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Field-based and overspeed potentiated warm-ups increase clubhead speed and drive carry distance in skilled collegiate golfers

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ABSTRACT

Warm-ups utilising post-activation performance enhancement (PAPE) strategies have been shown to increase clubhead speed (CHS) in golfers. However, the effectiveness of overspeed training using weighted clubs to elicit PAPE in CHS is unknown. The purpose of this investigation was to compare traditional, field-based warm-up activities with no potentiation activity (CON), against a field-based potentiated warm-up using high rate of force development bodyweight movements (BWP), and an overspeed warm-up using speed sticks (SSP) as the potentiation method. Thirteen skilled adult male golfers (handicap 1.0 ± 2.1) completed three testing sessions, separated by seven days. The CON, BWP and SSP warm-ups were identical, except for the potentiation method. After each warm-up condition, ten shots, separated by one minute, were recorded using a doppler radar launch monitor (Trackman 4) with CHS, ball speed (BS), carry distance (CD) and total distance (TD) recorded. A repeated measures one-way ANOVA with Bonferroni post hoc pairwise comparisons revealed increases in CHS in the BWP ($p = 0.004$) and SSP ($p = 0.003$) groups against CON, with no difference between BWP and SSP. Increased CD was observed for BWP ($p = 0.034$) and SWP ($p = 0.030$) against CON with no differences between BWP and SSP. No differences for BS or TD were observed. Warm-ups with BWP or SSP activities should be considered if players are attempting to increase CHS or CD of drives, although utilising overspeed potentiation methods appears to confer no additional benefit to bodyweight PAPE exercises in skilled collegiate golfers.

1. Introduction

Effective warm-ups for athletic performance typically follow the sequential "Raise, Activate, Mobilise, Potentiate" (RAMP) model originally proposed by Jeffreys (2007) where body temperature and heart rate are raised, muscles are activated and joints mobilised, before the musculature is primed or potentiated for the task about to be performed in a sequential manner. Golf warm-ups that contain these elements have been shown to improve determinants of drive performance in golf including clubhead speed (CHS), driving distance and strike quality (Langdown, Wells, & Graham, 2019). Conversely, warm-ups that focus on static stretching and do not adhere to the RAMP model have been demonstrated to contribute to decrements in these performance measures (Gergley, 2009). A recent review of warm-ups in golf has provided a thorough overview of the area, suggesting that to be practically viable, warm-ups should include some form of resistance exercise but with minimal equipment (Ehlert & Wilson, 2019). However, none of the studies systematically investigated contained golf-specific overspeed potentiation methods, or directly compared bodyweight resistance exercises and golf swing specific potentiation methods. The work of Tilley and McFarlane (2012) did use a weighted club, but this was used at the start of the warm-up. Overspeed potentiation methods have been shown to confer increases in swing speed in sports with a similar rotational striking movement such as baseball (Montoya, Brown, Coburn, & Zinder, 2009; DeRenne, Ho, Hetzler, & Chai, 1992). However, there is currently no evidence on overspeed potentiation methods in golf as an acute strategy to enhance CHS. Therefore, understanding whether warm-ups containing an overspeed potentiation strategy deliver maximal performance improvements is necessary.

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Research in this area is useful as it may offer simple methods by which to increase CHS, and subsequently drive distance. Although drive distance is underpinned by a myriad of factors, the principal component for increased drive distance is increased CHS (Hume, Keogh, & Reid, 2005). For example, CHS is strongly corelated with handicap index in amateur golfers, with better players demonstrating a strong correlation with CHS (Fradkin, Sherman, & Finch, 2004). At the elite level, long-hitting golfers are more likely to score better on par four and five holes on the PGA tour (Hellstrom, Nilsson, & Isberg, 2014).

