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Abstract

Previous research has highlighted the positive effect that different warm-up protocols have on golf performance (e.g. Sorbie et al., 2016; Tilley & MacFarlane, 2012) with the design of warm-ups and programmes targeting and improving golf performance through the activation and development of specific muscle groups. This study aimed to examine the acute effects of two warm-up protocols on golf drive performance in comparison to a control condition. Using a randomised counter-balanced design over three testing sessions, twenty-three highly skilled golfers completed the control, dynamic and resistance-band warm-up conditions. Following each condition, a GC2 launch monitor was used to record ball velocity and other launch parameters of ten shots hit with the participants own driver. A repeated-measures ANOVA found significant increases in ball velocity (η_p^2 = .217) between the control and both the dynamic and resistance-band warm-up conditions but no difference between these latter two, and a reduction in launch angle between control and dynamic conditions. The use of either a dynamic stretching or resistance-band warm-up can have acute benefits on ball velocity but golfers should liaise with a PGA Professional golf coach to effectively integrate this into their golf driving performance.

Key Words: golf swing; golf ball velocity; resistance; exercise; dynamic stretching

Introduction

There is a growing body of research seeking to establish strategies that significantly increase golfers' performance, with one such strategy being the incorporation of a warm-up prior to performance (e.g. Fradkin, Sherman & Finch, 2004; Sorbie et al., 2016). A warm-up up can significantly increase clubhead velocity (CHV) (Fradkin et al., 2004; Sorbie et al., 2016), maximal drive distance (Tilley & Mcfarlane, 2012), ball velocity (BV), centredness of strike and lead to straighter swings paths (Moran, McGrath, Marshall & Wallace, 2009). Fradkin et al. (2004) reported that completing a warm-up regularly can increase CHV by 7-10 m/s (24.0%) which they estimated would equate to a seven shot reduction in handicap, however no improvements in distance or accuracy were reported. Despite these potential improvements, an observational study of 1040 golfers (Fradkin, Finch & Sherman, 2001) found that almost half did not perform any form of warm-up before play or practice.

Warm-up studies in golf have often been conducted with varying skill levels of participants (Henry et al., 2015), low sample sizes (Tilley & Macfarlane, 2012; Sorbie et al., 2016), or were limited in their ability to measure club and ball parameters due to the exclusion of a golf launch monitor (Sorbie et al., 2016). Fradkin et al.'s (2010) review supports that further research is needed to fully establish whether warm-ups can indeed significantly improve launch parameters and ball flight for golfers of all abilities.

Extensive research has shown that static stretching has no positive acute effects on performance (e.g. Shrier, 2004; Haddad et al., 2014). Indeed, studies within golf have evidenced that passive stretching leads to reduced CHV (-4.19%), distance (-5.62%) and accuracy (-31.04%) (Gergley, 2009). Alternatively, active warm-ups have been shown to have beneficial effects on subsequent performance (e.g. measures of jumping performance and force production (Young & Behm, 2003)) including a post-activation potentiation effect (Jeffreys, 2007). Dynamic stretching, a component of active warm-ups results in increased sensitivity of nerve receptors and speed of nerve impulses (Fletcher & Jones, 2004; McMillian, Moore, Hatler & Taylor, 2006), alongside physiological responses, such as, increased cross bridge formation and recruitment of higher threshold motor units (Behm, 2004; Enoka, 2008; Tillin & Bishop, 2009). Studies in golf have reported that following dynamic stretching there was increased drive distance and accuracy compared to static stretching (Sorbie et al., (2016) and increased ball velocities of 3.5 m/s and 3.3 m/s compared with static stretching and no stretching respectively (Moran et al., 2009).

It is important to recognise that a large majority of muscles in the body are active during the golf swing (McHardy & Pollard, 2005). During the downswing, the most active muscles in the lower body are the upper and lower gluteus maximus with the gluteus medius also actively contributing to this phase (McHardy & Pollard, 2005). The rhomboids, pectoralis major, upper serratus, upper and mid-trapezius, levator scapulae, subscapularis and infraspinatus are all active in the upper body (McHardy & Pollard, 2005). It is plausible to suggest that a dynamic warm-up that incorporates these muscles, may have a greater transfer to golf performance than no warm-up or a passive warm-up.

