Effects of different half-time strategies on second half soccer-specific speed, power and dynamic strength

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This study compared the effects of whole body vibration (WBV) and a field-based re-warm-up during half-time (HT) on subsequent physical performance measures during a simulated soccer game. Ten semi-professional male soccer players performed 90-min fixed-intensity soccer simulations (SAFT90), using a multi-directional course. During the HT period players either remained seated (CON), or performed intermittent agility exercise (IAE), or WBV. At regular intervals during SAFT90, vastus lateralis temperature ($T_m$) was recorded, and players also performed maximal counter-movement jumps (CMJ), 10-m sprints, and knee flexion and extension contractions. At the start of the second half, sprint and CMJ performance and eccentric hamstring peak torque were significantly reduced compared with the end of the first half in CON ($P < 0.05$). There was no significant change in these parameters over the HT period in the WBV and IAE interventions ($P > 0.05$). The decrease in $T_m$ over the HT period was significantly greater for CON and WBV compared with IAE ($P < 0.01$). A passive HT interval reduced sprint, jump and dynamic strength performance. Alternatively, IAE and WBV at HT attenuated these performance decrements, with limited performance differences between interventions.

There is a growing body of literature that has reported a decrement in the physical performance of soccer players during the initial phase of the second half of competitive match-play. The total distance covered (Bangsbo et al., 1991; Weston et al., 2011) and the distance covered at high speed (Bradley et al., 2009; Weston et al., 2011) have been shown to be reduced in the first 15 min of the second half in comparison with the corresponding period of the first half. Similarly, Mohr et al. (2003) observed a decline in the distance covered at high speed in the first 5 min of the second half in comparison with the same period of the first half.

The reason for this reduced physical performance after the half-time (HT) interval has been suggested to be a consequence of a lack of preparation for the second half (Mohr et al., 2004; Lovell et al., 2007), as the players routinely perform a pre-match warm-up before the start of the game, but not before the second half. As such, the 2.0 °C reduction in muscle temperature ($T_m$) observed after the HT interval (Mohr et al., 2004) has been purported as the primary mechanism, since an increased $T_m$ results in increased neural potentiation (Gray et al., 2006) and subsequently improves high-intensity exercise performance (Sargeant 1987; Stewart & Sleivert, 1988; Mohr et al., 2004). Furthermore, this period of play has also been associated with an increased incidence of muscular injuries (Hawkins & Fuller, 1996; Rahnama et al., 2002) that have also been linked to a reduced muscle temperature (Agre, 1985; Safran et al., 1988). In soccer players, hamstring strains are the most common injury reported (Arnason et al., 1996; Woods et al., 2004), with common etiological factors including muscle fatigue (Rahnama et al., 2002, 2003) and inadequate warm-up (Safran et al., 1988). Both of these factors result in muscle strength deficiency, which has been proposed to increase susceptibility to injury (Rahnama et al., 2003). Since 45 min of simulated soccer match-play has induced lower limb muscle fatigue and imbalance (Small et al., 2010), and a passive HT interval reduces $T_m$ (Mohr et al., 2004), it is surprising that to date studies have not assessed the impact of HT re-warm-up strategies on muscular strength.

Regardless of any tactical alterations or pacing strategy that may also affect the tempo of the game, it is clear that players are physically sub-optimally prepared subsequent to a 15-min passive HT interval. Research has shown that sprinting performance (Mohr et al., 2004) and soccer-specific endurance (Lovell et al., 2007) are decreased after a passive HT
interval. However, when a moderate-intensity (~70% heart rate maximum) active re-warm-up was undertaken by the players for the final 7 min of HT, these performance decrements were abolished (Mohr et al., 2004; Lovell et al., 2007). However, the data from the Mohr et al. (2004) study were recorded during a non-competitive match. While this methodological approach provided a high degree of ecological validity, the internal validity in a field based setting could be questioned given the high degree of match-to-match variability in high-speed activities (~16–30%, Gregson et al., 2010). Furthermore, the intermittent nature of soccer match-play causes players to experience “temporary fatigue” after short-term intense periods (Mohr et al., 2003; Krustrup et al., 2006; Bradley et al., 2009), and a degree of inter-player variation in high speed running exists due to positional demands (Bradley et al., 2009; Gregson et al., 2010). Accordingly the physiological status of the players in the Mohr et al. (2004) study is likely to have been variable during sprint performance testing at the end of the first half. Therefore, laboratory-based studies using standardized soccer match-play simulations are warranted to isolate the effects of different HT re-warm-ups on aspects of physical performance.

