High-intensity warm-ups elicit superior performance to a current soccer warm-up routine

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4 authors:

James Zois
Victoria University Melbourne

David John Bishop
Victoria University Melbourne

Kevin A Ball
Victoria University Melbourne

Robert J Aughey
Victoria University Melbourne

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Original research

High-intensity warm-ups elicit superior performance to a current soccer warm-up routine

James Zois [a], David J. Bishop [a,b], Kevin Ball [a], Robert J. Aughey [a,c,*]

[a] School of Sport and Exercise Science, Institute of Sport, Exercise and Active Learning (ISEAL), Victoria University, Melbourne, Australia
[b] Institute of Sport, Exercise and Active Learning (ISEAL), Victoria University, Melbourne, Australia
[c] Western Bulldogs Football Club, Melbourne, Australia

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Abstract

Objectives: This study investigated the acute effects of a currently implemented team-sport warm-up and two alternative, high-intensity, short-duration protocols – 5 repetition maximum leg press and small-sided games. *Design*: Ten male soccer players participated in a randomised, cross-over study. *Methods*: Participants performed a team-sport, a leg-press, or a small-sided game warm-up. Subsequent performance tests included counter-movement jump, reactive agility, and 15 × 20 m sprints embedded in an intermittent exercise task. Physiological measures included core temperature, blood lactate concentration, heart rate and rating of perceived exertion. Data were analysed using the effect size statistic with 90% confidence intervals, and percentage change, to determine magnitude of effects. *Results*: Counter-movement jump height improved following the small-sided game (6%, ES: 0.8 ± 0.8) and leg-press warm-up (2%, ES: 0.3 ± 0.5), but not after the team-sport warm-up ('unclear' effect). Reactive agility improved after the small-sided game (4%, ES: 0.8 ± 0.7) and leg-press warm-ups only (5%, ES: 1.1 ± 0.7), when compared to baseline. Mean 20-m sprint times during the intermittent exercise task improved following the leg-press warm-up, when compared with the small-sided game (9%, ES: 0.9 ± 0.3) and team-sport warm-ups (7%, ES: 0.6 ± 0.6). Core temperature was lower following the leg-press warm-up compared to small-sided game (1%, ES: 0.9 ± 0.7) and the team-sport WUs (2%, ES: 2.4 ± 0.8). Blood lactate was highest following the small-sided game (67%, ES: 2.7 ± 0.8) and team-sport warm-ups (66%, ES: 2.9 ± 0.9). *Conclusions*: A leg-press and small-sided game warm-up may improve acute team-sport performance tests when compared to a traditional warm-up protocol.

Keywords: Post-activation potentiation; Small-sided games; Sprint-ability

1. Introduction

The benefits of an active warm-up (WU) have been attributed to increases in muscle temperature, nerve conductivity, and the speeding of metabolic reactions.[1] Non-temperature-related benefits include an increased blood-flow to working muscles, elevated baseline oxygen consumption, and the induction of a post-activation potentiation (PAP) effect.[2] While typical WU routines involve constant-intensity exercise, team-sport athletes are increasingly utilising WUs which simulate the movement and metabolic demands of team sports. However, no research has investigated the acute effects of currently implemented WU protocols on team-sport-related performance.

Typical team-sport WU routines include 30–40 min of moderate- to high-intensity activities,[3] whereas research suggests that 5–10 min at 40–70% of maximal oxygen consumption ($\dot{V}O_{2max}$) is sufficient to improve short, intermediate and long-term performance.[4] Longer WU routines could impair subsequent performance by increasing pre-competition fatigue, depleting muscle glycogen stores, and prematurely elevating core temperature (potentially compromising the body's ability to store and dissipate subsequently generated heat).[5] Further research is therefore required to compare the efficacy of current team-sport WUs with that of shorter WU protocols.

* Corresponding author at: Victoria University, PO Box 14428, MCMC, Melbourne, Victoria 3011, Australia.
E-mail address: robert.aughey@vu.edu.au (R.J. Aughey).

