Original Research

Efficacy of Vibration Exercise as a Warm-up Modality for Overground Sprinting

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ABSTRACT

International Journal of Exercise Science 8(4): 385-393, 2015. This study investigated the efficacy of vibration exercise (VbX) as a warm-up modality for maximal overground sprinting. Ten national level sprinters participated in a randomized crossover design (14.0 ± 7.4 days washout period). A VbX warm-up was compared to a warm-up involving sprint-specific exercises (control condition). The VbX warm-up involved 10 × 1 minute bouts delivered by a Galileo 900 side-alternating plate (frequency = 26 Hz, peak-to-peak displacement = 9 mm) with 30 s rest between bouts (total time = 15 minutes). The sprint-specific warm-up involved jogging, dynamic exercises and sprinting drills followed by 3 × 40 m sub-maximal sprints not exceeding 95% of maximal speed over a 15 minute period. After each warm-up (within 2 minutes), 6 × 40 m maximum sprints were completed from a crouch start position with starting blocks. Outcome measures were recorded by timing gates (Swift Performance, Australia) and a Vicon Motion Measurement System (Oxford, UK). Measures recorded were sprint time over the 0-4 m, 5-10 m, 10-20 m, 20-40 m and 5-40 m intervals. The stride length, stride velocity and stride time of both legs were recorded over the 0-4 m interval by the Vicon system. All measures remained unchanged across warm-up modalities. It is reasonable to conclude that VbX may be used as an alternative warm-up for sprinting over 40 m. Given its time efficiency and suggested relatively low metabolic cost, VbX may be a suitable warm-up for activities requiring multiple sprints over a competition day or game period.

KEY WORDS: VbX, vibration exercise, warm-up, sprint performance, VICON

INTRODUCTION

Active warm-ups involving sprint-specific exercises have been shown to improve sprinting gait performance (2, 4), whereas passive warm-ups involving static stretching exercises have been shown to impair performance (9, 23, 27). Active or competition-specific exercises are known to increase muscle activation, muscle temperature, blood flow and oxygen delivery to working muscles (18). Acute bouts of vibration exercise (VbX), defined as a single session of intermittent exposure (repeated bouts of no more than 60 seconds) delivered by either a synchronous (where both feet move vertically at the same time) or side-alternating plate, produce a warm-up effect similar to that achieved by active or competition-specific warm-up exercises (10). VbX has been shown to increase leg power (8, 24, 25), muscle activation, muscle temperature and leg blood flow (12, 13, 17). Therefore, it seems reasonable to propose that VbX may be used as an alternative warm-up for maximal sprinting (10).

Studies have shown that VbX in isolation to (i.e. VbX only), or performed simultaneously with, preconditioning exercises such as half-squats, improves sprint time immediately following a warm-up involving sprint-specific exercises. For example, the 10 and 20 m ice rink sprint times (from a standing start) of fifteen male ice hockey players improved ($p < 0.01$) after simultaneously performing 15 half squats and 30 s of synchronous VbX (3 mm peak-to-peak displacement [p-p], 50 Hz) (21). Similarly, the 40 m sprint time (from a standing start) of nine male amateur soccer players improved ($p < 0.05$) after simultaneously performing half squats and 30 s of synchronous VbX (3 mm p-p, 50 Hz) (20). Finally, the sprint time (from a standing start) of eight female premier club netball players was found to improve over a distance of 1.5 m ($p = 0.04$), but not over 3 and 4 m, after five one-minute bouts of VbX was performed with a side-alternating (6 mm p-p, 26 Hz) plate (11).

Not all studies have shown improved sprint time following VbX. An investigation involving 14 National Collegiate Athletic Association Division One athletes (sprinters, jumpers and throwers) found no effect on 40 m sprint time after "high knee" running was performed simultaneously with short bouts of VbX (16). Firstly, the athletes completed sprint-specific warm-up exercises followed by a 40 m maximal sprint (control condition). After three minutes of rest, 4 × 5 second bouts of "high knee" running in conjunction with synchronous VbX (1.5 mm p-p, f = 0, 30, 40, 50 Hz) were performed with 30 seconds rest between bouts (the different VbX frequencies were delivered on separate days). This was followed by two maximal 40 m sprints. No significant differences were found between the sprint times (control versus post-VbX). This shows that short bouts of VbX combined with "high knee" running has no additional effect on 40 m sprint time.