The application of re-warm-ups at HT is challenging at the professional level due to governing body regulations, for example, the English Premier Leagues Pitch Protection Policy only permits substitutes to use the playing surface during the HT interval. As such, practical dressing-room-based interventions such as acute whole body vibration (WBV) exercise might be more appropriate in these settings. WBV exercises have been shown to increase acute maximal power (Torvinen et al., 2002; Cochrane & Stannard, 2005), with an observed residual effect of up to 5 min (Busco et al., 1999). This enhanced muscle power is thought to be produced via improved neuromuscular functioning (Cardinale & Bosco, 2003; Rittweger et al., 2003), and an elevated $T_m$, the latter of which is generated at a greater rate than during steady-state moderate intensity exercise (Cochrane et al., 2008).

Therefore, the purpose of this study was to investigate the effects of a soccer-specific re-warm-up and acute intermittent WBV exercise during HT on subsequent explosive physical performance and the physiological responses during a simulated game under laboratory controlled conditions.

Materials and methods

Ten male semi-professional outfield soccer players (mean: age 20 ± 1 years; height: 1.83 ± 0.09 m; weight 79.9 ± 7.0 kg; VO$_{2\text{max}}$ 60.5 ± 4.2 mL kg$^{-1}$ min$^{-1}$) consented to participate in the study, which had ethical approval from the institutional board. The study was conducted during the mid-season in which the players typically performed one competitive match and two to three training sessions each week. Participants were included in the study if they had no recent history of musculoskeletal injury or rehabilitation during the testing schedule.

Players initially reported to the laboratory to perform a graded-exercise test on a motorized treadmill to determine maximal oxygen uptake (VO$_{2\text{max}}$) and maximal heart rate (HR$_{\text{max}}$) for future exercise prescription and classification of sub-maximal intensity. The exercise test consisted of an initial running velocity of 10 km h$^{-1}$ with 1 km h$^{-1}$ increments every minute until exhaustion. The treadmill grade was maintained at 2% throughout the test. Breath-by-breath gas analysis was performed using a portable telemetry system (Cortex Metamax 3B, Leipzig, Germany) that was calibrated in accordance with the manufacturer’s instructions before each test. Breath-by-breath data were averaged over 15-s intervals, whereas HR$_{\text{max}}$ was taken as the highest recorded value measured at 5-s intervals (Team System, Polar, Kempele, Finland).

Within 4 weeks of the initial visit, the players attended the laboratory on three subsequent occasions for randomized trials, having performed no vigorous exercise or consumed caffeine or alcohol in the previous 24 h. The pre-trial diet and hydration strategy were standardized for each trial, which were separated by 4-8 days and commenced at the same time of day to account for chronobiological rhythms. Participants performed a standardized soccer-specific warm-up for 25 min that consisted of multi-lateral movements, dynamic stretching and high-intensity exercises before resting for 10 min to replicate the common pre-match routines of professional players. Players then performed a 90-min fixed-intensity soccer simulation (SAFT$^{90}$) interceded by a 15-min HT period (see Fig. 1). The SAFT$^{90}$ protocol uses an agility based course, performed in individual lanes of 20 m, and is based on contemporary time-motion analysis data from English Championship level match-play (Prozone®, Leeds, UK). The protocol incorporates acceleration, deceleration, cutting, side-stepping, and backwards and forwards running in a randomized and intermittent fashion prescribed by verbal signals from an audio CD. The players cover 10.8 km in total, 17% of this distance (1.8 km) is performed at high-speed (≥15 km h$^{-1}$) with 1269 changes in speed (every 4.3 s), and 1350 changes in direction over the 90 min. A full description of the protocol has been previously reported (Small et al., 2010) and the physiological responses are indicative of the demands of competitive match-play (Lovell et al., 2008).

