Wearable resistance sprint running is superior to training with no load for retaining performance in pre-season training for rugby athletes

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ABSTRACT

This study determined the effects of a six-week lower-limb wearable resistance training (WRT) intervention on sprint running time, velocity, and horizontal force-velocity mechanical variables. Twenty-two collegiate/semi-professional rugby athletes completed pre- and post-intervention testing of three maximal effort 30 m sprints. A radar device was used to measure sprint running velocity from which horizontal force-velocity mechanical profiling variables were calculated. All athletes completed two dedicated sprint training sessions a week for six-weeks during pre-season. The intervention (wearable resistance, WR) group completed the sessions with 1% body mass load attached to the left and right shanks (i.e. 0.50% body mass load on each limb), whilst the control group completed the same sessions unloaded. For the control group, all variables were found to detrain significantly ($p \leq 0.05$) over the training period with large detraining effects (ES > 0.80) for theoretical maximal horizontal force, slope of the force-velocity profile, maximal ratio of force, index of force application, 5 m and 10 m times. For the WR group, there were no significant changes to any recorded variables (all $p > 0.05$) and all effects of training were trivial or small (ES < 0.50). After adjustment for baseline differences, significant between group differences were found for all variables (large effects, ES > 0.80) except theoretical maximal velocity, 30 m time, and maximal velocity. The addition of light wearable resistance to sprint training during a six-week pre-season block enables the maintenance of sprint performance and mechanical output qualities that otherwise would detrain due to inadequate training frequencies.

Keywords: acceleration, force-velocity profiling, longitudinal, resistance training, specificity, sprinting

INTRODUCTION

Lower-limb wearable resistance training (WRT) involves attaching an external load, as little as 0.5% body mass (BM), onto the athlete's thigh or calf allowing them to perform sport-specific movement tasks under resistance. Attaching an external load directly to the limb increases the mechanical work required to move the limb through the joint range of motion due to the increased rotational inertia provided by the added mass.[1,2] The load can be positioned to directly overload joints, and therefore muscles, of interest for the given movement task. For example, with lower-limb WR the athlete can perform resisted sprint training at high movement velocities targeting the involved musculature across the hips and/or knees. This provides a more specific and targeted overload than that possible with other forms of resistance training equipment (e.g. sleds or motorized resistance) or the attachment of loads to the torso. This makes lower-limb WRT a movement and velocity specific form of resistance training for fast sprint running. Consequently, any strength and metabolic improvements should optimally transfer to the movement task of interest, e.g. sprint running.[3]

Researchers investigating the acute effects of WR have shown that lower-limb WRT provides an appropriate overload for sprint running training.[4] Specifically, contact time and step frequency are significantly overloaded (increased and decreased, respectively) during the acceleration and maximal velocity phases of sprint running.[5,6] This occurs with no significant coinciding change to step length or flight time. It appears that lower-limb wearable resistance (WR) can be used to selectively overload particular aspects of sprint running.[4] Overloading step frequency especially may be an ideal training strategy for well-trained sprinters as it has been suggested that training at this level should target enhancing step freqency.[7] Similarly, as coaches identify performance detriments for their athletes, they may choose lower-limb WR to cue and stimulate changes in step frequency whilst other overload methods may provide different training benefits.[8,9] It is not surprising that reported acute changes in step frequency with lower-limb WR come with a change to contact time due to the greater system mass that must be accelerated in every ground contact. The lack of change to step length could indicate that spatial joint kinematics are largely unchanged when using the loading schemes investigated to-date.

Researchers have also reported significant acute changes in the horizontal force profiles of the athlete when performing sprint acceleration with WR. Significant changes in the relative force-velocity (F-v) profile have been found with 3% BM lower-limb WR, reflecting more force dominant profiles, compared to an unloaded condition in amateur to semi-professional male rugby athletes.[6,10] These significant acute profile changes of ~10.0% resulted from a significant reduction in theoretical maximal velocity (-3.57% to -6.49%) and concurrent non-significant increase in theoretical maximal horizontal force (5.08%-6.25%).[6,10] These findings indicate that as little as 3% BM lower-limb WR provides a sufficient overload to velocity production during acute use. Considering theoretical maximal velocity production has been shown to be positively correlated to sprint running performance[11], lower-limb WRT may have the potential to elicit improved sprint performance over time due to alterations in the mechanical sprint profile. However, the chronic adaptation to these acute changes has not been documented.