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Anecdotal evidence indicates that some team sports are experimenting with the inclusion of explosive jumping and sprinting activities, aimed at inducing a PAP effect, during pre-game WU routines. Post-activation potentiation is a phenomenon by which muscular performance is acutely enhanced when preceded by maximal or near maximal neuromuscular activation.[6] Two proposed mechanisms responsible for PAP are an increase in the phosphorylation of myosin regulatory light chains[2] and increased recruitment of higher order motor units.[7] Voluntary resistance methods of inducing PAP (e.g., loaded squat exercises) can improve CMJ (countermovement jump) height[8] and short-sprint performance.[9] A sport-specific WU aimed at inducing PAP in volley ball has also been reported to improve CMJ height by ~2% more than traditional resistance methods.[8] However, the effects of a WU aimed at inducing PAP on subsequent team-sport-specific tasks, such as reactive agility (RA) and intermittent exercise performance, have not been investigated.

There are also reports of some team sports utilising small-sided games (SSG), including passing, shooting and ball-control activities, within WU routines (unpublished observation). Small-sided games incorporate activities and movement patterns specific to competitive team-sport tasks and are aimed at simulating the skill/metabolic demands of a sport.[10] The specificity of SSGs has been suggested to provide additional ergogenic benefits over generic conditioning methods by increasing neuromuscular activation.[11] Only one study to date has investigated the application of SSG as a WU protocol, finding no beneficial effect compared with closed-skill activities (i.e., forward skipping, lateral skipping and 20-m maximal effort sprints).[12] Limitations of that study include the use of a 22-min WU, far greater than previously recommended,[4] unspecified recovery periods prior to testing, and the inclusion of static stretching during the WU protocol, despite previous research reporting performance decrements following static stretching.[13] Therefore, a high-intensity, short-duration, SSG WU may enhance subsequent performance if intensity and duration conform to previous research, and static stretching bouts are avoided. Accordingly, this study examined the acute (short-term) effects of one WU which aimed to produce a PAP effect (5RM leg-press), another which replicated a SSG activity, and a currently implemented WU routine.

2. Methods

Ten male, amateur football (soccer) players competing in the Italian Serie D competition gave written informed consent to participate. The mean age, height, body mass and maximum heart rate (HR_{max}) of participants was 23.3 ± 2.5 y, 1.78 ± 0.04 m, 69.1 ± 4.1 kg, and 191 ± 8 bpm, respectively. Physical screenings were conducted by medical staff to establish each candidate's previous injury history, general health, and suitability for participation.

Participants attended one familiarisation, one baseline and three experimental sessions. Sessions were separated by ≥72 h. Familiarisation included a 5-min baseline jog WU maintaining HR at 60% of the predicted HR_{max} (220 – chronological age), followed by all physiological (blood lactate, rating of perceived exertion, HR, core temperature) and performance (CMJ, RA, 20-m sprint time) tests. The YO-YO Intermittent Recovery test (level 1)[14] was then administered to determine each individual's intermittent exercise performance and HR_{max}. During the baseline session, participants repeated all physiological and performance tests (excluding the YO-YO Intermittent Recovery test). Participants then completed a seated 5RM leg-press test. Following this, participants rehearsed the SSG and team-sport WU protocols with additional player assistance, and standardised verbal instructions.

The three experimental sessions were completed on a natural-grass soccer field, in a randomised, crossover and counterbalanced order. Participants wore specific soccer boots and clothing, and were instructed to avoid strenuous exercise prior to or during the testing period, to avoid caffeine and alcohol ingestion, and to maintain their usual nutritional intake. Sessions were completed at similar times for each participant (within 1 h) to minimise circadian influences.[15] Environmental conditions (°C, humidity and wind speed) were accessed and recorded via a local meteorology station (Golosine, Verona). Mean temperature, humidity and wind speed were 26.4 ± 3.3 °C, 46.9 ± 18.9% and 2.2 ± 1.3 m s^{-1}, respectively. For each experimental session participants completed a 5-min baseline jog WU at 60% HR max followed immediately by one of the three WU interventions.

