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Running Head: Effect of sprint interval training on golf performance

Location of study: Abertay University Research Laboratory, Dundee Institute of Sport & Exercise and Drumoig Driving Range.

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ABSTRACT

BACKGROUND: Improving golf fitness is one way to improve club head velocity and subsequently golf performance. The purpose of the study was to investigate the effect of a three-week upper-body sprint training (SIT) program on power output and golf performance.

METHOD: Eleven golfers (handicap: 5.5 ± 2.8) completed the SIT intervention. This was a self-controlled experiment with three testing points (pre-control, post-control and post-intervention) where subjects completed a ballistic bench press, upper-body Wingate and golf testing session.

RESULTS: Significant improvements were observed (13.3–15.5%) in peak and mean power production during the Wingate post-intervention in comparison to pre and post-control time points ($p < 0.05$). This was replicated in peak power for the ballistic bench press for both peak power ($p < 0.05$), but significance for mean power was only observed between post-control and post-intervention (p < 0.05) (improvements of 6.1–8.5%). These improvements were not seen consistently in golf performance variables measured, with no significance identified for the 7-iron and significant improvements ($p < 0.05$) observed in Carry Distance (2.2%) and Ball Velocity (1.4%) between pre-control and post-intervention.

CONCLUSION: Lack of golf performance improvements could be because of the natural variation in club-head velocity across sessions or the inability of subjects to utilise their power gains during the golf swing. Longer SIT interventions may be needed to observe improvements in golf performance.

KEY WORDS: Athletic Performance, Sprint Interval Training, Muscle Strength

INTRODUCTION

Golf is a sport where physical, technical and psychological factors contribute to performance success (1,2). The primary goal of using a Driver, fairway wood or long iron in golf is to hit the ball as far as possible whilst still maintaining accuracy (3,4). The ability to drive a golf ball greater distances is significantly associated with lower scores on Par-4 and Par-5 holes within the professional game (4). A number of biomechanical factors have been identified to determine drive distance, however, it is commonly accepted that drive distance is most influenced by the club head velocity (CHV) at the instant of impact transferring force generated by the body to the golf ball (2,3,5,6). Fradkin et al. (7) found CHV to be highly correlated (r = 0.950) with handicap indicating greater CHV is associated with better skill levels. Thus, professional and amateur golfers should strive to increase their CHV for improved performance. Improvements in CHV can be achieved through making technical amendments to the golf swing (8). Technical changes are made to better utilise ground reaction forces, effectively transfer bodyweight, effectively utilise the X-factor stretch and optimisation of the sequential summation of forces, with CHV determined by the angular velocity and length of the arm-club lever (3,9). Enhancement in CHV is particularly important as it has a direct relationship with ball velocity, whereby increased CHV would equate to increased ball velocity (based on same impact point on clubface) and subsequently improved shot distance (10). Previously it has been demonstrated that 5.3 km/h improvements in CHV will result in 10-15 meters more carry distance (6).

An alternative to technical adjustments to improve CHV is exercise modalities that promote strength and power development (5,6,11). Increases in power and force outputs will potentially benefit a multitude of sports, including ones involving a ball-striking component such as golf (11,12). Traditionally, golf is predominantly thought of as a strategic technical sport rather than focusing on physical fitness (13,14). This is despite a body of scientific evidence showing improved performance (CHV) with increased muscle activity and improved power throughout the golf swing (2,5,11,12,15–19). A range of improvements have been observed for CHV and carry distance, Doan et al. (2) identified a 1.6% increase in CHV with Lephart et al. (20) and Fletcher et al. (15) showing improvements of 1.5 – 5.2% and 4.3 – 7.7% for CHV and carry distance respectively. Additionally, strong relationships have been identified between upper body power capabilities and golf performance (CHV and ball velocity) (21). Based on these results golf driving performance is enhanced by improving power capabilities of the golfer.