Research on longitudinal outcomes of lower-limb WRT for sprint running is limited, with only one study completed to date. Researchers found that six-weeks of sprint running with 5% BM ankle WR produced a significant increase in stride length (5.32%) and a significant decrease in stride frequency (-5.60%) with no changes to maximal running speed in University physical education students.[12] Although increases in step length have been shown to occur concurrently to increases in running speed over time and are believed important for maximal sprint running[13], the accompanying decrease in stride frequency negated any possible positive training effect on maximal sprint speed.[12] Ultimately, it is challenging to apply these findings to an athlete population as the training status or history of the participants used was not disclosed and the very large magnitude of rotational overload presented with 5% BM placed on the ankle is not respective of that investigated to date with athletes[4]. In summary, there is a lack of research-based evidence detailing how an athlete population might respond to lower-limb WRT for sprint running.

Given this paucity of research investigating the longitudinal effects of sprint training with lower-limb WR in athletes, it is of value to determine the performance adaptations that occur as an effect of lower-limb WRT. This is pre-requisite to understanding how the body responds to control the limb load and how this can be manipulated for performance improvements. Therefore, the purpose of this study was to determine the effects of a six-week lower-limb WRT intervention presented within the context of a pre-season training programme on sprint running time, velocity, and horizontal force-velocity mechanical variables in well-trained rugby athletes. We hypothesized that the WRT would decrease sprint running time, increase velocity, and positively influence the horizontal force-velocity mechanical variables.

METHODS

Participants.

Thirty-two male athletes volunteered to participate in this study and were all members of the same collegiate/semi-professional rugby training squad. Minimum inclusion criteria required athletes to have a minimum of one year of resistance training experience, be currently training, and trained as a field-based sport athlete. All playing positions were included. Athletes were excluded if they were under the age of 16, had a current or previous lower extremity injury that may be further aggravated by participating in the training, or did not pass the Physical Activity Readiness Questionnaire. After attrition due to transfer to a different training squad (2), unrelated injury (2), and dropout from the team programme (6), twenty-two athletes completed the study. Ten athletes completed the unloaded training, i.e. control group (24.6 ± 2.99 years, 92.5 ± 12.9 kg, 178.8 ± 5.69 cm) and twelve athletes completed the WR training (22.6 ± 2.94 years, 96.5 ± 13.6 kg, 182.6 ± 8.60 cm). All study procedures were approved by the host University Institutional Review Board.

Performance Testing.

Athletes reported to an indoor fieldhouse on two occasions to complete pre- and post-intervention performance testing. Each testing session started with a warm-up protocol consistent with the athletes' typical practice session preparation. Following this, each athlete completed three maximal effort 30 m sprints, separated by a minimum of five minutes of rest. Each sprint was performed from a two-point, split stance start position, and was initiated by the athlete when they felt ready. The testing was conducted on a wood sports floor (Gransprung, Granwood Flooring Systems, Alfreton, UK). A radar device (Stalker ATS II, Applied Concepts, Dallas, TX, USA) was used to measure athlete velocity at 47 Hz. The radar was positioned 5 m directly behind the starting position and at a vertical height of 1 m to approximately align with the participant's centre of mass.[6]. STATS software (Version 5.0.2.1, Stalker ATS II, Applied Concepts, Dallas, TX, USA) was used to collect all data.

Training Intervention.