One of the WU interventions included 3 repetitions of a 3 vs. 3 SSG WU with 2 min of play, interspersed with 2 min of passive rest (approximately 12 min total time). Pitch-size increased from 20 m (length) × 12 m (width) in the first repetition to 25 m × 15 m in the second repetition and to 30 m × 18 m in the third repetition, to progressively increase the WU intensity. Teams aimed to continuously perform five successful passes/possessions, and were required to maintain high-intensity throughout the duration of the SSG (~70–80% HR_{max}). Unlimited ball control touches were allowed.

The effect of a 5-min jog WU followed by a 5RM seated leg press (Techno gym, Italy) lasting approximately 15 s, was investigated on a separate day. Standardised foot settings and 90° knee-flexion was maintained prior to the commencement of each pressing phase.

Finally, a currently used premier league football (soccer) club WU routine, which lasted approximately 23 min, was modified and administered (see supplementary 1). The strength and conditioning staff assisted with modifications to this protocol to account for differences in fitness levels. The WU included general activities (high-knees, butt-kicks and body-weight squats; performed at medium intensity [sub-maximal velocity] for 6 min), specific movements (back and forth sprinting, lateral skipping and change of direction movements; performed at high intensity [maximal velocity] for 9 min) and ball-control activities (dribbling, passing and run-throughs; performed at high intensity for 6 min). One 60-s and two 30-s passive recovery periods were interspersed within the routine. Four minutes post each intervention, physiological and performance measures described below were recorded.

Performance measures such as counter-movement jump height were calculated via Opto Jump (Lynx System Developers, USA); a day-to-day CV of 2.7% was established during preliminary testing. Participants performed maximal-effort CMJs, with the average of two jumps recorded. A self-selected knee depth in the CMJ was instructed, while hands were placed on hips at all times during the jump trials. Trunk flexion was avoided, as was knee flexion prior to final decent. Reactive agility, as described elsewhere,[16] was also measured post interventions. Total time taken to change direction and sprint through finishing gates was measured using Photocells (Lynx Systems Developers, USA); a CV of 2.8% was established during preliminary testing. Thereafter, participants completed an intermittent exercise task including physical activities specific to team sports.[17] Briefly, participants completed 15, 60-s circuits that included activities such as sprinting, slalom, walking, jogging, decelerations, changes of direction, backwards running and striding (see supplementary 2). During each circuit, 20-m sprint times were recorded at the beginning of each repetition using Photocells (Lynx Systems Developers, USA); a CV of 0.8% for sprint times was established.

Following each intervention the CR1–10 rating of perceived exertion scale was implemented using 1 unit integers.[18] This scale uses descriptors linked to a numbered scale ranging from 0 (rest) to 10 (maximal effort). Rating of perceived exertion was then multiplied by duration (min) of activity to analyse data as load units.[18] Blood lactate concentration was determined from ear lobe blood samples (30 μL) immediately post WU interventions and analysed via an automated analyser with an enzymatic approach (Biosen C Line; EKF Diagnostics, Germany). Calibration was completed as per manufacture instructions with the use of samples of known lactate concentration. Heart rate was continuously recorded every 5 s using a short-range telemetry HR monitoring systems (VantageNV, S710, and Xtrainer models, Polar Electro, Kempele, Finland). Finally, core temperature was measured using an ingestible telemetric sensor (CORETEMP™ COR-100 Wireless Ingestible Temperature Sensor, HQ Inc., Palmetto, FL, USA).[19] As per manufacturers instructions, sensors were ingested 3 h prior to testing. Temperature signals were transmitted via radio waves to an external temperature-recording device (CORETEMP™ CT2000 Miniaturized Ambulatory Recorder, HQ Inc., Palmetto, FL, USA).

