International Journal of Strength and Conditioning

Bright, T. E., Hughes, J. D., Handford, M. J., Annis, B., Westwood, C. (2022).The Acute Effects of Weighted Vest Protocols on 20-Metre Sprint Performance in Youth Soccer Players. International Journal of Strength and Conditioning
https://doi.org/10.47206/ijsc.v2i1.104

The Acute Effects of Weighted Vest Protocols on 20-Metre Sprint Performance in Youth Soccer Players

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ABSTRACT

This investigation examined the effects of a warm-up containing weighted vest (WV) sprints on subsequent 20-metre sprint time relative to a control (C) condition in youth soccer players (n =12, mean ± SD age 16 ± 0.60 years, height 175.17 ± 5.92 cm and body mass 61.85 ± 5.88 kg). The main experimental trials consisted of three WV conditions at 10, 20 and 30% of body mass (WV10, WV20 and WV30) and C. Participants were required to complete one 20-metre sprint with each of WV conditions or without additional mass as part of C prior to a 20-metre sprint at 4-, 8- and 12-minutes. A two-way repeated measures ANOVA revealed no significant difference between any of the conditions and rest periods (p = >0.05). The between condition effect sizes for 20-metre sprint times were moderate at 4- and 12-minutes post WV10 (d = -0.86 and -1.15, respectively) and 12-minutes post WV20 (d = -0.84) and WV30 (d = -0.80). Moderate effect sizes were also observed at 4-minutes post WV10 (d = -1.04) and WV20 (d = -0.67) for 10-metre sprint times. These findings demonstrate that WV loading has no significant effect on 20-metre sprint time in youth soccer players. However, there is an opportunity for S&C coaches to implement WV warm-ups of no more than 30% body mass to improve 20-metre sprint times.

INTRODUCTION

The acute effects of warming-up on measures of physical performance have been studied since the 1930s (45). These investigations have typically found the completion of an active warm-up prior to training or competition to have a positive impact on athletic performance (8,20,51). A review by Radkin et al. (39) concluded that there is little evidence to suggest that warming-up is detrimental to performance with post-warm-up improvements noted between <1% and 20% for tasks such vertical jumping, long jump and agility. Furthermore, similar improvements were found in sporting performance, including softball, basketball and golf (39). The traditional warm-up incorporates a brief period of submaximal aerobic activity followed by a series of static and/or dynamic stretching routines and sport-specific exercise (32,35). In more recent years, the addition of a post-activation performance enhancement (PAPE) complex within a warm-up has grown in popularity amongst strength and conditioning (S&C) coaches (11,26). This method involves performing a conditioning exercise (CE) prior to an explosive movement with similar biomechanical characteristics (15,26,44).

To date, a number of studies have examined the acute effects of a heavy resistance CE within a warm-up on sprint performance (42,56). This commonly involves the execution of a multi-joint free weight exercise at loads exceeding 80 to 85% of an individual's one repetition maximum (1-RM) (44,56). The most frequently used heavy resistance CE is the back squat with findings demonstrating significant improvements in sprint performance over distances of 10 to 40-metres following 1 to 5 repetitions at >85% of 1-RM (p = <0.05) (5,9,29,34,57,58).

The ability to attain the accompanying PAPE benefits are, however, thought to be associated with the physical conditioning of the individual (4,37,57) and their level of muscular development (40). These characteristics can be directly influenced by the age of the participant as children possess less voluntary muscle speed, strength and power, even when corrected for age or biological maturation (1,38). Likewise, children and adolescents possess a significantly lower percentage of type IIx muscle fibres when compared with adults (27,28,46) and have a reduced ability to utilise higher-threshold motor units (13,16,19,23,40,43) which are more responsive to heavy resistance exercise (24,54). The combination of these factors may influence the ability of adolescent participants to derive benefits from heavy resistance CE. Therefore, alternative methods of warming-up that may be better tolerated are appealing.

Recently, Grimes et al. (22) investigated 20-metre sprint performance 5-, 6- and 7-minutes after a sled push at 50 and 100% of body mass amongst male soccer players. Despite no significance in either condition, a moderate effect size at 6- and 7-minutes (d = -0.71 ± 0.57 and -0.62 ± 0.65, respectively) in the 50% of body mass condition was observed alongside no decrements in sprint performance following both conditions and all recovery durations. It is likely that the lack of significance may have been as a result of the sled pushing altering participants natural sprint mechanics through removal of the arm action, excessive forward trunk lean and an increase in ground contact times (30). Likewise, the load imposed during the 100% of body mass condition may have been too great, lacking transfer to that of maximal sprint speed and the ability of youth participants to derive benefits from heavy resistance CE (47). The ability to access sleds and sufficient load may also be restrictive to youth-based team sports, hence, alternate means of adding load to dynamic movements may be more applicable.