The sprint training occurred in tandem with a pre-season training block (which also included rugby skill and maximal aerobic speed sessions) in which the athletes reported to two dedicated sprint training sessions a week. The athletes were match-pair randomised into the WR and control groups using the pre-intervention 30 m sprint times. The WR group completed all sprint training sessions with 1% BM load attached to the shanks (i.e. 0.50% BM load on each limb) with a specialized compression garment (Lila™ Exogen™ Compression Calf Sleeves, Sportboleh Sdh Bhd, Malaysia). Due to the loading increments available (200 and 300 g), exact loading magnitudes ranged from 0.90 – 1.11% BM. Due to the lack of previous research on lower-limb WRT, the 1% BM load was chosen to match the load magnitude and placement commonly used by the coaching staff that advises our research group. The shank location was chosen to coincide with the most practical approach to lower-limb WRT as the compression calf sleeve is the easiest to put on and take off during training and comes at a lower cost than the compression shorts used for thigh WR. The load placement progressed through the training block from a proximal shank location to mid-shank and finished at a distal shank location to provide a simple method of progressive overload through the duration of the training programme following previous recommendations[14]. A summary of the training sessions and WR placement protocol are listed in Table 1, and the load placements are visualised in Figure 1. The WR loads are manufactured in a teardrop shape and each athlete used two loads per limb. To balance the load around the shank and not bias a particular plane of motion, the small end of one load was placed with the large end of the other load. The testing sessions occurred on Mondays while the training sessions occurred on Tuesdays and Thursdays. The control group was prescribed an identical sprint training program, with the exclusion of any WR and compression garments. All sprint and maximal aerobic speed training sessions were consistent between the WR and control groups. The only individualised or position-specific training was present within the rugby skill sessions.

After each training session, all athletes were asked to rate their perceived exertion (RPE) on a 0-10 modified Borg Rating of Perceived Exertion scale.[15] The athletes were experienced in using RPE but were provided formal instruction at the onset of the study and reminder instructions weekly. This allowed the research staff to monitor the WR group's response to the intervention to ensure the training session intensity did not extend beyond what was originally intended. This also allowed for an identification of any differences in perceived exertion between the control and WR groups.

Data Analysis.

The velocity-time data collected pre- and post-intervention were processed to calculate the horizontal force-velocity mechanical variables commonly used to profile an athlete's sprint running capabilities for each trial. The raw velocity-time data were fit by an exponential function according to procedures outlined elsewhere.[16] Following, the individual linear force-velocity (F-v) profiles were computed to describe the general mechanical ability to produce horizontal external force during sprint-running.[16] From this, the mechanical capabilities of the lower limbs were further characterised by the variables: theoretical maximal velocity (V_0); theoretical maximal horizontal force (F_0), peak power (P_{max}), maximal ratio of force (RF_{max}), and index of force application (D_{RF}).[17] These mechanical profiling variables, along with sprint split times (5, 10, 20 and 30 m), maximal velocity of the measured sprint (V_{max}) and slope of the F-v profile (S_{FV}), were calculated consistent with the method previously validated[16,18] with a custom-made

MATLAB script (MATLAB R2019b, The MathWorks, Inc., Natick, Massachusetts, USA). The calculated data from the three trials were averaged.

Statistical Analysis.

A series of preliminary analyses (independent t-tests) were used to determine if there were significant differences between the control and the WR group for each of the dependent variables at the pre-intervention testing time point. To determine the effect of the sprint training intervention (with or without the WR), a paired samples t-test was conducted for the dependent variables measured for each group. For each of the dependent variables, no outliers were found as assessed by inspection of a boxplot. The differences between the pre- and post-intervention measures were normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$) and Normal Q-Q Plot visual inspection. When an exception was found, the testing continued as the paired-samples t-test has been reported to be robust to violation of normality for Type I error.[19]

To compare the control and WR group responses to the sprint training, a one-way analysis of covariance (ANCOVA) was conducted on post-intervention dependent variables with pre-intervention measures as the covariate.[20,21] For each dependent variable, there was a linear relationship between pre- and post-intervention measures and homogeneity of regression slopes as the interaction term was not statistically significant ($p > 0.05$). Standardized residuals for the interventions and overall model were normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$). There was homoscedasticity and homogeneity of variances, as assessed by visual inspection of a scatterplot and Levene's test of homogeneity of variance ($p > 0.05$), respectively. There were no outliers in the data, as assessed by no variables with standardised residuals greater than ± 3 standard deviations. A series of follow-up analyses (ANCOVA) were planned to compare the control and WR group responses to the sprint training with training session attendance as the covariate. However, attendance as a covariate was not linearly related to the dependent variable (post-intervention score) for each variable of interest, violating the linearity assumption for the

ANCOVA test. Instead, Pearson's product-moment correlation was used to report on the relationship between training session attendance and difference scores (post – pre) for each of the dependent variables.