Post-activation potentiation (PAP) is a commonly used technique by strength & conditioning practitioners to acutely improve physical qualities of athletes that are required to perform forceful muscular contractions (Evetovich, Conley, & McCawley, 2015). Traditionally, PAP is observed by evoking a muscle twitch using electrical stimulation after an intense voluntary contraction, although it has also recently been defined as a voluntary force or power enhancement after a high-intensity warm-up (Blazevich & Babault, 2019). This linked, but separate phenomenon is termed the post-activation performance enhancement (PAPE) effect and is thought to result from increases in muscle temperature, muscle and muscle fibre water content, and other central and peripheral mechanisms to improve muscle activation (Blazevich & Babault, 2019). Previous studies in golf have shown that PAPE activities can elicit positive and transferable effects to golf driving performance and CHS. Research conducted by Read, Miller and Turner (2013) has shown that skilled golfers increased CHS by 2.25 miles per hour (mph) after completing a series of bodyweight countermovement jumps (CMJ). However, golfers may be reluctant to perform this type of warm-up because it is not common amongst their peers or (because it is a generic athletic movement rather than a golf movement) they may not know how to (Ehlert & Wilson, 2019). Conversely, a study of skilled golfers undergoing professional training demonstrated that warm-ups are perceived to be beneficial for golf performance, and that over 50% of players undertake air swings with a golf club as part of their preparations (Wells & Langdown, 2020). Furthermore, studies investigating changes to CHS in golf following weighted club warm-ups are lacking. Based on the research of Ehlert & Wilson (2019), this type of warm-up may be more attractive as it mimics the golf swing, but it does involve specialist equipment.

Enhancements in muscular force production from PAPE exercises have been observed following dynamic, high-speed activities (Blazevich & Babault, 2019). Studies from sports with similar rotational hitting/striking profiles to golf such as baseball have found that performing maximal effort swings as part of a warm-up with lighter than normal, or normally weighted bats can increase subsequent normal bat swing velocity by approximately 4%, but heavier bats confer no benefit (Montoya et al., 2009). Therefore, it was the purpose of this study to compare the effects of both high-rate of force development bodyweight PAPE exercise (BWP) or an overspeed warm-up using speed sticks (SSP) on golf drive performance.

2. Methods

2.1. Participants

Thirteen skilled adult male golfers (age = 20 ± 1 yrs; height= 1.82 ± 0.08 m; body mass = 77.55 ± 7.11 kg; handicap = 1.0 ± 2.1) were recruited to the study. To be included in the study, participants must have been a category one handicap (5.4 or lower) or professional. Twelve participants were amateur and one was professional, who was given a handicap of zero for the purposes of the study. Participants were recruited from a research advert which was placed at a golf college in the United Kingdom (UK) and golf clubs local to the university. All participants were free from injury. Power analysis was carried out using G*Power (v3.1.9.7) *a priori*, determining that with an estimated effect size of 0.6 (based on the similar work of Coughlan et al., (2018)) and an alpha level of 0.05. 12 participants were required to achieve a power >80%. The study was conducted in accordance with the principles of the Declaration of Helsinki (2013) and ethical approval was granted by the institution's ethics committee.

2.2. Apparatus and Task

Participants attended all testing sessions at the same time of day, separated by one-week. Participants were instructed to avoid strenuous activity 24-h prior to assessment and to arrive in a rested condition. Participants were asked to avoid eating or drinking anything other than water at least 2-h prior to assessment, and to avoid consumption of any nutritional supplements on the day of assessment. For the golf assessment, all testing sessions were carried out in an outdoor, covered driving range in the UK in similar weather conditions. A computerised launch monitor (Trackman 4, Trackman Golf, Denmark) was used to collect shot data. Participants used their own drivers, although the same balls (Srixon Range Balls, Srixon Sports Europe, UK) were used for each participant. The launch monitor was calibrated and set to a "normalised" setting for all testing sessions to account for variables such as wind direction, ground conditions, ball quality etc. Data fields recorded were: CHS, ball speed (BS), carry distance (CD) and total distance (TD). Previous research has demonstrated that the Trackman 3e (the previous model to the 4) has a median accuracy of 0.18m/s and 0.09m/s for CHS and BS respectively (Leach, Forrester, Mears, & Roberts, 2017). The Trackman 4 is a newer model than the 3e and is expected to be as accurate, if not more accurate than its predecessor (Turner, Forrester, Mears, & Roberts, 2020). If an error occurred and the launch monitor did not record all of these fields the participant was asked to re-hit.

2.3. Procedure

Participants undertook three separate protocols. Each was categorised by the type of warm-up. Each warm-up was identical in nature, except for the final activities which aimed to elicit a PAPE effect. Protocol one (CON) consisted of players completing the standardised warm-up (Table 1) with no potentiating activity and acted as a control. Protocol two added high rate of force development bodyweight plyometric exercises as a potentiating activity to the standard warm-up (BWP). Protocol three added overspeed training using Speed Sticks (SuperSpeed Golf, Tulsa, OK, USA) to the CON protocol to act as the potentiating activity (SSP). The Speed Sticks were light (20% lighter than a standard men's driver), medium (10% lighter) and heavy (around standard driver weight or up to 5% heavier). After completion of the warm-up, participants would rest for one minute before hitting 10 maximum effort drives with a 60 second rest between shots in accordance with previous research (Bliss, McCulloch, & Maxwell, 2015). Participants were asked to "swing as hard as possible, but with a technique that you would use when playing a real course".