One such method is the use of a weighted vest (WV) CE included within a warm-up (7,50). For example, Faigenbaum et al. (18) found that when adolescent athletes (15.3 ± 1.2 years) continually wore a WV of 2% body mass during a dynamic warm-up, jump performance was significantly improved compared with a dynamic warm-up alone (42.1 ± 5.2 cm vs 37.1 ± 5.1 cm, respectively; p = 0.04). A weighted vest of 6% body mass, however, did not improve performance, suggesting that the additional load may have been too great. Similarly, Reiman et al. (41) also found no advantageous effects of a dynamic warm-up with the addition of a WV at 5% of body mass on subsequent lower body power output. When a weighted vest of 10% body mass was worn only for the last 4 of 12 dynamic exercises, jump performance was significantly improved compared to dynamic movements alone (49). These findings suggest that improvements can be established following heavier WV activity, however, the amount of time participants wear the WV during the warm-up must be carefully considered to ensure fatigue is managed and potentiation is realised (50). In further support, Turner et al. (55) observed significant improvements in 20- and 10-metre sprint performance after 3 sets of alternate leg bounds with the addition of a WV at 10% body mass, albeit in adult participants. It is evident from these findings that to benefit from the acute effects of WV drills contained within a warm-up, factors such as the volume and intensity of added mass along with the duration of recovery prior to performance must be well-thought-out.

When considering the recovery period following heavy resistance CE, performance is initially impaired, potentiation is then realised, peaks and decreases in an inverted U-shaped fashion (6,52,56). However, when considering a lighter CE, that of a WV, the same level of agreement is yet to be reached with the reporting of equivocal results. Nonetheless, previous investigations have found potentiating effects in numerous physical performance tasks (i.e., vertical jump, long jump, medicine ball toss and 10-yard sprint) 2-minutes post warm-up containing dynamic exercise with a WV at 2% of body mass (18). Similar results have been demonstrated after <60 seconds (33,53) and 3-minutes (12,48,49). It would therefore appear that the recovery duration necessary to observe a potentiated response may be lower than would be required following heavy resistance CE given the significant reduction in system mass loading (21). Despite the aforementioned investigations suggesting that a lighter CE requires less recovery prior to subsequent physical performance, very few have attempted to examine the effects on more functional indices of sporting performance in youth populations, such as sprinting. Hence, further research is warranted to determine an optimal load and recovery period following a warm-up containing WV activity prior to sprint performance in youth soccer players.

The potential that a dynamic warm-up protocol with the inclusion of a WV could result in enhanced subsequent sprint performance could have significant implications for S&C coaches who work with young soccer players. Accordingly, this study aimed to examine the acute potentiating effects of WV sprints at 10, 20 and 30% of body mass on subsequent 20- and 10-metre sprint performance after 4-, 8-, and 12-minutes of rest, relative to C. It was hypothesised that all WV conditions would significantly enhance 20- and 10-metre sprint performance in comparison with C.

METHODS

Participants

Participants (n = 12) were a mixture of attackers, midfielders and defenders from the male under 16 age group of a sub-elite soccer club (mean ± standard deviation (SD) age 16 ± 0.60 years, height 175.17 ± 5.92 cm and body mass 61.85 ± 5.88 kg). All participants took part in an average of 6 ± 1 hours of combined soccer specific training and competitive play per week and had 1.5 ± 1 years of plyometric and sprint training experience. Following a full explanation of the procedures and potential risk, parental consent and participant assent were gained. Procedures were pre-approved by the Plymouth Marjon University ethics committee. Participants were healthy, non-smokers and had all been injury free for at least 8 months prior to taking part. In the 12-hours leading up to data collection, participants were encouraged to replicate their normal diet, avoiding alcohol and caffeine. Recommendations were made to refrain from strenuous physical activity 48-hours prior to testing, in line with similar previous research (55).
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Study Design

A within participants repeated measures study design was used to compare the effects of WV sprint running within a warm-up on 20- and 10-metre sprint time, relative to C. Participants completed four experimental trials involving a standardised warm-up followed by an unloaded 20-metre sprint (C) or a CE consisting of 20-metre WV sprint running with an additional mass of 10, 20 or 30% of body mass (WV10, WV20 and WV30, respectively). After performing one of the four conditions, 20-metre sprints were re-tested without additional mass at 4-, 8- and 12-minutes to profile transient fatigue and potentiating effects. The order of CE for each participant was determined using an online block randomisation tool (Research Randomizer, Version 4) and participants were informed of the condition they would be exposed to at the start of each visit.

Procedures

Familiarisation

Prior to the main experimental trials, participants attended a familiarisation session whereby anthropometric measurements of stature and body mass were taken (Seca, mBCA 514, Birmingham, UK) and sprint performance testing was practiced. Each participant also familiarised themselves with sprinting whilst wearing a WV to ensure they were sufficiently prepared for the main experimental trials. The first of the main experimental trials was performed 48-hours after familiarisation and no less than 48-hours separated all subsequent main trials. Test-retest reliability for our participants during 20- and 10-metre sprints met recently recommended criteria (intraclass correlation = 0.957-0.978; coefficient of variation percentage = 2.47-2.46) (2).