All data presented are unadjusted unless otherwise stated. Analyses were performed using SPSS Statistics (Version 25, IBM, Armonk, NY, USA). Significance was set at $p \leq 0.05$. Effect size (ES) statistics (Cohen's d) were calculated and described as trivial (<0.20), small (0.20), moderate (0.50) and large (0.80)[22].

RESULTS

A preliminary analysis was performed and confirmed that there were no significant differences between the control and WR group for each of the dependent variables at the pre-intervention testing time point. There were no significant differences for mass measures between the pre-intervention and post-intervention testing time points for either group (Table 2). The exponential modelling of the velocity-time data was well fit with an average $R^2 = 0.98$ and all $R^2 > 0.95$. Mean and standard deviation for the sprint running time, velocity, and horizontal force-velocity mechanical variables are presented in Table 2.

The results of the paired-samples t-tests are reported in Table 2. With regards to the control group, all variables were found to detrain significantly over the training period with the largest detraining effects (ES > 0.80) noted for F_0, S_{FV}, D_{RF}, RF_{max}, 5 m and 10 m times. In terms of the WR group, there were no significant changes to the recorded variables and any effects of training were trivial or small (all ES < 0.50).

The ANCOVA test was used to determine differences between groups on post-intervention measures. The results are reported in Table 3. After adjustment for pre-intervention measures, significant between group differences of a large effect were found for all variables except V_0, 30 m time, and V_{max}.

There were no significant differences in athlete RPE or attendance scores between the control and WR groups. The average reported RPE scores were 6.62 ± 0.86 for the control group and 6.58 ± 0.86 for the WR group. Athletes in the control group attended 66.4 ± 25.0% of training sessions, whilst athletes in the

WR group attended 65.9 ± 18.6% of training sessions. There were no statistically significant correlations between attendance and difference score for any variable for either the control or WR group ($R^2 < 0.36$ for all variables).

DISCUSSION

This study determined the effects of a 1% BM lower-limb WR sprint running training intervention on performance measures in collegiate/semi-professional rugby athletes. The athletes that participated in this study displayed sprint performance levels (i.e. sprint times) aligned with other high-level competitive rugby athletes.[23] The main findings were: 1) the control group experienced significant detraining over the course of the intervention with large detraining effects (ES > 0.80) noted for F_0, S_{FV}, D_{RF}, RF_{max}, 5 m and 10 m times; 2) the use of WR enabled the WR group to retain pre-intervention magnitudes for the variables of interest over the course of the intervention with all changes being non-significant and considered trivial to small; 3) WRT proved superior to unloaded training in maintaining all the F-v variables of interest except for V_0, 30 m time, and V_{max}; and 4) RPE was similar between groups. The hypothesis that the WRT would decrease sprint running time, increase velocity, and positively influence the horizontal force-velocity mechanical variables was therefore rejected.

Training for sprint running requires sufficient recovery and training frequency to produce positive muscular performance adaptation.[24] The control group was found to detrain across several variables suggesting the recovery time between training sessions was insufficient or the sprint training protocol was insufficient to provide a training stimulus to maintain or improve performance. However, considering the WR group did not display a decrement in performance over the training period, the recovery time between training sessions appears to have been sufficient and there are no indicators to suggest that the general fatigue status increased due to sudden exposure to pre-season training. Whilst the exact training frequency required to maintain sprint performance through sprint training alone is not known, a training frequency of 2-3 times per week has been suggested to produce sprint performance improvements using resisted sled training.[25] The consideration of training frequency cannot be made without the consideration of training session volume and intensity (i.e. volume load). The athletes in this study were allocated two sprint training sessions a week through the pre-season; this volume load was thought to be adequate to maintain or improve performance capabilities for the allocated training frequency. However, attendance rates were low (control group = 66.4%, WR group = 65.9%), resulting in a lower training frequency than initially prescribed for many of the athletes. It appears that the use of WR increased the volume load of each training session, reaching a threshold necessary to maintain performance capabilities for the short distance sprint running measured in this study.