2.4. Statistical Approach

A statistical package (IBM SPSS Statistics, v24.0, IBM Corporation, USA) was utilised for data analysis. Descriptive statistics are presented as mean ± standard deviation. The score for each dependent variable was taken as the mean value of all shots performed per condition after any outliers were removed in accordance with previous research (Bliss, McCulloch, & Maxwell, 2015) The outlier analysis employed box-and-whisker plots to remove any mishit shots. Values outside of 1.5* the lower bound for each dependent variable were removed. A one-way repeated measures analysis of variance (ANOVA) with partial eta squared (η_p^2) effect size calculations was conducted to compare means of the three groups for each dependent variable. Data were checked for sphericity using Mauchly's test, with any violations adjusted using the Greenhouse-Geiser correction. Effect sizes were classified as ≥ 0.1 = small; ≥ 0.3 = medium; ≥ 0.5 = large (Cohen, 1988). Where significant effects were observed, Bonferroni *post hoc* comparisons were used. An alpha level of ≤ 0.05 was used for significance.

Table 1: Standardised sequential RAMP-based warm-up protocol

Raise		
Skipping (2 minutes)		
Activation and mobilization		
Leg swings x 10 ES		
Resistance band shoulder external rotations 10 ES x 2		
Single leg kneeling kickbacks x 10 ES		
Lunges with rotations x 10 ES		
Overhead squats with golf club x 12		
Golf Swing Specific		
Sand wedge pitch shots x 3		
Sand wedge full shots x 3		
7 iron full shots x 2		
Driver full shots x 2		
Potentiation		
	Condition	
CON	**BWP**	**SSP**
None	CMJ 10 reps x 3	SSS Light DS x 10 reps
	Plyometric Press Ups 10 reps x 2	SSS Light NDS Side x 10 reps
		SSS Medium DS x 10 reps
		SSS Heavy DS x 10 reps

ES = Each side. CMJ= Countermovement Jump. SSS= Super Speed Stick. DS = dominant side. NDS= non-dominant side. Reps = repetitions

Table 2: Mean (± SD) values for drive variables across warm-up conditions

	CON	**BWP**	**SSP**
CHS (mph)	110.1 ± 5.5	111.6 ± 5.1*	111.6 ± 5.2*
BS (mph)	160.5 ± 8.0	161.8 ± 7.2	161.9 ± 7.9
CD (yards)	261.5 ± 16.4	267.1 ± 14.3*	268.2 ± 16.0*
TD (yards)	285.1 ± 17.8	287.7 ± 15.7	289.2 ± 18.0

*= statistically significant ($p \leq 0.05$) increase vs CON condition

3. Results

From 390 shots performed, the outlier removal process disregarded 24 shots. All participants had at least seven data points for each dependent variable for each protocol following outlier removal. Descriptive data are displayed in Table 2. ANOVA revealed significant, large effects of warm-up on CHS ($F_{(2,24)}$= 14.822, $p \leq 0.001$, $\eta_p^2 = 0.553$) and significant medium effects on CD ($F_{(2,24)}$= 5.569, $p = 0.01$, $\eta_p^2 = 0.317$). Bonferroni *post hoc* comparisons revealed, when compared to the CON condition, increased CHS in the BWP (110.1 ± 5.5 mph vs 111.6 ± 5.1 mph, $p = 0.004$, ES = 0.28) and SSP conditions (110.1 ± 5.5 mph vs 111.6 ± 5.2 mph, $p = 0.003$, ES = 0.28), but no difference between BWP and SSP ($p = 1.000$). Compared to the CON protocol, increased CD was observed for the BWP (261.5 ± 16.4 yards vs 267.1 ± 14.2 yards, $p = 0.034$. ES = 0.37) and SSP conditions (261.5 ± 16.4 yards vs 268.2 ± 16.0 yards, $p = 0.030$, ES = 0.41), but no difference between BWP and SSP ($p = 1.000$). No other significant effects were found for BS or TD (all $p > 0.05$). The dependent variables with significant effects are displayed in Figure 1.

4. Discussion

The aim of this study was to investigate three identical warm-up protocols that varied in potentiation method only and their effects on golf driving performance in skilled adult golfers. The novel element of this study is the use of overspeed training utilising weighted clubs as a potentiation method in a warm-up. The study found that utilising BWP or SSP methods can acutely increase CHS and CD in skilled golfers, but do not influence BS or TD.