Sprint Time

Sprint performance was assessed over 20-metres using a timing gate system (Brower Timing Systems, Utah, USA) positioned at 0-, 10- and 20-metres at a height of approximately 60-cm. These methods were similar to those of Turner et al. (55) to ensure light beams were not broken by the lower arm or lower leg. Participants began each sprint following a 3-second countdown from a 2-point staggered stance at a distance of 0.3-metres behind the first set of timing gates to ensure light beams were not broken before the start of each sprint. The countdown was used to make sure that participants were focused and ready to give maximal effort. A 10-metre deceleration zone was marked to encourage participants to accelerate beyond the 20-metre finish line. Timing started and finished when the beams of the first and last gates were broken respectively.

Conditioning Exercise

During the main experimental trials, participants reported to the Sport and Exercise Science Laboratory between 18.00 and 20.00. After being informed of their condition, participants underwent a standardised warm-up containing light jogging, a series of dynamic movements emphasizing activation of the key lower body musculature associated with sprinting (10 repetitions each of bodyweight squats, walking lunges and glute bridges), before progressively increasing the intensity of 20-metre sprinting to near-maximal speeds (i.e., 1x50%, 1x70% and 1x90% of maximal effort). Following a period of active recovery (~2 min), participants completed one of the four WV conditions (C, WV10, WV20 or WV30; Weighted Vest - Perform Better Limited, UK). In the WV conditions, participants performed one 20-metre sprint with the addition of WV10, WV20 or WV30. For each of the WV conditions, participants were instructed to start with a three-step run up before sprinting to the finish line whilst maintaining their normal running technique. In the C, participants performed an unloaded 20-metre sprint. Thereafter, participants in all conditions repeated the 20-metre sprint assessments after 4-, 8- and 12-minutes of recovery without additional mass. All experimental trials were similar in duration.

Participants consumed water ad libitum during the trials and a single member of the research team administered all tests such that the potential variation in test instruction was minimised. All tests were conducted in a laboratory that was maintained at an air temperature of 20 ± 0.6 °C.

Statistical Analysis

All statistical analyses were performed using SPSS software (Version 28) and data are presented as mean ± SD. Two-way repeated measures analyses of variance (ANOVA; within participant factors; group [control, WV10, WV20, WV30] x time [4-, 8- and 12-minutes]) were used. Significance was accepted as $p < 0.05$. Additional effect sizes (*d*) were calculated between the C and WV10, WV20 and WV30 for all recovery durations ((mean 2 – mean 1)/pooled SD). The magnitude of ES was considered trivial (<0.20), small (0.20-0.59), moderate (0.60-1.19), large (1.20-1.99) and very large (>2.00) (25).

RESULTS

Mean ± SD for 20- and 10-metre sprint times following each of the CE and rest periods are shown in Figures 1 and 2, respectively. Percentage change values and effect sizes are provided in Table 1.

20-Metre Sprint Time

A two-way repeated measures ANOVA found no effect of group ($F_{(2, 1.827)} = 0.014$, $p = 0.167$) or group by time ($F_{(6, 1.186)} = 0.009$, $p = 0.321$) for 20-metre sprint performance. Between condition effect sizes