Although our hypothesis was rejected, the WR used in this study provided an adequate training load to retain sprint performance and mechanical capabilities for the intervention group athletes and this WRT was superior to the unloaded training in maintaining the variables of interest except for 30 m sprint time, V_{max}, and V_0. It seems that WRT could be used to increase training load when sprint specific training frequency is low, which often occurs during pre-season and in-season time frames. This idea is supported by previous work that has found that carrying an additional load on the limb during running is associated with an increased physiological cost and directly affects the mechanical work needed to move the limb segments.[1,26] The micro-loading inherent to WRT allows the athletes to perform the sprint running movement pattern under resistance at or near unloaded movement velocities.[4,8,27] This is a valuable consideration when planning training as the velocity adaptations that occur with resistance training are greatest at or near the velocity of the training performed[28] and sprint running requires rapid muscular force production.

Proficiency for faster sprint running acceleration relies on the ability to apply high levels of force to the ground and to orientate the force vector in a more horizontal direction.[17,29] The F-v profile was used in this study to quantify these abilities and showed that WRT was effective in maintaining F_0, whilst there was no difference between groups in the change in V_0 across the intervention. The lack of difference in the change in V_0 between the control and WRT groups suggests that this factor is less affected by detraining but may require a different type of intervention for enhancement. Findings of this nature are useful when practitioners desire to deploy targeted training based on an athlete's unique F-v profile characteristics and perceived areas for improvement.[30] An athlete's technical ability to apply force into the ground with increasing speed is quantified using D_{RF}[30], which has been shown to be significantly correlated to maximal speed, mean 100 m speed, and 4-second distance measures.[11,31] Athletes in the control group experienced a large change in D_{RF} (-16.6%) indicating a less steep decline in the ratio of force for a given increase in speed which could potentially be considered a technical improvement. However, this should be interpreted with respect to the large decrease in RF_{max} (-7.69%, ES = 1.18) and the small increase in V_{max} (1.90%, ES = 0.27). Changes to these variables indicate that, rather than being a higher ratio of force for a given speed, the ratio of force was lower at all speeds in post-testing until speeds approaching V_{max}. This global change in sprint performance impacted D_{RF}, and the D_{RF} change in this instance should not be considered a technical performance improvement when considered in the context of the other changes to the mechanical output variables and the resulting significant increase in sprint times. Athletes in the WR group experienced no significant changes to these variables. Overall examination of the significant post-intervention between group differences point to the mechanical output changes which are influenced with shank WRT - it appears that WRT offers a means to maintain an athlete's technical ability to produce horizontal force at low velocities and maintain a horizontally oriented ground reaction force with increasing speed. These technical abilities are particularly applicable for field-based sport athletes where short distance acceleration is a valuable performance attribute and can carry greater importance than maximal speed ability for some playing positions. In elite rugby, the average sprint running duration has been reported to be less than 3 s for forwards, which is likely a time frame too short to allow for reaching maximal velocity.[32]

Session RPE was used to monitor athlete response to the training loads. These data provided information throughout the training intervention time frame to monitor the WR group's response to completing the sprint running protocol with additional limb load (compared to the control group) and to determine how the progressive overload of moving the WR placement distally was handled. There were no differences in average RPE scores between the two groups. This is surprising as information from previous research[1,26] and anecdotal athlete feedback has indicated an increased difficulty in performing running with lower-limb WR. It may be that session RPE does not provide the sensitivity needed to distinguish objective differences in training loads associated with lower-limb WRT, or that a 1% BM WR loading scheme allows the athletes to complete a relatively higher training load without an increase in perceived exertion. RPE has been reported as a valid measure to indicate exercise intensity[33] but any potential relationship between WRT induced changes in RPE and objective internal workload measures has yet to be investigated.

A limitation of this study was the low attendance rates which resulted in a lower training volume than what was prescribed to improve performance through the pre-season. It is unknown if an increase in performance would have occurred with the WRT beyond the unloaded training if the athletes attended all prescribed training sessions. Another limitation was the lack of specificity between the training and testing protocol running distances. Researchers have previously suggested that separate training strategies may need to be employed to elicit improved sprint running times for different distances.[34] The training protocol employed in this study used a variety of running distances (10-80 m) whilst the testing protocol measured one sprint distance (30 m). It is unknown how the athletes' sprint times changed over longer distances (40-80 m). Future work to understand the effects of lower-limb WRT for sprint running should consider investigating the necessary exposure to WRT needed to elicit sprint running performance improvements, potential changes to step and joint kinematics, and how to best quantify the internal and external workload changes associated with different WR magnitudes and placements for applied scenarios.