One exercise modality that has not been explored within golf performance is sprint interval training (SIT), characterised by short bursts bouts (typically 4 to 10) of maximal effort of 30 seconds or less (22). Power based performance improvements from SIT include peak power output (PPO), mean power output (MPO), total work (TW) during a Wingate and motor unit activation (22–28). It is now considered that SIT is a viable time efficient training method that can induce both central and peripheral adaptations (29). A mode of delivering SIT is upper body arm cycling. There is limited information regarding upper body SIT however, upper body high intensity training (bouts of > 30 seconds) have been shown to effectively improve PPO (43.6 ± 20.7%) (30) and significantly associated with bench press throwing power (31). Upper body arm cycling has been shown to be an effective exercise targeting arm, shoulder and trunk musculature (32) all of which are activated during the golf swing to generate power (33). In addition, physiological changes to SIT have been shown to occur during short interventions (22,34). An intervention such as upper body arm cycling therefore has the potential to improve neuromuscular firing and coordination of these muscles leading to increased CHV and golf drive performance (18). Therefore, the aim of this study was to assess a three-week upper body SIT invention on power output and golf drive performance. It was hypothesised that the intervention would improve performance measures during a Wingate, ballistic bench press and golf drive performance.

METHOD

Participants

Following institutional ethical approval (School of Applied Sciences at Abertay University), twelve skilled right-handed golfers were recruited to participate in this study. Eleven golfers completed the three-week self-controlled period and three-week SIT intervention and were therefore included for analysis (mean ± SD: age: 34 ± 9 years; height: 182.1 ± 5.7 cm; mass: 77.9 ± 11.6 kg and handicap: 5.5 ± 2.8). Skilled golfers were recruited due to their increased and more consistent technical ability. All participants were free of musculoskeletal injury for a period of three months, gave informed written consent and completed a PAR-Q prior to any testing. Participants were required to abstain from conditioning or resistance training 48 hours prior to the testing session. During the control and intervention period golfers were requested to maintain their normal golfing and training routine (it was confirmed with participants that a minimum of one practice session and one golf round was completed weekly).

Procedures

Prior to testing sessions participants were familiarised with all tests and sessions were completed with at least 48 hours between them to ensure muscular fatigue did not affect results.

Ballistic Bench Press Assessment

In order to determine upper body power, participants performed a bench press throw ballistically with a load equal to 50% of their one-repetition maximum (1RM) (31). All bench press throws were performed on a Smith Machine restricting the bars displacement to one vertical plane of motion. This allowed for accurate measurement of peak power (W), mean power (W), relative peak power (W/kg) and relative mean power (W/kg) using a GymAware linear position transducer (LPT) (GymAware Lite v2.10, Mitchell, Australia). The LPT was connected to an iPhone 3 (Apple Inc., Cupertino, USA). A tether were attached to the right hand side of the bar, with the encoder placed directly below to record bar displacement (31).

Prior to maximal bench press throws being executed, participants completed a warm up of 10 repetitions at 20% 1RM and 10 repetitions at 40% 1RM, with 1 minute of rest between sets. Following a 5-minute rest participants completed two ballistic bench press throws with two minutes rest between repetitions (31). Technique was standardised to ensure consistency between participants, whereby, the bar was lowered until it came in contact with the chest approximately 3 cm superior to the xiphoid process, following one second the bar being thrown ballistically as high as possible. Participants were required to maintain contact with their head, shoulders and hips throughout the entire action (31).

Upper Body Anaerobic Wingate Test

An upper body Wingate cycle test was completed on an arm crank ergometer (Monark Ergomedic 891E, Vansbro, Sweden). Participants were aligned so that the central axis of the shoulder joint horizontally orientated with the central axis of rotation of the arm crank ergometer. Participants were in a kneeling position with the buttocks remaining in contact with the heels at all times to reduce the use of the lower body (35). Prior to the test, participants completed a 2-minute warm up against a cradle weight of 1 kg maintaining a minimum of 60 rpm. Following the warm-up, participants completed a 6-second familiarisation test to familiarize themselves with the resistance on the cradle. After a 1-minute rest period the participants pedalled with maximum effort for a period of 30-seconds against a resistance of 50g/kg of total body mass, equating to 5% resistance (31). Strong verbal encouragement was given throughout trials. Peak power (W) (max 5-second period), mean power (W) (average across 30-seconds), relative peak power (RPP) (W/kg) and relative mean power (RMP) (W/kg) were recorded using Monark software (Monark Anaerobic Test Software Version 2.24.2, Monark Exercise AB).