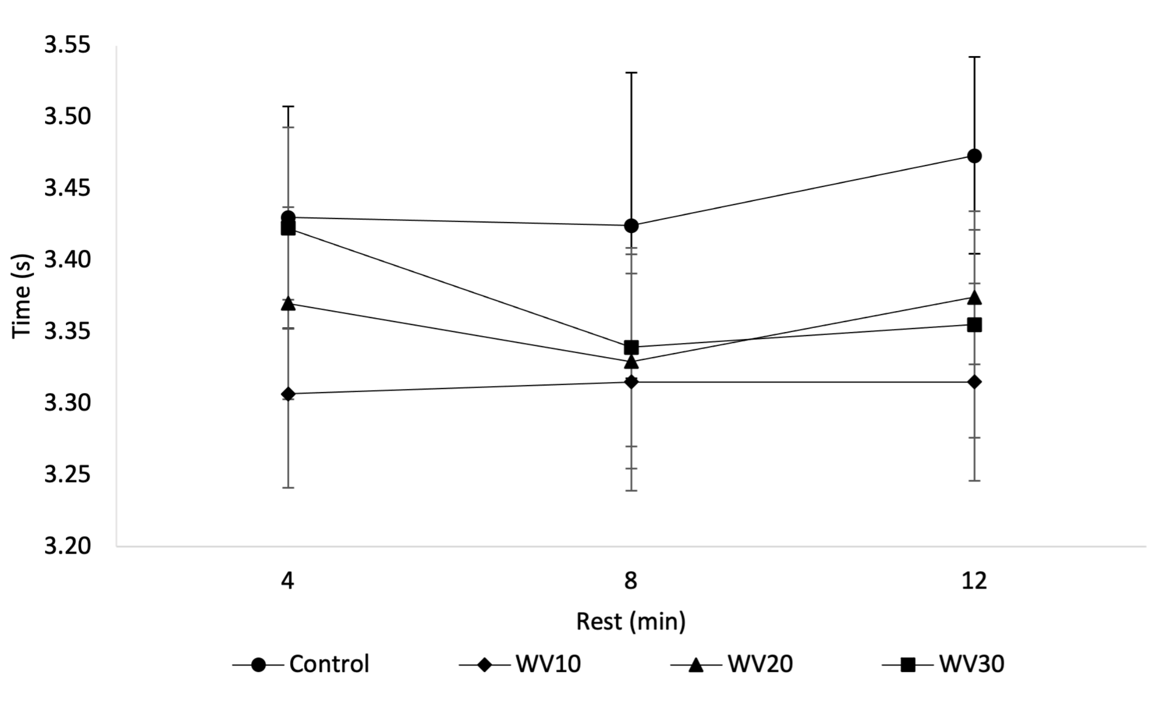

Figure 1. Mean ± SD 20-metre sprint times at 4-, 8- and 12-minutes following each condition.

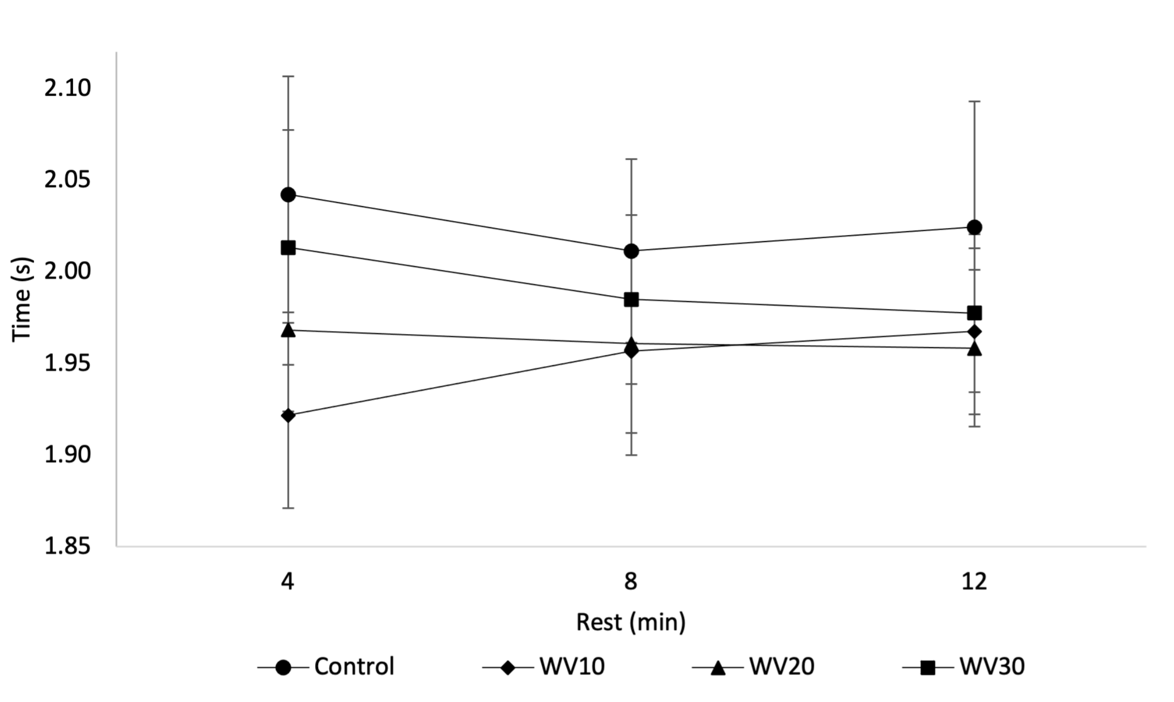

Figure 2. Mean ± SD 10-metre sprint times at 4-, 8- and 12-minutes following each condition.

were moderate at 4- and 12-minutes post WV10, 12-minutes post WV20 and 12-minutes post WV30.

10-Metre Sprint Time

A two-way repeated measures ANOVA found no effect of group ($F_{(2, 0.259)}$ = 0.001, p = 0.772) or group by time ($F_{(6, 1.395)}$ = 0.005, p = 0.226) for 10-metre sprint performance. Between condition effect sizes were moderate at 4-minutes post WV10 and WV20.

DISCUSSION

In the current investigation, adolescent soccer players performed WV sprints at 10, 20 and 30% of body mass to determine whether this intervention would acutely enhance 20- and 10-metre sprint performance relative to C after 4-, 8- and 12-minutes of rest. The main finding was that all of the WV conditions improved 20- and 10-metre sprint performance in comparison with the C. Although no statistical significance was found, the greatest reductions in 20-metre sprint times were observed after WV10 at 12-minutes. Similarly, WV10 was also superior in improving 10-metre sprint performance after 4-minutes. Nevertheless, the results fail to support our hypothesis.

