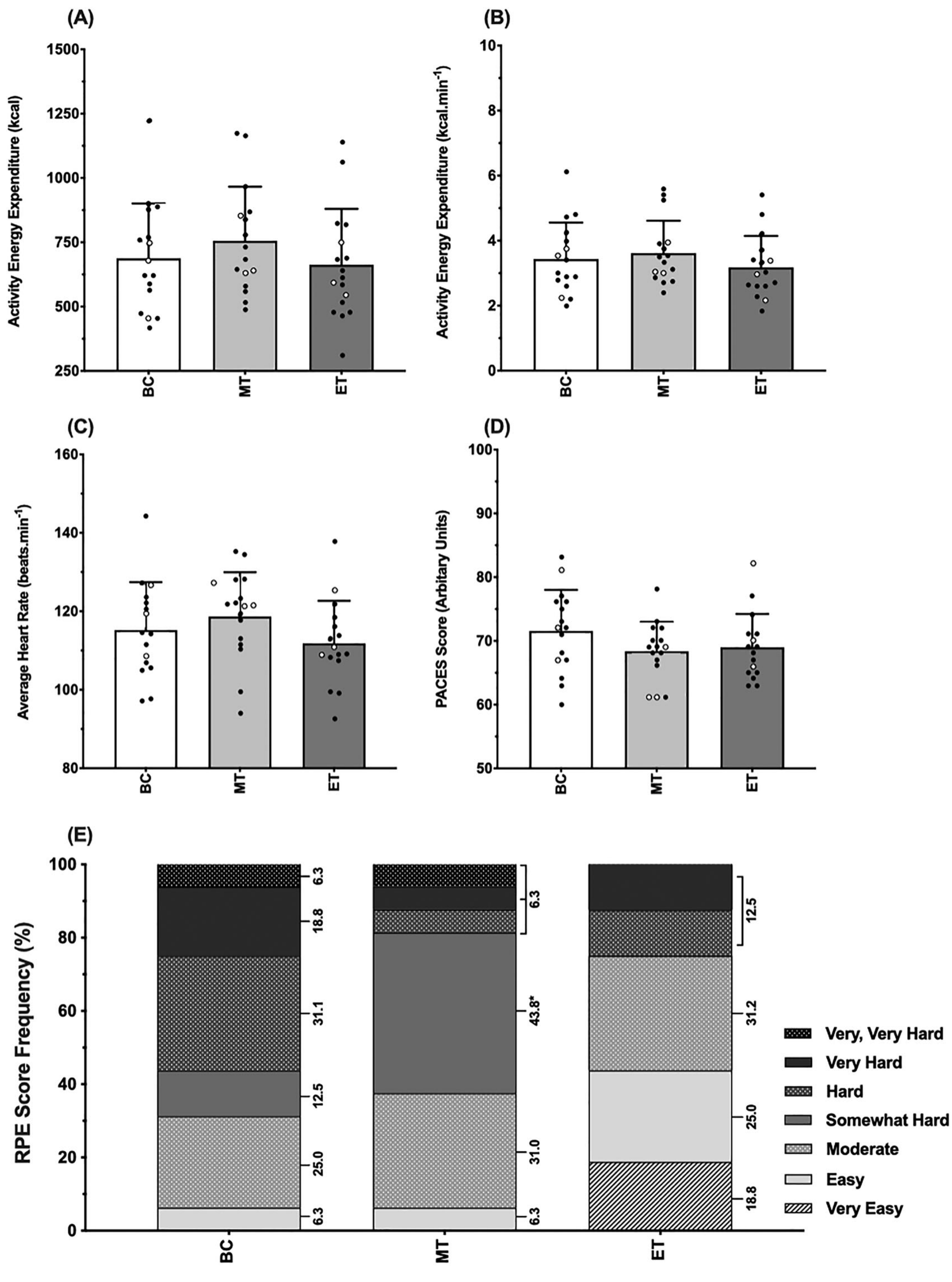

Figure 1. Means and individual scores for males (Black Circles) and females (White Circles) (A) Total AEE, (B) AEE per minute, (C) HR, (D) Enjoyment, and (E) RPE for Bag Carry (BC) vs. manual trolley (MT) vs. electric trolley (ET).

ES = 1.00; 95% CI = −5 to 0) and 7 beats.min^{-1} lower than the MT (p = .02; ES = 2.43; 95% CI = −12 to −1), resulting in *moderate* and *very large* effects, respectively. Despite a 4 beat.min^{-1} difference between BC and MT, this was not significant, independent of a *large* effect size (p = .23; ES = 1.34; 95% CI = −10 to 3).

Enjoyment

Despite differences in both AEE and HR between the transportation modes, this did not result in any significant differences in PACES scores between the groups (p = .26, Figure 1(D)). There was, however, a *small* effect between ET and BC (ES = 0.50) and *moderate* effect between ET and MT (ES = 0.70).

Ratings of perceived exertion

There was a significant difference between the mean RPE scores ($p = .05$) for the entire round, with ET being deemed the lowest in terms of perceived exertion (Figure 1(E)). Moreover, ET was the only mode of transportation participants found "very easy", accounting for 18.8% of all the responses. Almost 80% of the responses were "moderate" or less in ET compared with only 37% and 31% in MT and BC, respectively. In addition, ET was the only mode that participants did not score as "very very hard".