Variables measured were log transformed, to reduce bias due to non-uniformity of error, and analysed using effect size (ES) statistics with 90% confidence intervals (CI), and percentage change to determine the magnitude of effects, using a customised spreadsheet.[20] Magnitudes of change were classified as a substantial increase or decrease when there was a ≥75% likelihood of the effect being equal to or greater-than the smallest worthwhile change (estimated as 0.2× between subject standard deviation), and classified as small (ES: 0.2–0.6) moderate (ES: 0.6–1.2) large (ES: 1.2–2.0) and very large (ES: 2.0–4.0). Effects with less certainty were classified as trivial and where the ±90% CI of the ES crossed the boundaries of ES −0.2 and 0.2, the effect was reported as unclear.

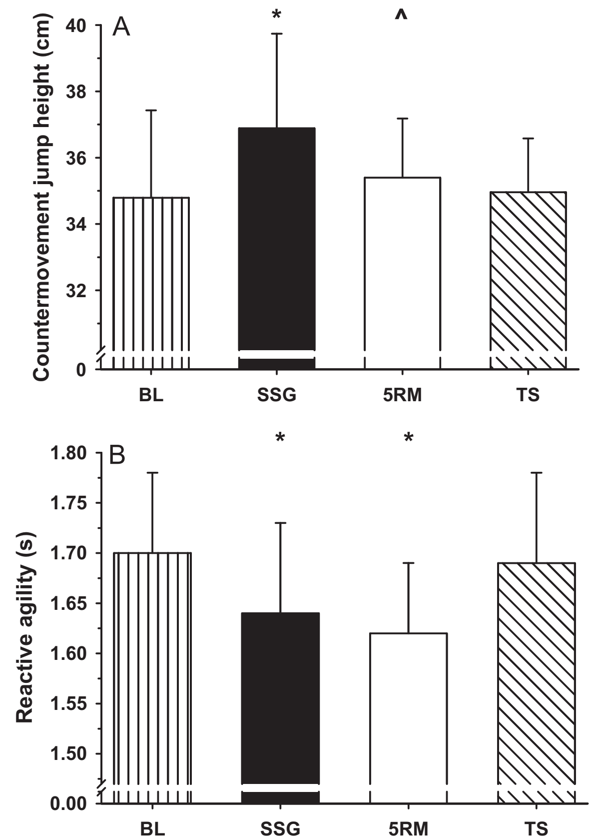

Fig. 1. Effect of interventions on (A) countermovement jump height expressed in cm and (B) reactive agility expressed in seconds (s). Vertically filled columns = baseline measures (BL), solid columns = SSG WU, open columns = 5RM WU, and diagonally filled columns = the team-sport (TS) WU. Data are mean ± SD, ∧ denotes a small improvement (ES: 0.2–0.6) from baseline measures; * denotes a moderate improvement (ES: 0.6–1.2) from baseline measures, $n = 10$.

3. Results

The mean YO-YO Intermittent Recovery score, 5RM leg-press strength and 5RM strength/body mass ratio of the participants was 1640.0 ± 208.4 m, 88.4 ± 8.4 kg and 1.3 ± 0.1, respectively. Compared to baseline measures, CMJ height was greater following the SSG (6%, ES: 0.8 ± 0.8) and 5RM (2%, ES: 0.3 ± 0.5) WU than the team-sport WU (<1%, ES: 0.1 ± 0.7; unclear) (see Fig. 1A). When compared