During the 15-min HT period players either remained seated (CON), or between 9 and 14 min performed intermittent agility exercise (IAE), or intermittent exposure to WBV. During the first experimental trial, players were invited to drink water ad libitum during the first 9 min of the HT interval, this volume was then recorded so that identical volumes could be consumed in subsequent visits. The IAE and WBV re-warm-up strategies were designed to be applicable to the professional team sports environment, allowing time for the players to rehydrate, and for the coaches to deliver any necessary tactical information and motivational encouragement. The IAE incorporated repeated 20-m soccer-specific runs using the SAFT$^{90}$ agility course. The players were asked to negotiate the course at moderate to high speed and then walk back to the start and await the signal for the next bout. The duration of the rest interval was manipulated during the intervention to elicit approximately 70% of the players predetermined HR$_{\text{max}}$. This intensity has been prescribed in previous HT re-warm-up articles and has improved soccer-specific sprinting (Mohr et al., 2004), and endurance (Lovell et al., 2007) performance at the start of the second half. The WBV trial was performed using a compact and portable commercial machine (Power Plate® pro5™ High Performance
by Power Plate International Ltd., London, UK) that has been previously used in elite team sports settings. During the WBV treatment, the players wore their indoor footwear and assumed a static partial squat posture (~30° knee flexion) on the platform, which produces vertical sinusoidal vibration. A similar isometric squat posture with continuous (5 min) exposure to WBV has been shown to increase muscle temperature by ~ 0.9 °C (Cochrane et al., 2010). However, pilot data indicated that prolonged isometric WBV reduced our acute measures of athletic performance, in line with other published data (Stewart et al., 2009). Since the aim of a HT re-warm-up strategy is to improve subsequent performance, an intermittent WBV protocol was administered in an attempt to achieve both an increase in $T_m$ and soccer-specific physical performance. Therefore, in the current study the players maintained the static posture on the plate for three sets of 60 s, interspersed with 60-s recovery periods. Furthermore, we considered that this protocol would be more suitable in team sports settings due to both the financial and logistical factors of inserting multiple WBV platforms in the dressing-room environment. The peak-to-peak z-axis vibration displacement was 0.83 mm (manufacturer range 0.71–0.96 mm), and the vibration frequency set at 40 Hz (manufacturer range: 38.4–41.6 Hz) to generate a maximal acceleration of 52.7 m s$^{-2}$ (5.4 g; manufacturer range: 44.8–60.6 m s$^{-2}$) as calculated using the following formula:

$$a_{max} = D_{pk}(2\pi f)^2$$

where $a_{max}$ is maximum (peak) acceleration, $D_{pk}$ is peak-to-peak displacement, and $f$ refers to the oscillation frequency. The peak-to-peak displacement administered in this study was low in comparison with other investigations as the portable platform had a more limited amplitude capacity. However, this comparatively low amplitude may also be caused by erroneous reporting the parameter in previous investigations (see Lorenzen et al., 2009).

Performance measures

Sprint performance was recorded (Smartspeed™, Fusion Sport, Queensland, Australia) as the average of three maximal 10-m sprints (using a 3 m rolling start) embedded in the SAFT™ protocol within each 15-min interval. After the pre-trial warm-up and at 15-min intervals throughout the SAFT™ simulation the players performed a number of performance tests to assess lower-limb strength and power. Firstly, two maximal vertical counter-movement jumps (CMJs) were performed on a force plate (AMTI, Watertown, Massachusetts, USA) with hands placed on the hips throughout. Each jump was separated by a 20-s rest period with the best performance at each time-point used in the analysis. Jump height was calculated using the flight time method equation (Lithorne, 2001). After a 1-min rest period, three maximal dominant limb isokinetic contractions were performed for concentric quadriceps (CQ), concentric hamstring (CH), and then eccentric hamstring (EH) strength, with a minutes rest in between. Isokinetic peak torque (gravity corrected) was measured using a dynamometer (Biodex System 3, Biodex Medical, Shirley, New York, USA) with an angular velocity of 2.09 rad s$^{-1}$ (120° s$^{-1}$) through a range of 0–90° knee flexion and extension (with 0° being full knee extension). This angular velocity was selected because it is the fastest and safest for reliable assessment of EH muscle contractions (Rahnama et al., 2003).