The augmentation of sprint performance through the use of different warm-up protocols has been well documented when using a heavy resistance CE such as a barbell back squat or deadlift (5,14,44). However, the validity of employing a heavy resistance CE prior to training or competitive performance has often been questioned (31,55). This type of protocol requires heavy loads, approaching 1.5 to 2x an athlete's body mass, with the addition of equipment such as a squat rack, barbell and plates (14). The ability of younger athletes to realise positive effects following a heavy resistance CE are also likely to be diminished given their relatively little quantity of type IIx muscle fibres and reduced ability to recruit higher-threshold motor units compared with adults (3,13,16,23,40). The incorporation of WV sprint exercise into an athlete's warm-up is therefore a far more practical approach and one which the current investigation has demonstrated as being efficacious in improving 20- and 10-metre sprint times. That the load of the WV does not need to be very heavy is also in support of similar observations (18,41,50,55).

Despite the lack of statistical significance, the results of this study demonstrate the WV10 condition to induce the greatest improvement in 20- and 10-metre sprint performance. Though improvements were noted, it is likely that WV20 and WV30 resulted in comparatively higher amounts of fatigue and thus, interfered with the potentiation response. To date, however, there is a limited amount of research in support of these findings, specifically regarding adolescent soccer players. Turner et al. (55) reported that following WV alternate leg bounds at 10% body mass, subsequent 20- and 10-metre

Table 1. Percentage change scores and effect sizes for 20- and 10-metre sprint performance following each condition and rest periods 4, 8 and 12-min, relative to control.

	20-metres						10-metres					
	4-min		8-min		12-min		4-min		8-min		12-min	
	% ± SD	*d*	% ± SD	*d*	% ± SD	*d*	% ± SD	*d*	% ± SD	*d*	% ± SD	*d*
WV10	-3.53 ± 2.89	-0.86	-2.85 ± 7.53	-0.59	-4.50 ± 3.63	-0.80	-5.73 ± 4.90	-1.04	-2.60 ± 5.98	-0.51	-3.27 ± 5.61	-0.49
WV20	-1.66 ± 3.95	-0.41	-2.54 ± 5.56	-0.51	-2.77 ± 3.29	-0.84	-3.42 ± 4.88	-0.67	-2.42 ± 4.47	-0.51	-3.70 ± 5.63	-0.58
WV30	-0.16 ± 2.97	-0.05	-2.22 ± 6.00	-0.47	-3.33 ± 4.74	-0.80	-1.28 ± 5.33	-0.22	-1.23 ± 3.82	-0.27	-2.80 ± 4.84	-0.41

Abbreviations: WV, weighted vest; min, minute; %, percentage change; SD, standard deviation; *d*, effect size.

sprint performance was impaired at 15-seconds by 1.4 ± 2.5% and thereafter, improved at 4-minutes (20-metre = -2.3 ± 2.6%; 10-metre = -2.2 ± 3.1%) and 8-minutes (20-metre = -2.6 ± 2.8%; 10-metre = -2.9 ± 3.6%), though the participants were adults. When using participants of a similar age to those of the current study, Needham et al. (36) and Faigenbaum et al. (17) observed improved sprint and jump performance following a dynamic warm-up containing numerous plyometric type exercises and front squats with 20% body mass. Interestingly, Faigenbaum et al. (18) also found significant improvements in jump performance after participants were instructed to wear a WV at 2% body mass throughout the entire warm-up. Though, when this was increased to 6%, no further improvements were observed. However, given that the WV was worn continually throughout the warm-up protocols, it is likely that high levels of fatigue were evoked, compromising any possible potentiation effect. Furthermore, only 2-minutes of rest were given post warm-up. Factors such as the type, volume and load of CE and the recovery duration therefore must be considered prior to the application of WV drills. In the current study no significant improvements were found following one set of WV sprints at 10, 20 or 30% of body mass, despite reductions in sprint times. Consequently, perhaps this protocol may benefit from an additional WV set to ensure a larger amount of potentiation is realised.

From studies where a heavy resistance CE has been used during a warm-up, performance is consistently compromised immediately after the CE (6,26,52). However, speculation exists regarding the rest duration required following a lighter mode of CE. In contrast to previous investigations (18,50), the current findings suggest that both 20- and 10-metre sprint performance were enhanced after each of the WV conditions at 4-, 8- and 12-minutes post, relative to C. The greatest improvements in 20-metre sprint performance were observed after 12-minutes rest, across all conditions. For 10-metre sprint performance, a 5.73 ± 4.90% reduction in sprint time was realised after 4-minutes, representing the largest improvement. When considering similar investigations, the majority have observed potentiating effects following the use of a lighter load CE after <3-minutes (10,12,49) and even <60-seconds in some cases (53). However, several methodological differences must be acknowledged. Firstly, the participants in each of these studies were either Division 1 Collegiate or professional athletes with far greater strength and plyometric training experience in comparison with those of the current investigation. Secondly, the CE ranged from depth jumps to a combination of various hopping and bounding drills, which, in comparison with the WV sprints are less intense and fatiguing (17,18). Therefore, it is likely that the conditioning of participants and the nature of their experimental procedures explains the differences in findings. Although performance in the current study was optimal after 12-minutes, it is also important to note that both 20- and 10-metre sprint performance was enhanced as early as 4-minutes following a CE.