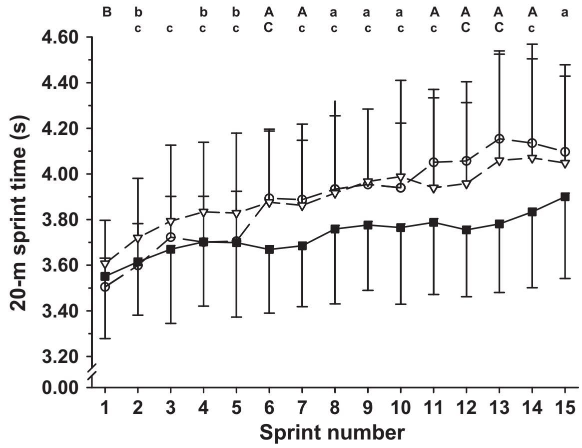

Fig. 2. 20-m sprint times expressed in seconds during the intermittent exercise task. Open circles = SSG WU, solid squares = 5RM WU, and open triangles = the team-sport (TS) WU. Data are mean ± SD, 'a' denotes a small performance difference (ES: 0.2–0.6) between the 5RM and SSG WUs; 'A' denotes a moderate (ES: 0.6–1.2) difference between the 5RM and SSG WUs; 'b' denotes a small difference between SSG and TS WUs; 'B' denotes a moderate difference between SSG and TS WUs; 'c' denotes a small difference between the 5RM and TS WUs; 'C' denotes a moderate difference between the 5RM and TS WUs, $n = 10$.

to baseline, reactive agility was 4.7% (ES: 1.1 ± 0.7) faster following the 5RM WU, 3.8% faster (ES: 0.8 ± 0.7) after the SSG WU and 'unclear' following the team-sport WU (0.9%, ES: 0.2 ± 0.7) (Fig. 1B).

Twenty-meter sprint times were faster following the 5RM WU, compared to following the SSG WU, from sprint six (5.7%, ES:0.7 ± 0.4) to sprint 15 (4.9%, ES: 0.5 ± 0.4), with a peak difference of 8.9% (ES: 0.9 ± 0.3) during sprint 13. Compared to the team-sport WU, 20-m sprint times were also faster following the 5RM WU from sprint two (2.9%, ES: 0.4 ± 0.4) to sprint 14 (5.8%, ES: 0.5 ± 0.4), with a peak difference of 7% (ES: 0.6 ± 0.5) during sprint 13 (Fig. 2). When comparing 20-m sprint times between the team-sport WU and SSG WU, sprint performance was faster following the SSG WU in sprint one (2.8%, ES: 0.6 ± 0.5) to sprint five (3.1%, ES: 0.4 ± 0.4), with an absence of a meaningful effect during sprint three ("unclear"). There was no difference between WU protocols for mean time taken to complete each circuit of the intermittent exercise task.

Core temperature was lower following the 5RM WU compared with both the SSG (1%, ES: 0.9 ± 0.8) and team-sport WU (2%, ES: 1.6 ± 0.5) (Fig. 3A). $[Lac^-]_b$ post-WU was higher following the SSG (67.2%, ES: 2.7 ± 0.8) and team-sport WUs (65.5%, ES: 2.9 ± 0.9) compared to baseline, while $[Lac^-]_b$ following the 5RM WU was unchanged (classified as 'unclear') (Fig. 3B). Mean HR following the 5RM intervention (128 ± 14 bpm) was lower than following both the SSG (37%, ES: 3.4 ± 0.8) (175 ± 10 bpm) and the team-sport WU (35%, ES: 3.2 ± 0.8) (172.9 ± 10.2 bpm), while load units were lower following the 5RM intervention (1.1 ± 0.2) compared to the SSG (78.0 ± 11.6) and team-sport WU (147.2 ± 32.9).