Physiological measures

During the first 15-min period of each half and during the half time intervention (9–14 min), breath-by-breath gas analysis was performed using a portable device, as described earlier. Oxygen uptake was recorded as the mean value over each measurement period. Throughout the simulation, HR was recorded at 5-s intervals (Team System, Polar, Kempele, Finland) and was reported as both the average elicited by
the SAFT\textsuperscript{90} simulation (excluding HT), and also during the intervention period of the HT interval (9–14 min). At selected intervals during the experimental procedures (see Fig. 1) \( T_m \) was recorded (MKA-08050-A, ELLAB, Rodovre, Denmark) during seated rest just before the dynamometry assessment. A needle probe (13050, ELLAB) was inserted 4 cm perpendicular to the vastus lateralis. To ensure consistency between repeated samples, a permanent pen was used to mark the mid-point of the line between the lateral epicondyle and the greater trochanter of the femur. A rubber bung was attached 4 cm down the shaft of the thermocouple to ensure consistency of measurement depth. The temperature was recorded 3 s after insertion and the needle was then immediately removed. Data from three participants were discarded or incomplete due to technical faults, and one player revoked their consent for this technique due to the discomfort experienced in their initial trial.

**Statistical analysis**

Statistical analyses were completed using SPSS for Windows software (release 17.0; SPSS Inc., Chicago, Illinois, USA). Normality of each dependent variable was checked using Q–Q plots and deemed plausible in each instance. The sample data were described using the mean (s). The effect of condition (CON, WBV, IAE) and time on all physiological variables, within-subjects, were analyzed using repeated measures linear mixed models. Condition and time and their interaction were modeled as fixed effects and subjects as a random effect. The linear mixed model also was used to analyze the effect of condition on the change in physiological responses from the end of the first half to the HT period, using the change scores as the dependent variable. Various covariance structures common to repeated measures data were assumed and the one that minimized the Hurvich and Tsai’s criterion (AICC) value was chosen for the final model for each dependent variable. In the event of a significant \( F \)-ratio, pairwise comparisons were conducted using Fisher’s least significance difference test. Paired \( t \)-tests were used to analyze the change in physiological responses from the end of the first half to the HT period within each condition. Two-tailed statistical significance was accepted as \( P < 0.05 \). Data are presented as mean ± standard deviation (SD).

**Results**

**Performance Measures**

Sprint times increased during SAFT\textsuperscript{90} \( (P < 0.001) \), with decrements in performance observed in the last 15 min of both the first (CON: 2.4 ± 2.6; IAE: 1.4 ± 2.6; WBV: 2.2 ± 1.5%) and second halves (CON: 7.2 ± 4.8; IAE: 5.8 ± 4.0; WBV: 4.5 ± 2.6%), in comparison with the first 15 min of the first half. Sprint times increased from the end of the first half to the start of the second in CON \( (P = 0.028) \), but there were no such changes observed for WBV \( (P = 0.32) \) and IAE \( (P = 0.82) \). The change in sprint times over the HT interval was greater for CON than IAE \( (P = 0.019) \). The difference denoted between CON and WBV was not statistically significant \( (P = 0.058) \), and there was no difference between IAE and WBV \( (P = 0.67) \); see Fig. 2.

**Isokinetic dynamometry**

The CQ, CH, and EH peak torques and the functional strength ratio (CQ:EH) for all three trials during SAFT\textsuperscript{90} are presented in Table 1. Peak torques for CQ, CH, and EH all demonstrated a main effect for time, with strength decreasing over the duration of the 90-min simulation \( (P \leq 0.001) \). The decrease in CH peak torque from the end of the first half to the start of the second was significantly less for IAE than for CON \( (P = 0.008) \), whereas the differences between CON and WBV \( (P = 0.065) \) and between WBV and IAE \( (P = 0.094) \) were not significant. The decrement in EH peak torque across the HT interval was significant in CON \( (P = 0.046) \), but not apparent in the intervention trials (IAE: \( P = 0.23 \); WBV: \( P = 0.81 \) ). There was no between-
Physiological responses

Muscle temperature data is presented in Fig. 4. The $T_m$ increased after the first 15 min, but did not further increase over the subsequent 30 min, in both the first and second halves. *Vastus lateralis* temperature decreased by 1.5 ± 0.4, 1.1 ± 0.4, and 0.5 ± 0.4 °C over the HT periods in CON, WBV, and IAE, respectively. Consequently $T_m$ was significantly higher at the end of HT in IAE, than in CON ($P = 0.002$) and WBV ($P = 0.005$), but no significant difference was observed between CON and WBV ($P = 0.41$). No other differences in *vastus lateralis* $T_m$ were observed between experimental conditions.