A potential limitation of the current investigation is related to the intensity of the WV warm-up, specifically the number of sets. In an attempt to evoke potentiation, the protocol was designed using a WV CE that involved the completion of one set of a 20-metre sprint at 10, 20 or 30% body mass. Theoretically, a multiple-set WV CE would've produced greater amounts of fatigue which may reduce the ability to express high levels of potentiation (37,57). However, recent studies (44,55,56) have compared multiple- and single-set CE with the findings demonstrating a far greater effect size proceeding multiple sets (d = 0.69 vs 0.24, respectively). Similarly, Till & Cooke (50) used a single set protocol (i.e., WV depth jumps at 10% body mass) and found no statistically significant improvements in 20- and 10-metre sprint performance. Therefore, future research should look to replicate the current study design with the addition of an extra WV CE set.

CONCLUSION

Training for sprint speed is an important consideration for S&C coaches who work with team sport athletes. The results of the current investigation demonstrate that, although not statistically significant, 20- and 10-metre sprint times in youth soccer players can be improved using WV sprints as part of a dynamic warm-up at 10, 20 and 30% of body mass relative to C, after 4-, 8- and 12-minutes of rest. More specifically, the WV10 warm-up protocol demonstrated the greatest improvements in 20-metre sprint performance. It is, however, important to acknowledge that the specific effect of each WV warm-up is largely individualised and as such, coaches should adopt a trial-and-error approach to identify the most suitable protocol for their athletes. Having only implemented one set of each WV condition, future research should look to include a multiple set WV CE whilst replicating the current study design to examine the effectiveness of this type of intervention.

PRACTICAL APPLICATIONS

The application of a WV within a warm-up has more recently been popularised as a result of a growing interest in more practical PAPE protocols. The principle is that through the addition of a WV an athlete can enhance their subsequent performance. In the current investigation, a WV warm-up at 10, 20 and 30% of body mass was superior to C in improving 20- and 10-metre sprint performance amongst trained adolescent soccer players. Despite no statistical significance, the moderate effect sizes observed following some of the conditions and rest periods demonstrates the practical implications of these findings. Table 2 shows an example of how a WV warm-up could be structured based upon the findings of this study. The suggested prescriptions are guided by the results but should be determined appropriately on an individual basis. The recovery duration necessary to observe a potentiated response in 20-metre sprint performance is less than previously reported post heavy resistance CE. Thus, this type of warm-up may be a more time-efficient way of harnessing potentiation.

Table 2. Example of how a warm-up can be constructed based upon the findings of this investigation.

Exercise/Activity	Suggested prescription
Light aerobic activity	5-min of light jogging, heel flicks, high knees, side steps
Dynamic movements	10 repetitions of BW squat, lunge, glute bridge and calf raises
20-metre sprint	~50%, ~70% & ~90% of max effort
Conditioning exercise	1 x 20-m sprint with additional WV at 10,20 or 30% body mass Rest 4- to 12-minutes
Performance task	20-m sprint without additional load

REFERENCES

1. Armstrong, N, Welsman, JR, and Chia, MYH. Short term power output in relation to growth and maturation. Br J Sports Med 35: 118–124, 2001.
2. Banyard, HG, Nosaka, K, and Haff, GG. Reliability and Validity of the Load–Velocity Relationship to Predict the 1RM Back Squat. J Strength Cond Res 31: 1897–1904, 2017.
3. Behm, DG, Faigenbaum, AD, Falk, B, and Klentrou, P. Canadian Society for Exercise Physiology position paper: Resistance training in children and adolescents. Appl Physiol Nutr Metab 33: 547–561, 2008.
4. Berning, JM, Adams, KJ, DeBeliso, M, Sevene-Adams, P, Harris, C, and Stamford, B. Effect of functional isometric squats on vertical jump in trained and untrained men. J Strength Cond Res 24: 2285–2289, 2010.
5. Bevan, HR, Cunningham, DJ, Tooley, EP, Owen, NJ, Cook, CJ, and Kilduff, LP. Influence of postactivation potentiation on sprinting performance in professional rugby players. J Strength Cond Res 24: 701–705, 2010.
6. Bevan, HR, Owen, NJ, Cunningham, DJ, Kingsley, MIC, and Kilduff, LP. Complex training in professional rugby players : influence of recovery time on upper-body power output. J Strength Cond Res 23: 1780–1785, 2009.
7. Bishop, C, Read, P, Walker, S, and Turner, A. Assessing movement using a variety of screening tests. Prof Strength Cond J 17–26, 2015.
8. Blazevich, AJ, Gill, ND, Kvorning, T, Kay, AD, Goh, AG, Hilton, B, et al. No effect of muscle stretching within a full, dynamic warm-up on athletic performance. Med Sci Sports Exerc 50: 1258–1266, 2018.
9. Chatzopoulos, DE, Michailidis, CJ, Giannakos, AK, Alexiou, KC, Patikas, DA, Antonopoulos, CB, et al. Postactivation potentiation effects after heavy resistance exercise on running speed. J Strength Cond Res 21: 1278–1281, 2007.
10. Chen, Z-R, Wang, Y-H, Peng, H-T, Yu, C-F, and Wang, M-H. The acute effect of drop jump protocols with different volumes and recovery time on countermovement jump performance. J Strength Cond Res 27: 154–158, 2009.
11. Chiu, LZF, Fry, AC, Weiss, LW, Schilling, BK, Brown, LE, and Smith, SL. Postactivation Potentiation response in athletic and recreationally trained individuals. J Strength Cond Res 17: 671–677, 2003.
12. Chiu, LZF and Salem, GJ. Potentiation of vertical jump performance during a snatch pull exercise session. J Appl Biomech 28: 627–635, 2012.
13. Cohen, R, Mitchell, C, Dotan, R, Gabriel, D, Klentrou, P, and Falk, B. Do neuromuscular adaptations occur in endurance-trained boys and men? Appl Physiol Nutr Metab 35: 471–479, 2010.
14. Crewther, BT, Kilduff, LP, Cook, CJ, Middleton, MK, Bunce, PJ, and Yang, G-Z. The acute potentiating effects of back squats on athlete performance. 25: 3319–3325, 2011.
15. DeRenne, C. Effects of postactivation potentiation warm-up in male and female sport performances: A brief review. Strength Cond J 32: 58–64, 2010.
16. Dotan, R, Mitchell, C, and Gabriel, D. Child — adult differences in muscle activation — a review. Pediatr Exerc Sci 24: 2–21, 2012.
17. Faigenbaum, AD, McFarland, J, Kelly, N, Ratamess, NA, Kang, J, and Hoffman, JR. Influence of recovery