Cambridge (2012) studied the influence of resistance-bands on gluteal muscle activation finding that using a mini-band during ‘monster walks’ and ‘sumo walks’ exercises significantly increased gluteal activation. Tilley and Macfarlane (2012) found that a functional resistance-band protocol showed significantly increased maximal driving distances compared to the active-dynamic (+13.70 m (5.59%)) and weights warm-up protocols (+11.87 m (4.81%)). However, the inclusion of exercises such as the barbell deadlift, squat and snatch require greater technical proficiency to perform and along with the equipment required it leaves this protocol impractical for the vast majority of golfers.

While there is adequate evidence to suggest a dynamic warm-up will yield positive results over a control group that do not perform a warm-up, there is a paucity of research examining preparatory exercises focusing on the use of resistance-bands and the acute effects on golf drive performance. The purpose of this study was to investigate the acute effects of three warm-up conditions (control, dynamic and resistance-band protocols) on driving performance based on measurements of ball launch parameters. It was hypothesised that the resistance-band and dynamic warm-up conditions would elicit significantly greater improvements in ball launch parameters compared to the control condition.

Methods

Participants

Ethics approval was obtained through the University ethics committee and all participants were informed of the benefits and risks to participation through an information sheet prior to signing an informed consent form. Participants were screened prior to completing the study by answering a PARQ health questionnaire and were excluded from the study if any underlying health problems existed.

Twenty-three (22 male & 1 female) highly skilled golfers were recruited using convenience sampling. Ten professional golfers (handicap equivalent = 0±0) and thirteen high level amateurs (handicap = 3.2±1.8) performed each of the three warm-up conditions (see Table 1) in a repeated within subject crossover design, with the protocols balanced for order. Skilled participants were chosen for their highly repetitive swing mechanics and average distance, making it more probable that any effects could be attributed to the effects of the warm-up.

Experimental Trials

The three protocols were selected due to a paucity of research using a control condition together with dynamic stretching and a resistance-band warm-up. Protocols were assessed in a counterbalanced design over three non-consecutive testing sessions during which levels of intensity were matched to ensure consistency across warm-up conditions (see Table 1).

The participants were randomly assigned into one of three groups to allow the counterbalanced design: Group 1 (n=8 age = 19.7±1.0 years); Group 2 (n=8 age = 19.4±1.0 years) and Group 3 (n=7 age = 19.5±1.0 years). Testing took place using a practice bay at a covered driving range on three non-consecutive occasions, separated by seven days across a three-week period. Participants were provided with a familiarisation session and documents (with descriptions and images of the exercises involved) one week prior to each testing session. Furthermore, the researcher provided a demonstration and verbal explanation, with each exercise delivered using standardised timings and procedures.

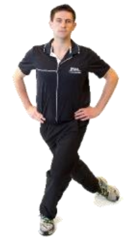
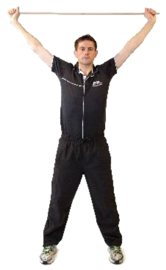
Table 1 Procedures for each of the experimental conditions

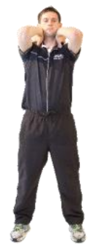
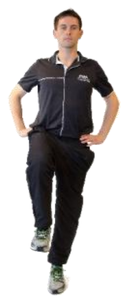
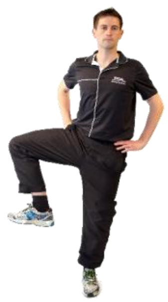
Condition		
Control	**Dynamic**	**Resistance-band**
10 balls with any club (participant choice)	Dynamic warm-up	Resistance-band warm-up
10 shots with the driver	10 shots with the driver	10 shots with the driver
10 recorded drives	10 recorded drives	10 recorded drives

Control Condition: Participants hit ten balls to prepare in their own way. Participants could change club or focus solely on one club. This allowed the control condition to be representative of a typical range-based preparation (without qualifying as a physical warm-up). The performance of stretches or pulse raising activity beyond the hitting of ten golf balls was not permitted. After hitting the first ten balls, the participants struck ten balls with their own custom fit driver for familiarisation. Following this, each participant then hit ten maximal drives which were recorded.

Dynamic Condition: This protocol required the participants to perform a ten minute warm-up consisting of five exercises including clock lunges, overhead squats, scapula wall slides, hip rotations and thoracic rotations (Table 2).