Average VO$_2$ during the SAFT$^{90}$ was not different between the three experimental trials (CON: 65.5 ± 6.3; IAE: 64.9 ± 5.1; WBV: 65.7 ± 8.7% VO$_{2\text{max}}$). However during the intervention stage of the HT period (9–14 min), VO$_2$ was significantly different between all three conditions (CON: 6.3 ± 1.9; IAE: 31.8 ± 4.8 mL kg$^{-1}$ min$^{-1}$ [55 ± 9% VO$_{2\text{max}}$]; WBV 10.8 ± 2.8 mL kg$^{-1}$ min$^{-1}$, $P \leq 0.001$).

The HR during the SAFT$^{90}$ protocol was not significantly different between conditions (CON: 161 ± 8; IAE: 157 ± 10; WBV: 157 ± 10 bpm; $P = 0.29$). The IAE trial elicited an average HR of 140 ± 6 bpm (73 ± 2% HR$_{\text{max}}$) during the HT intervention period, which was greater than both CON (92 ± 13 bpm, $P < 0.001$) and WBV (104 ± 11 bpm, $P < 0.001$).

**Table 1.** Isokinetic dynamometer data during the 90 min soccer match-play simulation in each of the three experimental trials [mean (SD)]

<table>
<thead>
<tr>
<th>Condition</th>
<th>PWU</th>
<th>PMU</th>
<th>HT</th>
<th>Half-time (min)</th>
<th>45 min</th>
<th>30 min</th>
<th>15 min</th>
<th>10 min</th>
<th>5 min</th>
<th>0 min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CON</strong></td>
<td>243.3 (30.0)</td>
<td>244.3 (24.3)</td>
<td>243.3 (29.3)</td>
<td>243.3 (28.3)</td>
<td>243.3 (27.4)</td>
<td>243.3 (26.5)</td>
<td>243.3 (25.6)</td>
<td>243.3 (24.7)</td>
<td>243.3 (23.8)</td>
<td>243.3 (22.9)</td>
</tr>
<tr>
<td><strong>WBV</strong></td>
<td>243.9 (31.6)</td>
<td>244.5 (21.3)</td>
<td>244.5 (20.3)</td>
<td>244.5 (19.4)</td>
<td>244.5 (18.5)</td>
<td>244.5 (17.6)</td>
<td>244.5 (16.7)</td>
<td>244.5 (15.8)</td>
<td>244.5 (14.9)</td>
<td>244.5 (14.0)</td>
</tr>
<tr>
<td><strong>IAE</strong></td>
<td>243.4 (24.4)</td>
<td>242.0 (23.5)</td>
<td>242.0 (22.6)</td>
<td>242.0 (21.7)</td>
<td>242.0 (20.8)</td>
<td>242.0 (19.9)</td>
<td>242.0 (19.0)</td>
<td>242.0 (18.1)</td>
<td>242.0 (17.2)</td>
<td>242.0 (16.3)</td>
</tr>
</tbody>
</table>

**Table 1 continued...**
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![Graph](image_url)

**Fig. 4.** Mean ± SD Vastus lateralis muscle temperature (n = 6) during the 90-min soccer match-play simulation in each of the three experimental trials. Like letters above error bars represent significant differences between means (P < 0.05). The vertical dashed line represents the half-time period. CON, control; WBV, whole body vibration; IAE, intermittent agility exercise.

**Discussion**

The main findings of the current study were that IAE attenuated the decreases in $T_m$ and soccer-specific sprint, power and dynamic strength performance typically observed after a passive HT interval. In contrast to our hypotheses, WBV did not prevent the HT associated decrease in $T_m$, however sprint and CMJ performance did not deteriorate. A novel observation of this investigation was a maintained eccentric hamstring dynamic strength at the start of the second half of soccer match-play when IAE or WBV was used as a HT intervention strategy. Since strength deficiency is considered to increase the players susceptibility to muscular strain, the intervention strategies used in this study may also have the potential to reduce hamstring injury risk.