Undertaking a warm-up prior to golf performance, despite recent evidence, appears to be a behaviour that is perceived as important by skilled professional golfers (Wells & Langdown, 2020) but is not well established in amateur golfers (Ehlert & Wilson, 2019). This is surprising given that much recent research has demonstrated the positive benefits of doing so (Coughlan et al., 2018; Langdown et al., 2019; Tilley & McFarlane, 2012). A key finding from this study is that undertaking maximal effort activity using BWP or SSP to finish the warm-up appears to cause a PAPE effect and creates increases in CHS and CD when compared to a warm-up with no potentiation activity. However, it also appears that there are no differences between the increase if the potentiating activity is generic (BWP) or sport-specific (SSP).

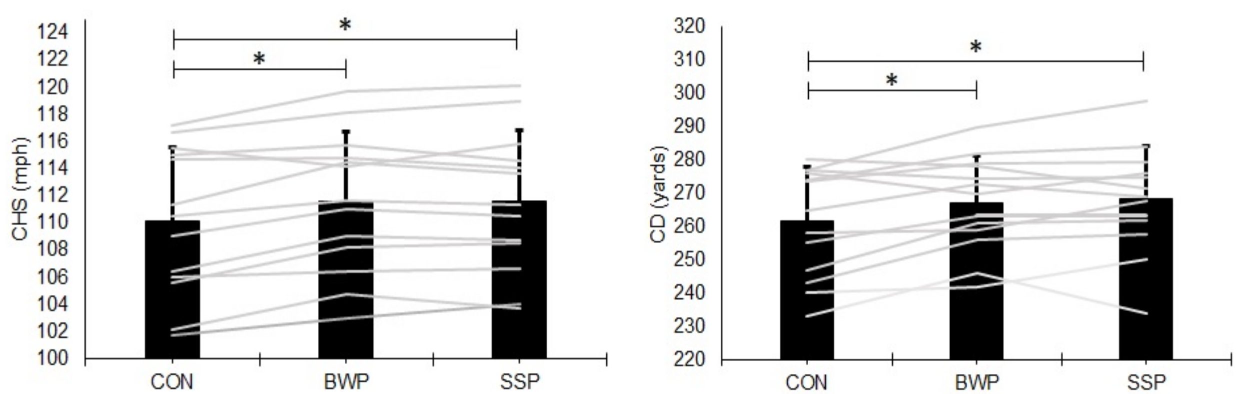

Figure 1: Mean CHS (left) and CD (right) for all warm-up conditions. Error bars represent SD. Grey lines represent individual responses. *= significant difference ($p < 0.05$)

This finding is similar to that of Langdown et al. (2019) who reported that even though both conditions were greater than the control group, there were no differences in any of the five drive metrics (BS, launch angle, total spin, dispersion, CD) monitored between their dynamic warm-up and resistance band-warm-up, with the exception of launch angle which showed a larger reduction in the dynamic group. Interestingly, while Langdown et al. (2019) did not measure CHS (they report an increase in BS), they showed no difference in CD, but increases were found in this study. This may be explained by impact conditions (spin rates, launch angles etc.) or by the high-intensity, maximal effort potentiation activities utilised in this study in comparison to the multiple repetition or duration-based dynamic and banded activities undertaken in the work of Langdown et al. (2019). To substantiate this contention, Read et al. (2013) reported an increase in CHS when using CMJs to potentiate, with their increase (2.2% equating to 2.25 mph) greater than that reported here (1.4% equating to 1.50 mph) in the BWP group. While both increases were significant, the participants in this study had higher CHS (110.1 ± 5.5 mph in the CON no potentiation condition) than those in the Read et al. study (106.9 ± 6.6 mph) (Read et al., 2013). It may be that as the participant's "normal" CHS increases, that the effect size of a BWP warm-up becomes smaller. Future research could address this by comparing warm-ups designed to elicit a PAPE effect in high and low CHS participants.

Overspeed training is a practice that has garnered attention in other rotational striking sports such as baseball (Montoya et al., 2009; DeRenne et al., 1992) but has seen a recent revival in golf, through the use of weighted golf clubs. However, despite these implements being widely used across all levels of golf including the elite level, there is currently no peer-reviewed evidence to support their use. In baseball, warm-ups utilising maximal effort wings with lightweight or normally weighted bats elicited improvements (8.3% and 4.8% increases, respectively) in bat swing speed against using heavily weighted bats (Montoya et al., 2009). In a separate warm-up study utilising a range of weighted baseball bats from very light to very heavy as potentiation methods, bats within 10% of the weight of a normal bat produced the greatest swing speeds (DeRenne et al., 1992).