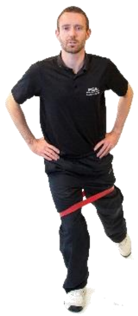
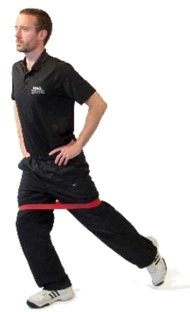
Table 2 Dynamic Stretching Warm-up Protocol

Exercise	Sets/Reps	Start position	Mid position (where applicable)	Final position
Clock lunges	2 x 4 reps each side. Forwards, lateral, reverse, crossed reverse lunge each side.			
Overhead squat (with club overhead)	1 x 10 reps			

Contingency – Arms down squat	1 x 10 reps. Used when golfer is unable to complete an OHS maintaining torso angle to at least parallel to the shin and dropping below thigh parallel to the floor.		
Scapula wall slides	2 x 30 seconds with 10 seconds rest in between sets		
Open and close the gate	1 x 6 reps each side for each exercise		

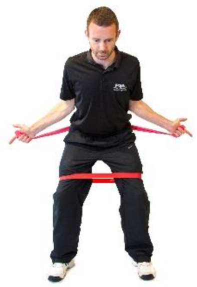
Single leg balance and rotation	1 x 6 reps each side rotating both sides per rep			
Contingency – Back foot down for single leg balance and rotation	1 x 6 reps each side rotating both side per rep			

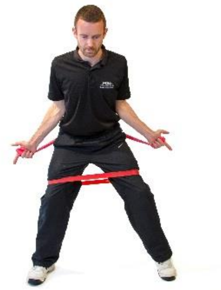
Table 3 Resistance-band Warm-up Protocol

Exercise	Sets/Reps	Start position	Mid position (where applicable)	Final position
Reverse lunge and rotate	1 x 6 reps each side with the torso only rotating over the front leg.			
Speed Skaters	1 x 6 reps each side keeping the torso upright and squatting through the front leg.			

Crab walks with scapula stabilisers activation

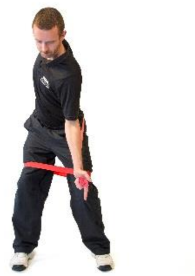
2 x 10 steps left and 10 steps right with forearms circling backwards continuously. Feet stay at least shoulder width apart throughout.





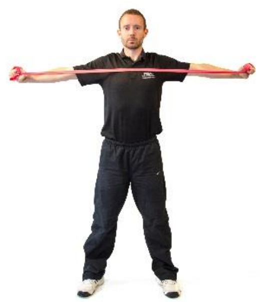
Dynamic stomp and rotate

1 x 30 seconds stomping up and down alternating feet. Continuous rotation of the torso left and right with forearms circling backwards.



Scapula retractions

1 x 30 seconds



Resistance-Band Condition: This protocol was comprised of a reverse lunge with a thoracic rotation against a resistance-band, speed skaters with a mini-band, crab walks with scapula pulses, mini-band stomps with thoracic rotation and scapula retractions (Table 3).

Following both warm-up conditions participants hit ten shots using their own driver for familiarisation before then hitting ten recorded drives.

Drive Performance: The driver was selected as it is associated with the greatest BV and carry distance, whilst requiring accuracy to land the ball on the fairway. Data was recorded using a Foresight® Sports Game Changer 2 launch monitor (GC2) that has a ball velocity capture range of 0.89-89.41 m/s, and measured ball variables immediately post-impact.

Driving performance was measured (or calculated) by the following variables: BV (m/s), vertical launch angle (LA) (°), and total spin (TS) (RPM) were all measured immediately post-impact through stereoscopic photos of the ball (captured at 4000Hz), whereas carry distance (CD) (m) and drive dispersion (i.e. accuracy) (DISP) (m offline from a pre-determined target, with left = -ve and right = +ve) were calculated by GC2 from initial launch conditions (Foresight Sports, 2013). Leach, Forrester, Mears and Roberts (2017) reported that 99% of ball velocity measurements were accurate to within 1.12 m/s, that 97% of launch angle measurements were within 1 ° accuracy and that 91% of total spin measurements were within 150 rpm.

To maintain ball striking ability, participants were encouraged to continue with their playing/practice routine throughout the testing period but were instructed to avoid physical exercise 48 hours prior to data collection.

The participants were asked to perform maximal drives without sacrificing accuracy towards a pre-determined target with the GC2 aligned parallel to the ball to target line. The participants were instructed to "drive the ball as if you were playing a par-5 in a competitive situation. This means that you will want to drive as far as possible to be closer to the green for your second shot, yet maintain accuracy to stay on the fairway", based on Moran et al. (2009).