Discussion

The aim of the current study was to quantify AEE within an experienced cohort of elite golfers, whilst simultaneously investigating the effects of three popular equipment transport modes (carrying the bag, manually pushing a trolley, and using an electric trolley). We report that although there was a statistically significant difference in AEE between the transportation modes, these differences were deemed *trivial* to *small*. These findings suggest that TEE during a round of golf is not meaningfully affected by the transportation mode of the equipment but is largely due to the locomotive cost of walking around the golf course combined with a small contribution from the physical exertion of the golf swing. Despite no meaningful differences in AEE between the modes of transportation, carrying the bag elicited the highest perceived effort levels (e.g. *Hard*, 31.1%; *Very Hard*, 18.8%; *Very*, *Very Hard*, 6.3%). These novel data are of particular interest as we quantify the AEE for the first time in golf (3.4 ± 1.0 kcal.min^{-1}), providing a basis to construct nutritional interventions for experienced golfers, as well as helping with exercise prescription for recreational golfers.

Government guidelines recommend >150 min of brisk walking weekly (National Health Service, 2021). Within the current study, we observed an average round of golf to be 200–210 min, with a heart rate of between 92 and 144 bpm (which equates to roughly 46% to 73% of maximum heart rate of the participants) expending approximately 3.4 ± 1.0 kcal.min^{-1} as AEE. It is, therefore, reasonable to assume that one round of golf per week may significantly contribute to the minimum recommended exercise requirements for adults. We also hypothesise that the major component of the AEE within golf stems from the physical demands of locomotion rather than the method of transporting the clubs. This hypothesis is based upon there being no major differences in the energy expended between using the electric trolley and carrying the clubs combined with the fact that the kcal expended per minute of golf was not dissimilar to that of walking. This is an important observation for recreational golfers, who may want to pursue golf for health reasons, yet find carrying a golf bag uncomfortable.

Following the removal of estimated RMR, the AEE for an 18-hole round of golf in the present study was 702 ± 213 kcal, with AEE per minute on the course being 3.4, 3.6 and 3.2 kcal.min^{-1} for BC, MT and ET conditions, respectively. Over the time period of an entire round, this would equate to a difference of 93 kcal between the highest and lowest conditions, which could be deemed of low physiological relevance. The data reported in the present study are lower than previous studies (926 kcal ± 292 kcal) (Zunzer et al., 2013), which could be related to previous work reporting the TEE rather than the AEE, variation in the methodologies to measure EE, and/or differences in the playing standard of the participants. Indeed, in a recent scoping review, a range of 1936 kcal was reported for total energy expended across a round of golf (range 531–2467 kcal) (Murray et al., 2017). Our findings are towards the lower end of what is reported in this review, although we are the first to utilise validated Actiheart® technology, whilst using a homogenous playing level of participants all regarded as high-standard players.

It is well documented across sport that elite athletes have improved physiological profiles in comparison with recreational athletes, specifically with regards to resting HR and responses to exercise. In the present study, HR profiles were similar to previously published data within golf (males: 105 ± 14 beats.min^{-1}, females: 103 ± 12 beats.min^{-1}) (Luscombe et al., 2017). It is interesting to note that the BC condition displayed the highest range of HR across the round (47 beats.min^{-1}) as well as the highest overall HR (144 beats.min^{-1}) compared with ET and MT. This leads to speculation that carrying the bag may cause increased HR fluctuation, which may impact choice of transportation for the elite golfer and could adversely affect match performance, although these suggestions are speculative and require further investigation.

The present study was not without its limitations, which were largely a result of attempting to collect real world data that had immediate translational potential (Close et al., 2019). For example, although the course length was known, the total distance that subjects covered was not directly measured; however, it is reasonable to assume that with golfers of a similar ability, any differences between rounds would be trivial. It is worth noting that differences may be more pronounced in the general population due to factors such as age, gender and physical activity status. Indeed, this may be more pronounced still amongst middle-aged and older adults that are generally less active than the younger cohort used in the current study. It is likely that this group may experience greater benefits to energy expenditure and as such future research may wish to investigate these differences. In addition, the course terrain was relatively flat and, therefore, AEE may be greater on courses with elevated topography. A second limitation was the imbalance between the gender of the participant sample (77% male, 23% female). Players were recruited from a specialised golf college where there were significantly more males enrolled in the college than females. As such, data was analysed as an entire population and future studies may wish to further explore the effects of gender using a more balanced approach. Whilst perceived effort and HR were lowest in ET, we were not able to assess if this had any effects on performance and this could be explored in future research. Finally, at the time of the current study, golf buggy use was not permitted due to the COVID-19 pandemic and as such, it was not possible to explore the effects of riding the course using a golf buggy. Although ideally AEE of buggy transportation would have been measured in the current study, it is important to stress that ∼85% of golfers surveyed worldwide walk the course (The R&A, 2015) and golf buggy's are not permitted in most forms of competition golf. Future research, however, may wish further investigate the effects of golf buggy transportation on AEE.

In summary, we report for the first time the AEE within a cohort of high-standard golfers using 3 different club transportation conditions over 18-holes of golf under tournament conditions. We observed no meaningful differences in AEE, suggesting that this is not majorly affected by transportation mode. The perceived exertion and maximum HR were found to be lower when using the electric trolley, which could have implications for competitive performance, something that should be addressed in future research. The data presented here may allow the fuelling demands for training and competition to be calculated for competitive golfers, whilst providing key information for recreational golfers who may play golf as part of their overall physical activity regime. Finally, these data suggest that recreational golfers may choose a preferred club transportation mode, without concern that this will adversely affect energy expended and "calories burned", although there may be musculoskeletal benefits obtained from carrying golf clubs that should not be dismissed. Golf may be considered as an effective intervention to increase step count and improve physical activity levels across the general population regardless of the transportation methods of clubs.

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