Golf Drive Performance

Prior to measuring golf performance variables, all participants completed a standardized warm up. This consisted of dynamic stretches targeting lower and upper body structures, as well as practice swings and full golf shots (21). Participants then performed 8 golf shots with the Driver, with 30-seconds rest in between each trial (36). After a 1-minute interval this was then replicated using a 7-iron. After each shot golfers provided a rating for quality of strike from 1 to 5; with 5 being the best strike. If a shot was scored 1 or 2 these were excluded and additional shots were performed, up to a maximum of 12 shots for each golf club (5). Golf shots were executed on an artificial golf mat, with a self-selected rubber tee used for the Driver, 7-iron was struck directly from the mat. Participants were instructed to perform their standard full shot golf swing aiming to maximise distance and accuracy. Testing was performed with the participants own Driver and 7-iron wearing appropriate golf shoes (37).

During each golf shot, CHV, ball speed (BS) and ball carry (flight distance) were recorded using a Voice Caddie Swing Launch Monitor SC 100 GPS (La Mirada, USA). The launch monitor was positioned directly behind the ball orientated towards the target line of the shot at a distance of 1 m. After each shot performance variables were logged using Microsoft Excel (Excel 2016 (v 16.0)).

Sprint interval training intervention

Following a 3-week control period whereby normal golf routine was maintained, participants completed six sessions of SIT across a 3-week period (two sessions per week with a minimum of 48 hours between each session). Previous literature has shown physiological adaptations using lower body SIT within this time period (22,38). Sessions were formulated of a 2-minute warm up against a cradle weight of 1 kg maintaining a minimum of 60 rpm. After a 1-minute interval participants completed 6 x 10 s bouts with 30 seconds rest in between sprints. This was completed against a resistance of 35g/kg of total body mass (3.5% resistance). Participants were verbally encouraged during all bouts and performed a 3-minute cool down at a cadence and resistance of subject choice following each training session.

Data Analysis

Golf performance trials were selected based on CHV, with the 5 greatest being used for analysis (39). Following this averages for CHV (km/h), Ball Velocity (km/h) and Carry Distance (m) from the 5 golf shots was calculated. For the 2 ballistic bench press trials, the trial which had the maximum measure for peak power (W), mean power (W), relative peak power (W/kg) and relative mean power (W/kg) were used for analysis. Variables analyzed for the upper body Wingate test were Peak power (W), mean power (W), relative peak power (W/kg) and relative mean power (W/kg).

Statistical Analysis

All statistical analysis was completed using Jamovi (Version 1.0.1). Prior to statistical analysis all data was measured for normality using a Shapiro-Wilk test. Normality was assumed for all data. Therefore, a one-way repeated measures ANOVA was carried out for the following variables peak power (W), mean power (W), relative peak power (W/kg) and relative mean power (W/kg) for both the Wingate and ballistic bench press (BBP), golf performance variables were CHV (km'h), Ball Velocity (km/h) and Carry Distance (m). A Mauchly's test of sphericity was interpreted, if sphericity was violated a Greenhouse-Geisser adjustment was applied. Where significance was observed a Bonferroni post hoc test was run to determine between which time points the difference lay ([1] Pre-Control, [2] Post-Control, [3] Post-Intervention). Eta-squared (η^2) was calculated and interpreted as the following small (0.01), medium (0.06) and large (0.14). Significance was set at an alpha level of $p < 0.05$.

RESULTS

Descriptive statistics for CHV, ball velocity and carry distance are presented in Table 1. Descriptive statistics for performance variables during the Wingate and BBP are presented in Figures 1 – 4.

No significant differences were identified between Pre-Control and Post-Control time points for all golf performance measures for the 7-iron and Driver. The repeated measures ANOVA did however highlight significance within the model for the Driver Carry ($p = 0.008$, $\eta^2 = 0.013$)

and Ball Velocity (p = 0.034, η^2 = 0.008). The Bonferroni post hoc test identified differences were between Pre-Control and Post-Invention for both Driver Carry (p = 0.007) and Ball Velocity (p = 0.031). No differences were identified for the 7-iron between Pre-Control and Post-Intervention (p > 0.05).