Statistical Analysis

In contrast to Myers et al.'s (2008) reduction method that involved only 8 out of 10 drives from each participant included in their analysis, an approach representative of competition golf was used in this study. As such, all ten drives were kept for data analysis across each condition for the 'drive performance' variables. A repeated-measures ANOVA was used to test the independent variable's three levels: control, dynamic and resistance-band warm-up conditions and their impact on the drive performance variables. Significance was set to p<.05 and data was presented as mean ± standard deviation unless otherwise stated and where Mauchly's test showed that the assumption of sphericity was violated, degrees of freedom were corrected using Greenhouse-Geisser estimates. When significant effects were observed post-hoc tests with a Bonferroni correction (post-hoc alpha level correction p=.0167) were used to identify where differences existed between measures with η_p^2 (partial eta squared) used to demonstrate effect size ($\eta_p^2 \geq 0.1$ = small; $\eta_p^2 \geq 0.30$ = medium; $\eta_p^2 \geq 0.5$ = large; Cohen, 1988, 1992,).

Results

A significant and small effect of warm-up on BV was found ($F(2,44) = 6.09$, p=.005, η_p^2=.217). Post-hoc analyses showed an increase from the control condition (BV=66.29±4.45 m/s) to the dynamic (p=.032; BV=67.21±4.55 m/s) and resistance-band conditions (p=.025; BV=67.34±4.44 m/s). No significant difference between the dynamic and resistance-band conditions was observed (p=1.000).

A significant and small effect of warm-up on launch angle was also found ($F(2,44)$ = 4.59, p=.015, η_p^2=.173). Post-hoc analyses revealed a reduction in launch angle between the control condition (LA=11.69±2.92 °) and dynamic condition (p=.029; LA=10.34±2.14 °). However, no significance was observed between the control and resistance-band (p=.136; LA=10.61±2.19 °) conditions or the dynamic and resistance-band conditions (p=1.000). No significant difference was observed across the three conditions for total spin ($F(2,44)$ .445, p=.643, η_p^2=.020) and dispersion ($F(2,44)$ .678, p= .513, η_p^2=.030). Carry distance violated Mauchly's test of Sphericity and therefore the F value was re-calculated. No significant improvement was found between conditions for carry distance ($F(1,31)$, 2.89, p=.086, η_p^2=.116).

Table 4 Drive performance variables across each experimental condition

Condition	Control	Dynamic	Resistance-band	η_p^2
Ball Velocity (m/s)	66.29±4.45[a, b]	67.21±4.55[a]	67.34±4.44[b]	.217
Launch Angle (°)	11.69±2.92[a]	10.34±2.14[a]	10.61±2.19	.173
Total Spin (rpm)	3303.59±625.26	3437.80±573.30	3338.11±416.42	.020
Carry (m)	222.72±19.97	226.72±19.32	227.97±17.99	.116
Dispersion (m)	-1.87 ±14.45	-4.94 ±12.07	-1.86±10.79	.030

Note [a] indicates significant differences between control and dynamic conditions and [b] indicates significant differences between control and resistance-band conditions ($p<.05$). Dispersion values refer to distance from target: left = -ve values and right = +ve values

Discussion

The aim of this study was to compare the acute effects of control, dynamic and resistance-band warm-up conditions on golf driving performance in highly skilled golfers. To date this is the only study that compares the effects of a control and two warm-up protocols that are practically viable conditions for all golfers to implement. Results from this study reveal that, in comparison to the control protocol, there were significant increases in BV following both the dynamic and resistance-band warm-ups and a significant decrease in LA following the dynamic warm-up. Despite these findings, no significant difference was found in carry distance and dispersion. Across all drive performance variables, no mean significance was found between the dynamic and resistance-band conditions but individual responses raise interesting points of discussion.

With a variety of warm-ups used within research it is difficult to compare results due to variation in protocols and standard of golfers. Previous studies focussing on improving golf performance through an intervention (warm-up or exercise based) have reported increased CHV when recorded in an indoor setting (Fradkin et al., 2004; Moran et al., 2009), which is not representative of a range based practice session or competing in a tournament. This has often been combined with limited sample sizes, and the lack of a control condition.