Mohr et al. (2004) also reported a higher $T_m$ and sprint performance after a moderate-intensity re-warm-up during the soccer HT interval. The magnitude of the HT decrease in $T_m$ during the CON trial was equivalent (~1.5 °C) to that reported by Mohr et al. (2004). In comparison with Mohr et al. (2004), we observed a greater decrement in sprint performance (6.2 vs 2.4%) with a passive HT. It could be argued that the decrement observed in the present investigation could have more practical significance, given that the sprint distance is more indicative of players susceptibility to muscular strain, the intervention strategies used in this study may also have the potential to reduce hamstring injury risk.

In the current study, WBV attenuated the HT decrement in sprint, and power performance. Soccer-specific lower-limb power was measured with CMJ, which was performed within 60–90 s after WBV exposure, and was increased in relation to CON (~4%). This magnitude of temporary CMJ enhancement was within the range reported previously (8%, Cochrane & Stannard, 2005; 2.5%, Torvinen et al., 2002). Few studies have investigated the acute effects of WBV on sprint performance, and the results have not been positive (Bullock et al., 2008; Guggenheimer et al., 2009), this is not surprising given the complexity of the task and the myriad of causative factors on performance. However, in the current study sprint performance was maintained across the HT interval when WBV was applied, whereas sprint times increased in CON. While differences in the measurement of sprint performance and WBV dose may explain these discrepancies, comparisons should be made with caution as our aim was to examine the potential of WBV as a re-warm-up tool, which has additional confounding factors such as fatigue, heat dissipation, and the concurrent down-regulation of cardiovascular and metabolic systems. Furthermore, the different oscillatory nature of vibrating platforms (synchronous and asynchronous vibration), coupled with the wide variety of vibration frequency and peak-to-peak displacement administered by researchers makes between-study contrasts difficult, especially given the lack of clarity and uniform nomenclature for WBV parameters reported in the literature (Lorenzen et al., 2009).

There are a variety of physiological mechanisms for the acute, transient improvements in muscular power output with WBV exposure. The general consensus has been neuromuscular facilitation, through a depressed threshold for myotatic reflex leading to an up-regulated $\alpha$ motorneuron response (Bosco et al., 1999; Cardinale & Bosco, 2003; Cochrane & Stannard, 2005). However, recent evidence has challenged this assertion, as reflex potentiation has not been observed in the quadriceps (Hopkins et al., 2009; Cochrane et al., 2010). Cochrane et al. (2008) reported compelling evidence for the role of intra-muscular temperature in WBV-evoked power improvements. In that study, augmented muscular power output was comparable between a variety of warm-up modalities (including WBV) when increases in $T_m$ (1.5 °C) were matched. Our data does not support this hypothesis, since $T_m$ did not change with the WBV treatment in comparison with CON, despite comparative gains in both CMJ and sprint performance. The disparate $T_m$ findings are probably due to the higher intensity (160.1 m s$^{-2}$, 5.4 g) and consequently the elevated metabolic cost.
(19 mL kg min\(^{-1}\)) of the WBV protocol used by Cochrane et al. (2008), in comparison with this study (10 mL kg min\(^{-1}\)). Furthermore, the applied nature of the current study meant the players undertook WBV trials in footwear, which likely dampened the mechanical vibrations of the platform, thus reducing the generation of intra-muscular heat.

Dynamic strength was taken as the peak torque generated in concentric knee flexors (CH) and extensors (CQ). We observed no performance benefits of WBV on these isokinetic dynamometry measures, which were recorded approximately 3–4 min after the treatment. This supports previous work, which has failed to show acute improvement in peak torque (Pellegrini et al., 2010) and the rate of force development (de Ruiter & de Haan, 2003; Rittweger et al., 2000; Erskine et al., 2007) with WBV. Taken together these findings are indicative of neuromuscular inhibition (de Ruiter & de Haan, 2003; Rittweger, 2010), rather than facilitation and direct contrast to the power-related gains reported both in the current study and in previous studies (Bosco et al., 1999; Torvinen et al., 2002; Cochrane & Stannard, 2005). Rittweger (2010) suggests that this further supports the role of \(T_m\) with acute WBV, given its robust effect on muscle power but minimal effect on force generation (de Ruiter & de Haan, 2000). However, since WBV did not elicit \(T_m\) elevations at HT in this study, our data is not indicative of this phenomenon. Further work is warranted to establish the neurogenic responses to acute WBV exercise, especially given the wide variety of WBV protocols adopted by researchers.