time on warm-up effects in male adolescent athletes. Med Sci Sport Exerc 42: 545–546, 2010.

18. Faigenbaum, AD, McFarland, JE, Schwerdtman, JA, Ratamess, NA, Kang, J, and Hoffman, JR. Dynamic warm-up protocols, with and without a weighted vest, and fitness performance in high school female athletes. J Athl Train 41: 357–363, 2006.
19. Falk, B, Usselman, C, Dotan, R, Brunton, L, Klentrou, P, Shaw, J, et al. Child-adult differences in muscle strength and activation pattern during isometric elbow flexion and extension. Appl Physiol Nutr Metab 34: 609–615, 2009.
20. Fletcher, IM and Jones, B. The effect of different warm-up stretch protocols on 20 metre sprint performance in trained rugby union players. J Strength Cond Res 18: 885–888, 2004.
21. Gilbert, G and Lees, A. Changes in the force development characteristics of muscle following repeated maximum force and power exercise. Ergonomics 48: 1576–1584, 2005.
22. Grimes, N, Arede, J, Drury, B, Thompson, SW, and Fernandes, JFT. The effects of a sled push at different loads on 20 metre sprint time in well-trained soccer players. Int J Strength Cond 1: 1–7, 2021.
23. Grosset, JF, Mora, I, Lambertz, D, and Pérot, C. Voluntary activation of the triceps surae in prepubertal children. J Electromyogr Kinesiol 18: 455–465, 2008.
24. Hamada, T, Sale, DG, MacDougall, JD, and Tarnopolsky, MA. Postactivation potentiation, fiber type, and twitch contraction time in human knee extensor muscles. J Appl Physiol 88: 2131–2137, 2000.
25. Hopkins, WG, Marshall, SW, Batterham, AM, and Hanin, J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sport Exerc 41: 3–12, 2009.
26. Kilduff, LP, Bevan, HR, Kingsley, MIC, Owen, NJ, Bennett, MA, Bunce, PJ, et al. Postactivation potentiation in professional rugby players: Optimal recovery. J Strength Cond Res 21: 1134–1138, 2007.
27. Kindler, JM, Lewis, RD, and Hamrick, MW. Skeletal muscle and pediatric bone development. Curr Opin Endocrinol Diabetes Obes 22: 467–474, 2015.
28. Lexell, J, Sjöström, M, Nordlund, A-S, and Taylor, CC. Growth and development of human muscle: A quantitative morphological study of whole vastus lateralis from childhood to adult age. Muscle Nerve 15: 404–409, 1992.
29. Lim, JJ. and Kong, PW. Effects of isometric and dynamic postactivation potentiation protocols on maximal sprint performance. J Strength Cond Res 27: 2730–2736, 2013.
30. Macadam, P, Cronin, JB, Uthoff, AM, Johnston, M, and Knicker, AJ. Role of arm mechanics during sprint running: a review of the literature and practical applications. Strength Cond J 40: 14–23, 2018.
31. Maloney, SJ, Turner, AN, and Fletcher, IM. Ballistic exercise as a pre-activation stimulus: a review of the literature and practical applications. Sport Med 44: 1347–1359, 2014.
32. Marinho, D, Gil, M, Cardoso Marques, M, Barbosa, T, and Neiva, H. Complementing warm-up with stretching routines: effects in sprint performance. Sport Med Int Open 01: E101–E106, 2017.
33. Masamoto, N, Larson, R, Gates, T, and Faigenbaum, A. Acute effects of plyometric exercise on maximum squat performance in male athletes. J Strength Cond Res 17: 68–71, 2003.
34. McBride, JM, Nimphius, S, and Erikson, TM. The acute effects of heavy-load squats and loaded countermovement jumps on sprint performance. J Strength Cond Res 19: 893–897, 2005.
35. McGowan, CJ, Pyne, DB, Thompson, KG, and Rattray, B. Warm-up strategies for sport and exercise: mechanisms and applications. Sport Med 45: 1523–1546, 2015.
36. Needham, RA, Morse, CI, and Degens, H. The acute effect of different warm-up protocols on anaerobic performance in elite youth soccer players. J Strength Cond Res 23: 2614–2620, 2009.
37. Okuno, NM, Tricoli, V, Silva, SB, Bertuzzi, R, Moreira, A, and Kiss, MAPD. Postactivation potentiation on repeated-sprint ability in elite handball players. J Strength Cond Res 27: 662–668, 2013.
38. Van Praagh, E and Doré, E. Short-term muscle power during growth and maturation. Sport Med 32: 701–728, 2002.
39. Radkin, ANJF, Azryn, TSRZ, and Moliga, JAMS. Effects of warming-up on physical performance: a systematic review with meta-analysis. J Strength Cond Res 24: 140–148, 2010.
40. Radnor, JM, Oliver, JL, Waugh, CM, Myer, GD, Moore, IS, and Lloyd, RS. The influence of growth and maturation on stretch-shortening cycle function in youth. Sport Med 48: 57–71, 2018.
41. Reiman, MP, Peintner, AM, Boehner, AL, Cameron, CN, Murphy, JR, and Carter, JW. Effects of dynamicwarm-upwith andwithout a weighted vest on lower extremity power performance of high school male athletes. J Strength Cond Res 24: 3387–3395, 2010.
42. Rouissi, M, Turki, O, Bragazzi, NL, Owen, A, Haddad, M, Chamari, K, et al. Effect of post-activation potentiation induced by one, two or three half-squats on repeated sprint acceleration performance. Muscle Ligaments Tendons J 08: 28, 2019.
43. Sale, D. Postactivation potentiation: role in performance. Br J Sports Med 38: 386–387, 2004.
44. Seitz, LB and Haff, GG. Factors modulating post-activation potentiation of jump, sprint, throw, and upper-body ballistic performances: a systematic review with meta-analysis. Sport Med 46: 231–240, 2016.
45. Simonson, E., Teslenko, N., & Gorkin, M. Influence of warm-up on 100m run time. J Physiol 9: 152, 1936.
46. Sjöström, M, Lexell, J, and Downham, DY. Differences in fiber number and fiber type proportion within fascicles. A quantitative morphological study of whole vastus lateralis muscle from childhood to old age. Anat Rec 234: 183–189, 1992.
47. Suarez, DG, Wagle, JP, Cunanan, AJ, Sausaman,