In the current study, the resistance-band condition yielded the greatest mean BV (M=67.34 m/s) across subjects, with an average improvement of 0.73 m/s, which is a similar increase to the 0.90 m/s increase reported by Tilley and Macfarlane (2012). The exercises employed in both of the current warm-up protocols targeted muscles that are highly active during the downswing (McHardy & Pollard, 2005). Dynamic stretching has been suggested to enhance neuromuscular function, post activation potentiation (Faigenbaum, Bellucci, Bernieri, Bakker, & Hoorens, 2005; Yamaguchi & Ishii, 2005), increased recruitment of higher threshold motor units (Tillin & Bishop, 2009) and increased numbers and rates of cross bridge attachments, consequently increasing force production (Behm, 2004; Hough, Ross & Howatson, 2009). Despite this increase in BV no significant difference was observed in carry distance between the dynamic and resistance-band conditions.

A mean increase in carry distance of 5.25 m from the control to resistance-band condition could be considered a dramatic result for highly skilled golfers. In comparison, Tilley and Macfarlane (2012) found a greater increase in drive distance (M=13.70 m). The lack of a significant change in carry distance even with the increased BV might be due to changes in the impact conditions between the club and the golf ball. Alterations in golf ball spin and launch angle will impact upon the distance the golf ball flies (Tuxen, 2008), with even small changes that are not statistically significant having the potential to considerably alter ball flight over the 220m plus distances that were seen here. A lack of data on the clubhead at impact and particularly impact location of the ball on the clubface is a weakness of the current work.

It is possible that the warm-ups in the current study may have improved centredness of strike on the club compared to the control condition. Impact location is important in determining launch angle and BV (Betzler, Monk, Wallace, & Otto, 2014) and the reduction in mean launch angle of 1.35 ° from the control condition to the dynamic condition as well as the increased BV in the warm-ups may have been influenced by this. Alongside centredness of strike the other five impact factors (CHV, angle of attack, clubface alignment, swing path (Tuxen, 2009; Wiren, 1990) and dynamic loft (Jorgensen, 1999)) can all affect the initial launch angle and total spin. In order to establish the possible mechanisms associated with these results, future research should collect both clubhead and ball flight data.

When considering the individual response to a warm-up it is appropriate to note that each protocol would need to be adapted to the physical capabilities of each golfer (e.g. through the use of rate of perceived exertion (Borg, 1998)). Within the current sample there were examples of considerable differences in individual response to the three conditions and resultant impact on their drive performance. As an example, Participant A showed greatly increased drive performance, not only through BV (control BV=61.92 m/s; dynamic BV=64.02 m/s; resistance-band BV=64.64 m/s) but also changes to other launch parameters (e.g. total spin and launch angles decreased from 4500 rpm and 19.7 ° respectively in the control condition to 3353 rpm and 12.2 ° respectively in the resistance-band condition). This combination resulted in large gains in carry distance (control CD=178.58 m, dynamic CD=212.87 m; resistance-band CD=219.27 m), thus allowing a shorter and more preferential approach shot to the green. Individual results show that whilst all golfers in the sample were category-1 or professional, variability in response between the warm-up conditions exists.

It is important to recognise the limitations associated with the current study. For example, the lack of clubhead data to allow assessment of variables such as centredness of strike. Also, without 3D-kinematic data it is difficult to speculate on how the warm-up protocols affected each of these highly skilled golfers' swing-mechanics and launch parameters.

Conclusion

The findings from the current study highlighted that both dynamic and resistance-band warm-up protocols, each consisting of five exercises, significantly increased golfers' BV when compared with the control condition and significantly reduced LA from the control condition to the dynamic condition. There were no significant changes in CD, TS and DISP between all conditions.

Recording the initial launch parameters as a measure of overall golf performance is misleading as increases in BV do not always equate to improved performance. Along with the six impact factors, there are launch characteristics and environmental conditions (e.g. spin rates and the wind respectively) that all have an influence on carry distance and dispersion. It is therefore recommended that golfers work with PGA Professional golf coaches and strength and conditioning coaches to implement a warm-up design that activates the previously highlighted muscles and enhances their drive performance. While these results provide two viable warm-up protocols for golfers to affect their drive performance, it is vital that coach and subsequent golfer education increases the understanding and application of the research behind warm-up protocols and the subsequent impact upon drive performance. The application of these results should take into account that not all drives take place immediately post warm-up and that there is a walking phase and other shots taking place between each tee box and the subsequent drives.

Future studies should continue to use ball tracking technology on a range or golf course to record drive performance data in the most representative environment possible. Studies should also examine the 3D swing-kinematics and clubhead in more detail in order to accurately assess the influence of warm-up conditions on all impact factors, launch parameters and ball flight characteristics.

Disclosure Statement: The authors report no conflict of interest.

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