CONCLUSIONS

The athletes that completed the WRT intervention did not significantly improve (or decrease) in sprint running times or velocity. However, comparatively, these athletes were able to maintain baseline performance whilst the control group experienced detraining of mechanical output and sprint times. These results suggest a 1% BM lower-limb WRT intervention is sufficient to provide a training stimulus that retains sprint qualities, which is superior to training with no load. However, the volume or frequency of exposure needed to produce an increase in performance following introduction of the training stimulus is still unknown.

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Table 1. Training programme followed by both groups.

	Session 1^	**Session 2**	**WR Placement and Magnitude^^**
Week 0	Pre-intervention Test (3×30 m)		
Week 1	4×22 m 8×10 m	4× Flying 28 m 5× Change of direction (15 m-diagonal cut-20 m) 1×80 m, 1×60 m, 1×50 m, 1×40 m	Proximal 1% BM
Week 2	5×22 m 11×10 m	Training session cancelled due to weather	Proximal 1% BM
Week 3	6×22 m 14×10 m	5× Flying 28 m 8× Change of direction (15 m-diagonal cut-20 m) 1×80 m, 1×60 m, 1×50 m, 1×40 m	Mid 1% BM
Week 4	5×22 m 11×10 m	5× Flying 28 m 6× Change of direction (15 m-diagonal cut-20 m) 1× 80 m, 1×60 m, 1×50 m, 1×40 m	Mid 1% BM
Week 5	6×22 m 13×10 m	5× Flying 28 m 8× Change of direction (15 m-diagonal cut-20 m) 1×80 m, 1×60 m, 1×50 m, 1×40 m	Distal 1% BM
Week 6	6×22 m 16×10 m	5× Flying 28 m 9× Change of direction (15 m-diagonal cut-20m) 1×80 m, 1×60 m, 1×50 m, 1×40 m	Distal 1% BM
Week 7	Post-intervention Testing (3×30 m)		

^ The 10 m sprints were completed from a variety of start positions (e.g. kneeling, lying). All other sprints were completed from a 2-point split stance start position. ^^ Wearable resistance (WR) was worn by the WR group in all sessions, whilst no WR was worn by the Control group in any sessions.

Table 2. Pre- and post-intervention mean and standard deviation measures with within-group *p*-value and effect size statistics.

	Control group (n = 10)			**WR group (n = 12)**		
	Pre	**Post**	**Post-Pre**	**Pre**	**Post**	**Post-Pre**
	$\bar{x}$ (SD)	**$\bar{x}$ (SD)**	***p*-value; ES**	**$\bar{x}$ (SD)**	**$\bar{x}$ (SD)**	***p*-value; ES**
Body mass (kg)	92.5 (12.9)	92.2 (13.0)	0.06; 0.02	96.5 (13.6)	96.1 (13.3)	0.06; 0.03
F_0 (N·kg^{-1})	7.87 (0.91)	6.73 (0.71)	<0.01*; 1.25	7.50 (0.69)	7.27 (0.65)	0.20; 0.32
P_{max} (W·kg^{-1})	17.3 (2.52)	15.3 (1.94)	0.01*; 0.79	16.6 (1.68)	16.3 (1.84)	0.48; 0.16
V_0 (m·s^{-1})	8.83 (0.73)	9.18 (0.64)	<0.01*; 0.48	8.90 (0.58)	9.01 (0.67)	0.26; 0.19
S_{FV} (%)	-83.0 (15.7)	-68.1 (14.3)	<0.01*; 0.95	-81.7 (14.1)	-77.9 (13.0)	0.10; 0.27
D_{RF} (%·s·m^{-1})	-8.07 (0.98)	-6.73 (0.85)	<0.01*; 1.37	-7.67 (0.65)	-7.36 (0.78)	0.11; 0.48
RF_{max} (%)	52.0 (3.39)	48.0 (3.08)	<0.01*; 1.18	50.9 (2.56)	50.2 (2.75)	0.28; 0.27
5 m time (s)	1.27 (0.08)	1.37 (0.07)	<0.01*; 1.25	1.30 (0.07)	1.32 (0.07)	0.38; 0.29
10 m time (s)	2.04 (0.11)	2.14 (0.10)	0.01*; 0.91	2.07 (0.08)	2.08 (0.08)	0.42; 0.13
20 m time (s)	3.33 (0.19)	3.45 (0.15)	0.02*; 0.63	3.37 (0.12)	3.38 (0.15)	0.60; 0.08
30 m time (s)	4.54 (0.28)	4.64 (0.21)	0.05*; 0.36	4.57 (0.17)	4.58 (0.21)	0.77; 0.06
V_{max} (m·s^{-1})	8.41 (0.60)	8.57 (0.49)	0.01*; 0.27	8.44 (0.43)	8.52 (0.51)	0.33; 0.14