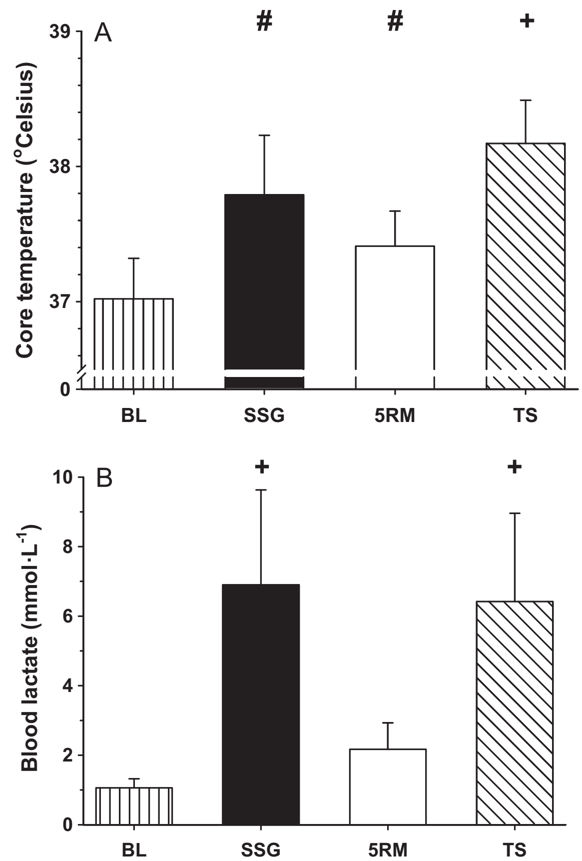

Fig. 3. Core temperature (°C) (A) and blood lactate concentration ($[Lac^-]_b$) (B) measured at the completion of WUs. Vertically filled columns = baseline measures (BL), solid columns = SSG WU, open columns = 5RM WU, and diagonally filled columns = team-sport (TS) WU. Data are mean ± SD, # denotes a large change (ES: 1.2–2.0) from baseline measures; + denotes a very large change (ES: 2.0–4.0) from baseline measures, $n = 10$.

4. Discussion

Compared to baseline measures, we observed a 6% and a 2% enhancement of CMJ performance following the SSG and the 5RM WU respectively, and ~4% improvement in RA following both. The 5RM WU was associated with small-large improvements in 20-m sprint times during the intermittent exercise task, minimized metabolic strain/internal load as indicated by core temperature (T_c), $[Lac^-]_b$ and load units, and provided greater performance benefits than a currently implemented, team-sport WU. Compared to baseline, the team-sport WU had no effect on CMJ or RA, while a 5% slower performance was evident during the 20-m sprints (sprints six to 15), when compared with the 5RM WU.

The absence of a positive effect of the team-sport WU on subsequent performance is surprising as we implemented a similar WU routine to that of a premier-league soccer club. However, previous WUs, using a similar intensity (60–80% $\dot{V}O_{2max}$) and duration (15–30 min), have also reported no improvement in various performance measures.[5,21,22] A 15-min kayak WU performed at 75% of $\dot{V}O_{2max}$ impaired subsequent 2-min kayak performance,[21] and similar decrements in treadmill running to exhaustion were observed following a 15-min WU at 80% of $\dot{V}O_{2max}$.[22] The fixed WU intensities in these previous studies make results difficult to compare, but it can be suggested that participants in the present study also experienced fatigue via repeated-bouts of maximal sprinting, changing of direction, bounding, jumping and dribbling during the team-sport WU. This is supported by a work load that was 0.86 and 131-fold greater than the SSG and 5RM WU.

Peripheral and/or central fatigue of locomotor muscles may have resulted from the prolonged high-intensity exercise incorporated into the team-sport WU. High-intensity exercise lasting 13.2 min can reduce force output of the quadriceps by ~30%, with the force output only recovering following 70 min of rest.[23] An increasing demand for respiratory muscle blood flow during high-intensity exercise compromises blood flow to working limbs due to sympathetically mediated vasoconstriction.[24] In turn, a locomotor vasoconstriction can decrease oxygen transport to working muscles and increase fatigue, as well as the level of perceived effort.[25] In the current study, the team-sport WU took longer to complete than the SSG WU, and was associated with greater load units, core temperature and $[Lac^-]_b$, compared to the alternative WU methods. This may be an indication of greater residual fatigue and inhibition of central and/or peripheral mechanisms responsible for muscular contraction. However, these mechanisms are beyond the scope of this study, and warrant further investigation.