Table 1. Descriptive statistics for each golf performance variable for the 7-iron and Driver. *indicates significant difference from Pre-Control (p < 0.05)

Club Selection	Performance Variables	Pre-Control (mean ± SD)	Post-Control (mean ± SD)	Post-Intervention (mean ± SD)
Driver	CHV (km/h)	165.5 ± 11.9	166.6 ± 11.3	167.8 ± 11.3
	Ball Velocity (km/h)	242.5 ± 17.4	244.5 ± 15.7	245.8 ± 15.7*
	Carry Distance (m)	224.5 ± 19.7	227.8 ± 17.6	229.4 ± 17.3*
7-iron	CHV (km/h)	142.7 ± 11.5	142.8 ± 10.7	144.0 ± 9.8
	Ball Velocity (km/h)	186.5 ± 14.1	187.4 ± 13.9	188.9 ± 13.7
	Carry Distance (m)	144.0 ± 12.5	145.4 ± 12.1	146.2 ± 11.2

During the Wingate test (Figures 1 & 2) significant differences were identified by the ANOVA for peak power (p = 0.002, η^2 = 0.088), mean power (p = 0.003, η^2 = 0.087), RPP (p = 0.002, η^2 = 0.096) and RMP (p = 0.004, η^2 = 0.104). Post hoc analysis identified the differences were between Pre-Control and Post-Intervention (peak power p = 0.008, mean power p = 0.013, RPP p = 0.009, RMP p = 0.014) and Post-Control and Post-Intervention (peak power p = 0.004, mean power p = 0.006, RPP p = 0.004, RMP p = 0.006). No significant differences were noted between Pre-Control and Post-Control (p > 0.05).

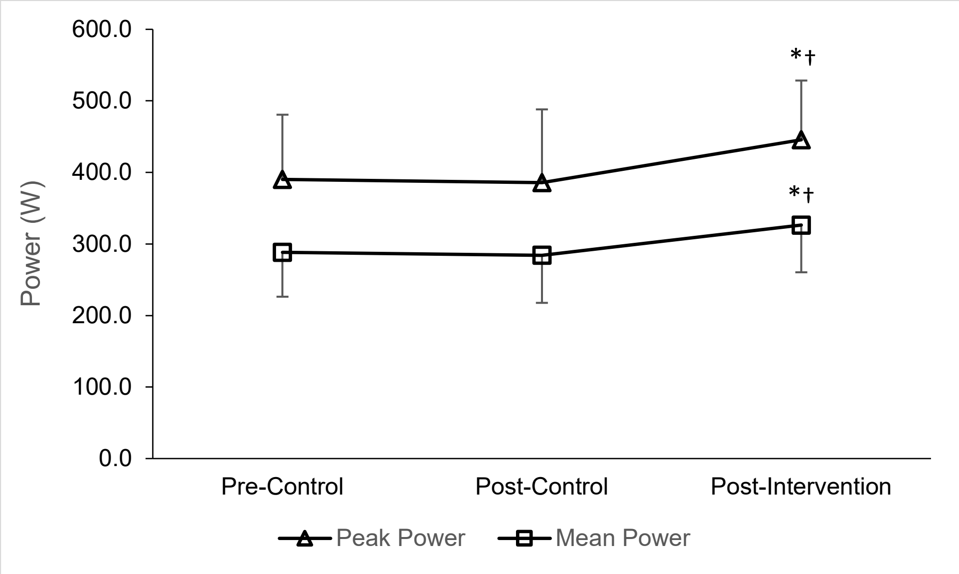

Figure 1. Peak and mean power during the Wingate test. *indicates significant difference from Pre-Control (p < 0.05); † indicates significant difference from Post-Control (p < 0.05).