* = within-group significant differences ($p \leq 0.05$)

Table 3. Adjusted mean difference scores for post-intervention measures with pre-intervention measures as a covariate with results of the one-way ANCOVA for between-group *p*-value and effect size statistics.

	WR-Control		
	Mean difference	***p* value**	**ES**
F_0 (N·kg^{-1})	0.71	0.01*	1.17
P_{max} (W·kg^{-1})	1.45	0.02*	1.08
V_0 (m·s^{-1})	-0.23	0.07	0.82
S_{FV} (%)	-10.8	0.01*	1.33
D_{RF} (%·s·m^{-1})	-0.83	0.01*	1.21
RF_{max} (%)	2.80	0.02*	1.15
5 m time (s)	-0.07	0.01*	1.17
10 m time (s)	-0.08	0.02*	1.03
20 m time (s)	-0.09	0.05*	0.89
30 m time (s)	-0.08	0.11	0.71
V_{max} (m·s^{-1})	-0.08	0.36	0.41

* = between-group significant differences ($p \leq 0.05$)

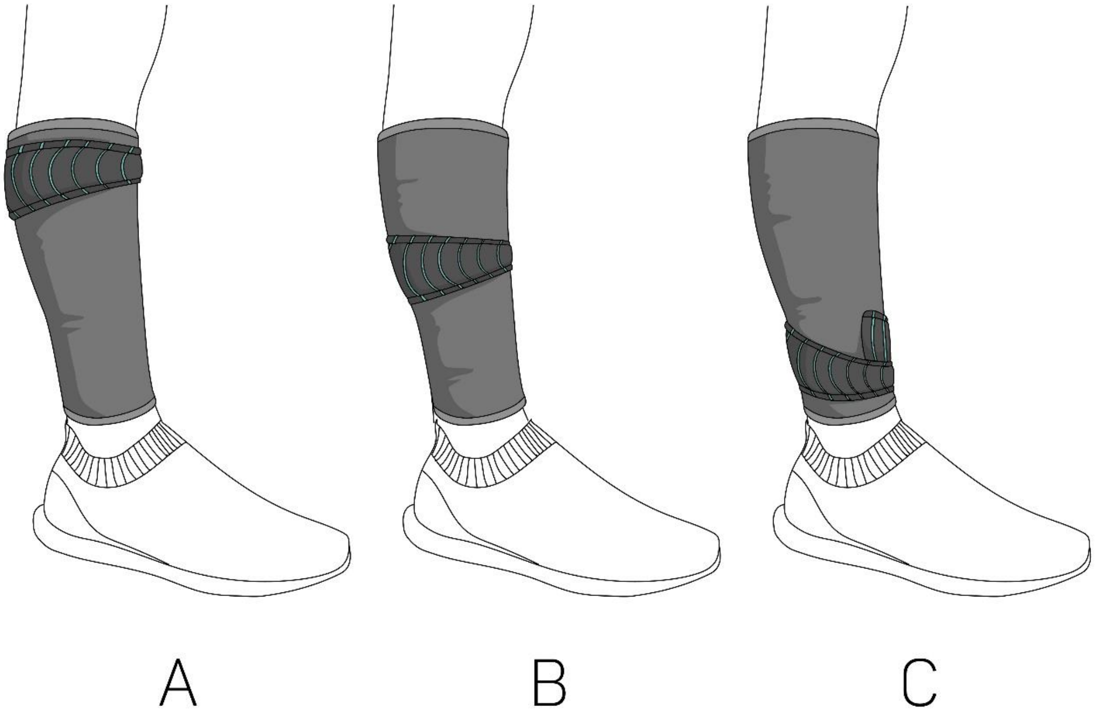

Figure 1.