A limitation of this study is that, even though the participants were accustomed to regular physical activity and we would not expect an order effect, the warm-up conditions were not randomised. Additionally, assessment of muscular recruitment pattern or activity (via electromyography) or force production (via force platform) was not conducted. Therefore, the mechanism by which the improvements in CHS and CD can only be speculatively attributed to a PAPE effect. Future research should investigate how kinetic and kinematic factors that underpin CHS or CD are enhanced as a result of a RAMP warm-up.

Although CHS and CD were enhanced in both BWP and SSP conditions, no other dependent variables demonstrated an improvement. This finding likely demonstrates that increases in CHS, while a major determinant of drive distance, is not the only factor that underpins drive performance. Launch angles (vertical and horizontal), spin rates, and centredness of strike on the clubface are also key factors that underpin early ball flight characteristics and ultimately TD (Sweeney, Mills, Alderson, & Elliot, 2013). Furthermore, Parker, Hellstrom, and Ollson (2019) demonstrated that individual swing techniques are a crucial aspect of CHS in males and females of comparable handicap and age to those in this study, although CD was less influenced by individual variance in technique. It was also suggested by that the factors that underpin CHS and CD are not transferable in males and females (Parker et al., 2019). In this regard, kinetic and kinematic variables relating to individual swing technique were not collected during the testing protocols and are limitations of this study. Further, it was conducted in a male only cohort and as such the findings should not be considered generalisable to female golfers. Future research should investigate whether there are kinetic and kinematic alterations to swing technique as a result of BWP or SSP activities in addition to monitoring drive performance.

Lastly, it is acknowledged that there were large interindividual differences in response to the BWP and SSP warm-up conditions. As an extreme example, one participant experienced a 20-yard increase in CD in the SSP condition vs CON, as where another saw a decrease of 9 yards when using a SSP warm-up versus no potentiating activity. This variation in response to warm-ups aiming to elicit a PAPE effect has been previously reported. These findings are similar to those of Langdown et al. (2019) who stated, that even though all participants in their study (and this study) were category 1, skilled players, there was considerable variability in response to warm-up conditions. Additionally, a study by Till and Cooke (2009) showed a variance of 15.3% between individual responses to PAP activities on sprint and jump performance in academy footballers. The authors stated that athletes with greater muscular strength and high training exposure had greater individual responses to PAP interventions (Till & Cooke, 2009). Furthermore, athletes with greater training experience have greater responses to PAP due to physiological make up of muscle fibres and motor units (Rixen, Lamont, & Bemben, 2007). Athletes with limited or no training experience have reduced responses to potentiating activity (Rixen et al., 2007) and lack of training experience or fitness levels is also shown to inhibit potentiating effects (Chiu, Fry, Weiss, Schilling, Brown, & Smith, 2003). Therefore, it is likely that the participant's strength characteristics will influence how they respond to RAMP based warm-ups and golfers with greater physical training experience may experience the most benefit. Limitations of this study were that strength characteristics of the participants were not measured and internal load was not monitored and therefore whether the individual responses to the BWP and SSP warm-up conditions could be attributed to strength levels is unknown. Future research in this area should collect field or laboratory measures of the participants' force generating capabilities or internal load (through heart rate or rating of perceived exertion as examples) to provide useful information that may support or help to explain the variations in drive performance between participants.

4.1. Conclusions

A warm-up that follows the RAMP protocol and contains either BWP or SSP activities elicit improvements in CHS and CD in skilled amateur male golfers. However, there were no differences between using BWP or SSP and therefore the type of potentiation activity at the end of a warm-up appears to be comparable. It is important that potentiation activities are performed at maximum effort. However, BWP and SSP warm-ups did not improve BS or TD and therefore the other kinetic and kinematic determinants of drive performance such as centredness of strike, launch angle, and spin rate need to be maintained when attempting to increase CHS and CD. Golfers can acutely increase CHS or CD through a physical warm-up if they perform BWP or SSP activities. This increase could support training or competition play and may help golfers improve their drive performance on the opening hole, which will acutely improve players' scoring potential. However, it is unknown how long these performance benefits will last and future research which studies the effects of a BWP or SSP warm-up over a longer playing duration than the opening drive is warranted.

Conflict of Interest

The authors declare no conflict of interest

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