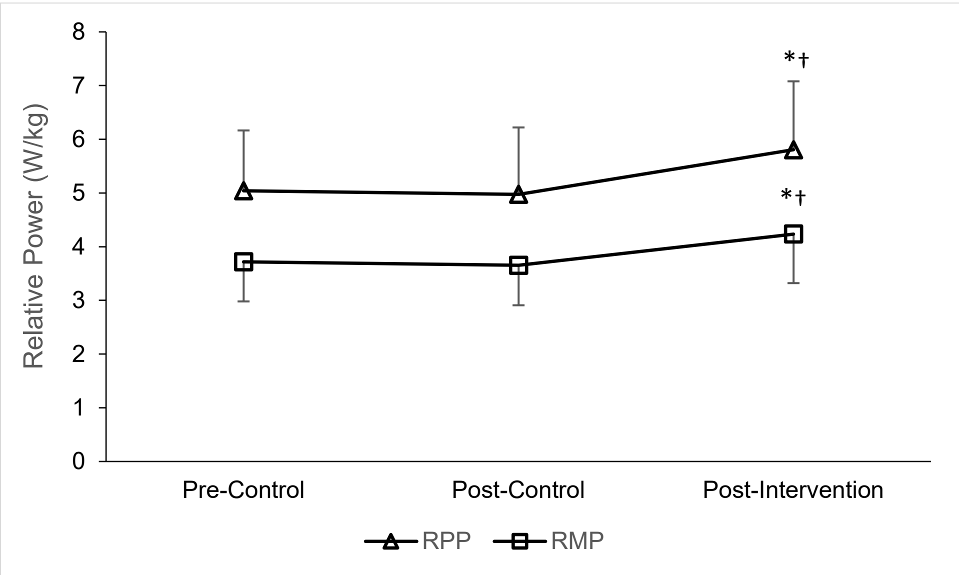

Figure 2. Relative peak and mean power during the Wingate test. *indicates significant difference from Pre-Control (p < 0.05); † indicates significant difference from Post-Control (p < 0.05).

Figures 3 & 4 present results for the BBP. Significant differences were identified within the ANOVA for peak power ($p = 0.008$, $\eta^2 = 0.012$), mean power ($p = 0.03$, $\eta^2 = 0.014$), RPP ($p = 0.007$, $\eta^2 = 0.01$) and RMP ($p = 0.022$, $\eta^2 = 0.14$). Bonferroni post hoc analysis showed differences were between Pre-Control and Post-Intervention for peak power (p = 0.022) and RPP (p = 0.022). Between Post-Control and Post-Intervention significant differences were identified for all variables (peak power p = 0.015, mean power p = 0.039, RPP p = 0.039 and RMP p = 0.029. No significant differences were shown between Pre-Control and Post-Control ($p > 0.05$).

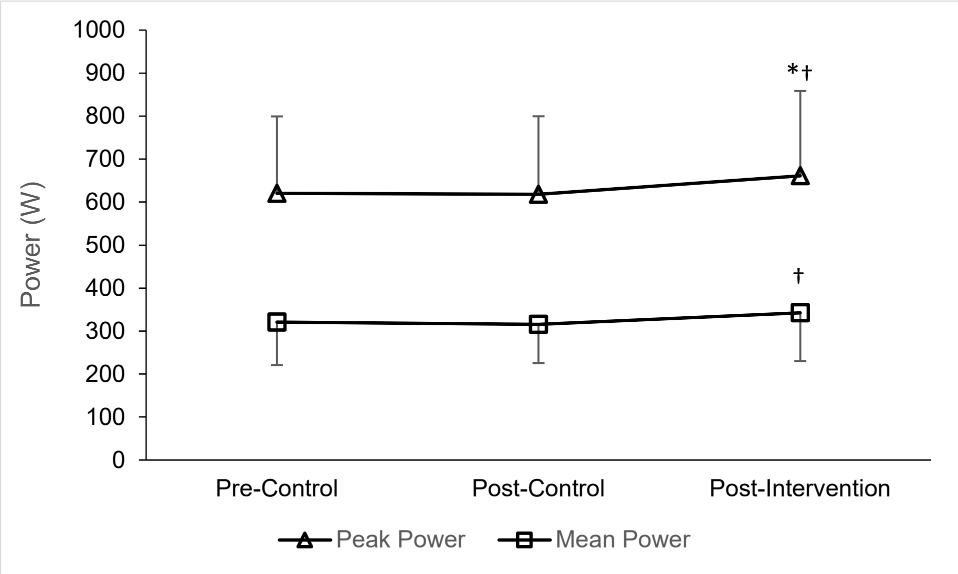

Figure 3. Peak and mean power during the ballistic bench press test. *indicates significant difference from Pre-Control ($p < 0.05$); † indicates significant difference from Post-Control ($p < 0.05$).