It is also possible that the deleterious effects experienced following the team-sport WU may have been exacerbated by the low fitness level of our participants. However, modifications to the WU protocol were accounted for, and the WU was judged as being similar to the participants' usual WU routine. Further research is required to investigate if current team-sport WUs are of any benefits at all, and alternatively, if more efficient methods of preparing athletes prior to team-sport competition exist. In the current study, a SSG WU bout increased CMJ height more than both the 5RM and the team-sport WU. This may be attributed to an intensity-dependent relationship[8] following repeated high-intensity sprinting efforts performed during the SSG WU. Dynamic bouts of activity, interspersed with movement-pattern-specific exercises, have shown similar improvements in CMJ height (~7%).[8] Although the mechanisms were not measured, performance enhancement was suggested via increases in muscle temperature, increased neural activation, and movement specificity of the WU.[8] In the current study, the SSG WU also included bouts of moderate-to-high intensity activity, as well as sport-specific tasks. The augmentation of mechanisms pertaining to muscle temperature (i.e., increased muscle blood flow, improved force–velocity relationship)[8,26,27] via SSG tasks may be responsible for the reported enhanced performance. In addition, the present study demonstrated that a SSG WU can also enhance reactive agility (4%), as well as CMJ performance (6%), suggesting that benefits may be transferable to tasks which closer replicate team-sport demands. Further research is required to elucidate the mechanisms responsible for the observed changes in acute performance following a SSG WU.

In contrast, our SSG WU did not improve 20-m sprint performance during the intermittent exercise task, when compared to the 5RM WU. Mean 20-m sprint times were, on average, 6% slower (during the last 10 sprint bouts) compared to the 5RM WU. Increased physiological strain compared to the 5RM WU may account for the slower sprint times reported during the intermittent exercise task. Although the SSG WU did enhance acute performance (i.e., CMJ and RA), it is likely that the high-intensity efforts during the SSG WU negatively affected prolonged high-intensity intermittent exercise specific to team sports.

This study demonstrated that a 5RM WU aimed at inducing PAP can improve CMJ performance, and team-sport related tasks, when compared to a team-sport WU. Improved reactive agility times suggest that the mechanisms involved in potentiation may also be transferrable to explosive change-of-direction tasks. Only one other study has investigated reactive agility performance following various WUs,[12] finding no improvement. Differences in sample population and methodologies may account for the variation in results, e.g., the current study recruited 10 young adult males compared to male and female youths[12] and excluded static stretching to avoid performance decrements previously reported.[13]

Following the 5RM WU, 93% of all sprint bouts were ≥3% faster than following the team-sport WU, and 67% of all sprint were ≥4.4% faster than following the SSG WU. Although PAP cannot improve maximal sprint speed/velocity, it can enhance the rate of force development.[28] Therefore, the positive influence of potentiation during the 20-m sprints may be due to an increased rate of acceleration and decreased time to attain maximal velocity. This study is unable to confirm whether potentiation per se is responsible for improved performances, or if the increased physiological demands associated with the opposing interventions caused the changes in performance. Nonetheless, these results have important implications for team-sport athletes relying on repeated, high-intensity, sprint efforts, with minimal recovery during competition, and raise issues pertaining to the appropriateness of current team-sport WU routines. Further research is required to identify the mechanisms responsible for improved repeated-sprint performance following a 5RM WU, and its potential performance application during half-time periods and/or following player substitution.

5. Conclusions

In this study, a 5RM leg press WU induced less physiological strain and minimised decrements in 20-m sprint times during a 15-min intermittent exercise task. Future research should investigate if similar effects are evident following team-sport specific intermittent exercise tasks longer than

15 min in duration, and the effects of team-sport WUs on the execution of skills. A 5RM or SSG WU may increase specific performance of team-sport athletes, however further research is necessary to confirm these findings with an elite population, and to investigate its practical application in professional team-sport competition.

6. Practical implications

- A 5RM and/or SSG WU may be of benefit to subsequent power and repeat-sprint tasks performed by team-sport athletes.
- A currently implemented team-sport WU routine did not provide a beneficial effect to subsequent team-sport-related physical tasks.
- Current WU practice may be negatively affecting athlete performance via an increase in pre-performance fatigue levels.

Ethical standards

The procedures of this study were approved by the Human Research Ethics Committee of Victoria University and conducted in accordance to the Declaration of Helsinki.

Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jsams.2011.03.012.

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