A unique observation in the current study was the reduced eccentric hamstring dynamic strength after a passive HT interval, yet this was maintained when IAE or WBV was used as an intervention strategy. Decreased eccentric strength of the knee extensors is acknowledged as a fundamental etiological factor associated with hamstring strain injury (Stanton & Purdam 1989; Garrett, 1990), which is the most common injury experienced by soccer players (Arnason et al., 1996; Woods et al., 2004), and its predisposing etiological factors include muscle fatigue (Rahnama et al., 2002, 2003) and inadequate warm-up (Safran et al., 1988). The peak torque decrements observed in EH strength (7.7–10.9%) during the first half of SAFT\(^{90}\) were not different between experimental trials, and were comparable to those recently observed in our laboratory (Small et al., 2010). However, the passive HT interval in CON further reduced EH strength, which potentially poses a greater risk to injury since fatigued muscles are more susceptible to stretch injury during eccentric contractions (Mair et al., 1996). In contrast, both WBV and IAE interventions attenuated any HT decline in EH peak torque, lowering the potential risk of hamstring strain. Given that acute WBV bouts have also been shown to increase hamstring flexibility (Cochrane & Stannard, 2005; Gerodimos et al., 2009), and that insufficient flexibility is another pre-disposing etiological factor for hamstring strain injury, WBV may be a useful tool to prevent injuries of this nature in the early stages of the second half. As Rahnama et al. (2003) have shown a relatively high proportion of injuries are sustained during the initial stages of the second half, the potential for injury prevention with HT re-warm-ups warrants further research.

It should be recognized that the reduction in distances covered at high speed soon after the HT interval may also be a consequence of a reduced match tempo, due either to a tactical alteration or a sub-conscious pacing strategy adopted by the players. Indeed, we have recently found evidence for this as players decrement in total distance covered, high-speed running distance, and sprinting distance after HT (46–60 min) was not different to that performed by the referees, yet the referees ability to keep up with play was improved immediately after HT (Weston et al., 2011). Nonetheless, the data reported both here and in previous studies (Mohr et al., 2004; Lovell et al., 2007) have shown that the players physical capacity for high-intensity exercise is compromised when a passive HT is administered. Furthermore, there were no differences apparent in either the performance or physiological measures after the initial stages of the second half. As such it may be reasonable to assume that the HT interventions adopted in this study had no additional fatiguing effects on sprint, power, and dynamic strength performance in the latter stages of match-play. However, further work is required to determine whether this phenomenon exists in other physical performance indicators.

**Perspectives**

This study supports previous work (Mohr et al., 2004; Lovell et al., 2007) demonstrating a negative effect of the sedentary HT interval in elite soccer match-play. While an altered tactical approach or a sub-conscious pacing strategy adopted by the players could reduce the tempo of the game after HT, there is clear evidence that players are sub-optimally prepared for explosive activities, which are regarded as the most decisive actions within a soccer game (Stolen et al., 2005). In addition, this study has observed that a sedentary rest interval reduces eccentric hamstring strength, which may leave players more susceptible to non-contact hamstring strain injury. However, performing an intermittent, moderate intensity re-warm-up during the last few
minutes of the HT period attenuated this decrement in sprint, power and dynamic strength performance. While beneficial, HT re-warm-ups are commonly not administered because of coaches’ unwillingness to sacrifice tactical/motivational discussions and governing body regulations. Performing WBV exercises in the dressing room may be more acceptable to coaches and does not contravene policy. In this study a short-duration, low-intensity and practical dose of WBV was also ergogenic for sprint and power performance and maintained eccentric hamstring peak torque, potentially reducing the risk of injury. As such WBV might be an appropriate intervention for practitioners where regulations and/or facilities inhibit typical warm-up regimens.

**Key words:** soccer, half-time, muscle temperature, re-warm-up, whole body vibration.

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