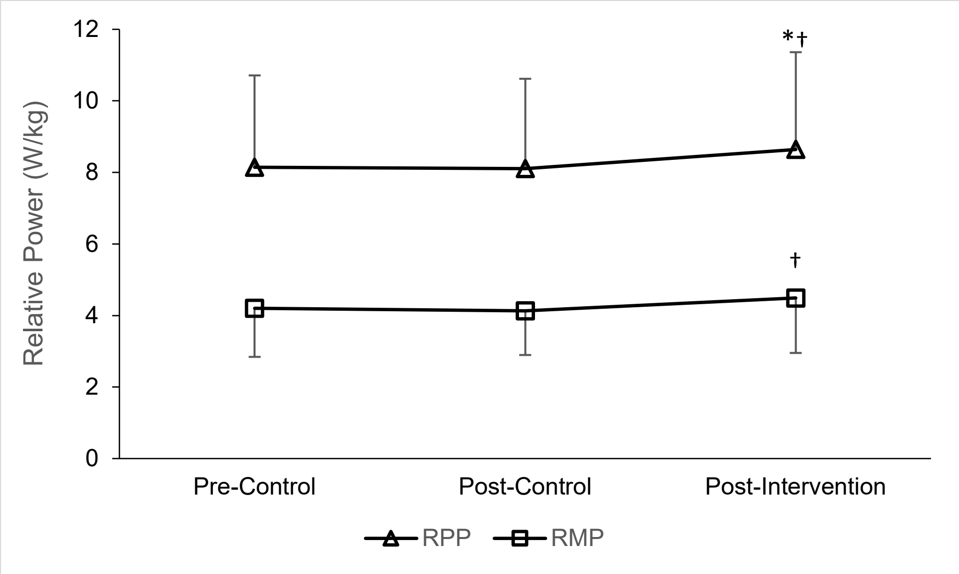

Figure 4. Relative peak and mean power during the ballistic bench press test. *indicates significant difference from Pre-Control ($p < 0.05$); † indicates significant difference from Post-Control ($p < 0.05$).

DISCUSSION

The findings of the current study demonstrated significant improvements post the 3-week SIT intervention for Wingate and BBP measures, however, these improvements were not observed in golf performance. All variables tested during the Wingate test showed significant improvements after the SIT intervention from Pre-Control and Post-Control measurement points. For the BBP both peak power and RPP significantly increased post-intervention from Pre-Control and Post-Control time points, however, mean power and RMP only significantly increased from the Post-Control measurement point. Two significant differences were identified for golf performance measures and these were for the Driver Carry and Driver Ball Velocity. Based on the findings the study hypothesis is accepted for the Wingate and BBP performance and rejected for golf performance variables.

From the results, it is evident that power-producing capabilities have improved in participants during the Wingate. This is evidenced by significant peak and mean power increases of between 14.2% and 15.5% pre and post intervention. This was also evident in relative peak and mean power increases of between 13.9% and 16.7%. Similar significant improvements were made in relative power measures These improvements are comparable to previous literature utilising short term lower body SIT training, with magnitudes of increase in peak power of 10.1% and mean power of 10.6% have been observed (40).

Significant improvements were also observed for the ballistic bench press with increases in absolute and relative peak power between the pre control and post intervention of 6.5% (absolute) and 6.1% (RPP). This was also evident between the post control measurement and post intervention with an increase of 6.9% for peak power and 6.6% for RPP. Significant improvements for the mean power (8.5%) and RMP (8.7%) were only observed between post control and post intervention. It can be noted though although not significant similar percentage improvements were observed between pre control and post intervention (mean power 6.7%, p = 0.012; RMP 7.0%, p = 0.09). These results are comparable to previous literature that utilised moderate loads (6.2%)(41).

Although not measured in the current study a number of physiological adaptations could have contributed to this improvement in Wingate and BBP performance including increases in mitochondrial markers and enzymatic activity (citrate synthase, B-hydroxy acyl dehydrogenase, and pyruvate dehydrogenase) (38), improved muscle adaptations (reduced phosphocreatine [PCr] degradation, enhanced glycogen content) (34,38). In addition there may have been neural adaptations including an increase in motor unit recruitment, firing rate and synchronisation, resulting in an increased ability to exert more force (27). There is however mixed evidence of the efficacy of short term SIT interventions to elicit these adaptations (42), therefore longer training interventions may be needed to elicit this response. Positive results in the BBP may have increased relevance to the golf swing due to the dynamic one effort movement executed for each movement with improvements within the early time intervals of a movement (43). The golf downswing is approximately 250 ms (44), therefore utilising power improvements early within a movement are imperative for golf performance.