RW, and Stone, MH. Dynamic Correspondence of Resistance Training to Sport: A Brief Review. Strength Cond J 41: 80–88, 2019.
48. Tahayori, B. Effects of exercising with a weighted vest on the output of lower limb joints in countermovement jumping. , 2006.
49. Thompsen, AG, Kackley, T, Palumbo, MA, and Faigenbaum, AD. Acute effects of different warm-up protocols with and without a weighted vest on jumping performance in athletic women. J Strength Cond Res 21: 52–56, 2007.
50. Till, KA and Cooke, C. The effects of postactivation potentiation on sprint and jump performance of male academy soccer players. J Strength Cond Res 23: 1960–1967, 2009.
51. van den Tillaar, R, Lerberg, E, and von Heimburg, E. Comparison of three types of warm-up upon sprint ability in experienced soccer players. J Sport Heal Sci 8: 574–578, 2019.
52. Tillin, NA and Bishop, D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. Sport Med 39: 147–166, 2009.
53. Tobin, DP and Delahunt, E. The acute effect of a plyometric stimulus on jump performance in professional rugby players. J Strength Cond Res 28: 367–372, 2014.
54. Tumkur Anil Kumar, N, Oliver, JL, Lloyd, RS, Pedley, JS, and Radnor, JM. The Influence of Growth, Maturation and Resistance Training on Muscle-Tendon and Neuromuscular Adaptations: A Narrative Review. Sports 9: 59, 2021.
55. Turner, AP, Bellhouse, S, Kilduff, LP, and Russell, M. Postactivation potentiation of sprint acceleration performance using plyometric exercise. J Strength Cond Res 29: 343–350, 2015.
56. Wilson, JM, Duncan, NM, Marin, PJ, Brown, LE, Loenneke, JP, Wilson, SMC, et al. Meta-analysis of postactivation potentiation and power. J Strength Cond Res 27: 854–859, 2013.
57. Wyland, TP, Van Dorin, JD, and Reyes, GFC. Postactivation potentiation effects from accommodating resistance combined with heavy back squats on short sprint performance. J Strength Cond Res 29: 3115–3123, 2015.
58. Yetter, M and Moir, Gavin, L. The acute effects of heavy back and front squats on speed during forty-meter sprint trials. J Strength Cond Res 22: 159–165, 2008.