Whilst performance increases were noted for the Wingate and BPP, this was not consistently observed in golf performance. No significant improvements were observed for any of the golf performance variables when using the 7-iron. The authors propose that this could be due to different constraints of the golf shot. Unlike the Driver the 7-iron has increased emphasis on accuracy regarding shot distance, whereas it is optimal for the golfer to hit the ball as far as possible. Previously trunk kinematics has been shown to be different between Driver and iron shots (45), this may be due to the different requirement of shots. Improvements observed with the Driver are inconclusive, with two significant improvements observed across golf performance variables between Pre-Control and Post-Intervention and none between Post-Control and Post-Intervention. This potentially could be attributed to the natural variation observed in CHV and ball velocity across sessions. Despite being skilled golfers a natural variation of effective ball striking is going to be evident across a period of weeks. Off centre golf shots have been identified to negatively affect ball speeds, through increased spin and reduced smash factor (10). This additionally could explain no differences being observed with the 7-iron.

Improvements may not have translated to golf performance due to the short nature of the intervention (3-weeks). Total exercise time equated to 6-minutes and therefore longer interventions may be needed to see improvements. Additionally, a factor could be that despite power producing capabilities being improved, golfers were unable to then adapt their golf swing technique to effectively utilise the improvements. Whilst vertical power output has been identified as an important factor in the golf swing (5), it may be necessary to involve rotational movements in upper body SIT interventions for improvements to be observed as rotational power has been positively associated with CHV (12). When considering participants on an individual basis it was clear that some did show performance improvements, particularly in those that started with lower CHV initially (Driver: 154 – 162 km/h) tended to show increased velocity post intervention with CHV increasing by 3-4 km/h. This is in contrast to those that began the trial with faster CHV (Driver: 170+ km/h), who demonstrated minimal changes to their swing velocity (-1 to 2 km/h).

There are some limitations with the current study that need consideration. All golf performance sessions took place at a local driving range and therefore were out with controlled laboratory conditions. However, this provided golfers with a more realistic practical experience. Additionally, accuracy and centeredness of the strike on the golf club were not measured in the current study which are other aspects needed for successful golf performance. In regards to research design no true control was used with a repeated measures design selected. The authors elected to take the latter approach to reduce the inter-subject variability between groups. Based on the positive results observed in the current study regarding improved power during the Wingate and BBP, longer interventions are worthy of investigation to see if improvements translate to golf performance. Additionally, fatigue resistance across 9 or 18 holes of golf could be worthy of investigation, with SIT training having been shown to improve endurance in other sports.

The practical application to these findings are strength and conditioning or golf professionals may be able to utilise upper body SIT to improve the health characteristics in golfers, however it is unclear whether this will improve golf performance in proficient golfers across a short-term period. If coaches identify golfers that have a slower swing speed a short term upper body SIT programme may help increase their CHV and subsequently ball velocity and carry. However, for golfers with fast swing speeds (170+ km/h) it may be more viable to complete strength and power training (11) over upper body SIT training. No detriments in performance were noted for any golfers and therefore upper body SIT training can offer potential improvements in some golfers with little time burden allowing for similar levels of golf specific technique training in proficient golfers.

In conclusion, SIT did not produce consistent golf performance improvements. However, did improve power producing capabilities during an upper-body Wingate (13.3-15.5% improvements) and BBP (6.1 – 8.7% improvements) in skilled golfers. Improvements in power development may not have translated to golf performance due to the short nature of the intervention or the inability of the golfers to utilise these power improvements during the golf swing. Future investigations should aim to include a rotational element to the SIT programme and investigate longer interventions, which may better translate to golf performance.

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Figure 1. Peak and mean power during the Wingate test. *indicates significant difference from Pre-Control ($p < 0.05$); † indicates significant difference from Post-Control ($p < 0.05$).

Figure 2. Relative peak and mean power during the Wingate test. *indicates significant difference from Pre-Control ($p < 0.05$); † indicates significant difference from Post-Control ($p < 0.05$).

Figure 3. Peak and mean power during the ballistic bench press test. *indicates significant difference from Pre-Control ($p < 0.05$); † indicates significant difference from Post-Control ($p < 0.05$).

Figure 4. Relative peak and mean power during the ballistic bench press test. *indicates significant difference from Pre-Control ($p < 0.05$); † indicates significant difference from Post-Control ($p < 0.05$).