Studies involving international (n = 7) and national (n = 5) level skeleton athletes investigated the effect of 3 × 60 second bouts of synchronous VbX on sprint time following its delivery in a rest period between two 30 m sprints (6, 7). The studies used vibration frequencies of 30 Hz and 45 Hz respectively (4 mm p-p) with the latter employing a longer rest period (10 minutes as opposed to 5 minutes) and time interval between VbX bouts (180 s as opposed to 60 s). In both studies, the athletes completed a warm-up involving sprint-specific exercises (aerobic activity, stretching, bounding, jumping and 90% accelerations over 30 minutes) before the first sprint. No significant differences in sprint times were found between the sprints. Possible effects, may have been masked by the extensive 30 minute sprint-specific warm-up exercises completed before the first sprint (10). Moreover, these studies involved small sample sizes, which may have increased the chances of a type II error.

To our knowledge, no study has unequivocally investigated the use of VbX (in isolation) as a warm-up modality for maximal overground sprinting gait. The primary aim of this study was to determine the efficacy of using VbX as warm-up modality for maximal sprinting gait over a distance of 40 m.

METHODS

Participants

Ten young adults (5 males, 5 females) volunteered for the study (mean ± SD: age 20.7 ± 3.2 years; stature 176.3 ± 7.9 cm; body mass 70.3 ± 9.8 kg). The participants had completed sprint training and competed regularly in national and regional sprint competitions over the past five years. The average personal best 100 m sprint time was 12.09 ± 0.82 s (females: 12.82 ± 0.10 s; males: 11.35 ± 0.39 s). Exclusion criteria were any recent history of neuromuscular or musculoskeletal impairment that would affect sprinting. Participants were recruited from local athletic clubs and a University community. Participants gave written informed consent and the study was approved by a University Human Research Ethics Committee.

Protocol

This investigation involved a randomized crossover design. The order of treatment or warm-up modality (VbX or sprint-specific warm-up exercises) was randomly allocated (stratified by gender) using computer generated randomization by an independent investigator using opaque sealed envelopes. Participants attended separate test sessions for each warm-up modality. The mean ± SD washout period between sessions was 14.0 ± 7.4 days. A control condition (no treatment) prior to maximal sprinting was not employed since sprinters are unwilling to commit to maximal sprints without a physical warm-up. More importantly, it is the consideration of the authors that it would be unethical to have athletes complete maximal sprints without a warm-up.

Participants wore standard running attire (singlet and shorts) and athletic running shoes commonly worn in training. The same shoes were worn for both sessions. At the beginning of each session, anthropometric measures of stature, body mass, leg length, knee and ankle width were recorded as required for the Vicon Plug-in-Gait model (version 1.3.109, Oxford, UK). Fifteen spherical passive reflective markers (14 mm diameter) were then placed (using non-allergenic double-sided tape) on known anatomical landmarks according to the Vicon Plug-in-Gait model. Following this setup, the participants completed one of the warm-up modalities followed by 6 × 40 m maximal sprints.

Test sessions were conducted indoors at a Sports Centre over a distance of 60 m. The indoor setting was necessary in order to accommodate the Vicon system. The running surface was sprung polished floorboards. Starting blocks were placed on two anti-fatigue non-slip recycled car tyre rubber mats (mat length: 1200 mm; width: 700 mm; height: 5 mm). A white starting line (width: 50 mm) was painted on the front mat and located 160 mm from the mat edge. This ensured that the initial right and left foot strikes landed on the polished floorboard surface.

Kinematic data were recorded by a six-camera (T–series) 3D Vicon motion measurement system (Vicon Motion Systems, Oxford, United Kingdom) operating at 120 Hz with a 3D capture volume of approximately 7000 mm (L) × 1500 mm (W) × 2000 mm (H). Knee alignment devices were used to identify knee joint centres. Vicon Nexus 1.6.1 software was used to capture, process and extract data. A Woltring filter (MSE = 20) was used post data capture and prior to data extraction. The starting block setup (lower leg joint position) was the same for each test session.

Both warm-ups were completed on separate days at similar times of the day for each participant (e.g. early morning, mid-morning etc.). The warm-up duration was 15 minutes. The VbX warm-up involved 10 × 1 min acute bouts of vibration (9 mm p-p, 26 Hz) with 30 seconds rest between bouts (5, 10, 11) using a Galileo 900 vibration side-alternating plate (Novotec, Pforzheim, Germany). The participants stood in 50° of knee flexion (assessed by a goniometer) with the back upright whilst wearing their running shoes. The knee angle was that formed between the line of the thigh and the lower leg (e.g. a straight leg is in 0° of flexion). This posture minimises the transmissibility of the ground-based vibrations to the pelvis and upper body (15, 22). Moreover, previous work has shown that leg blood flow increases when VbX is delivered in conjunction with a bent knee standing posture (17). All participants were encouraged to report any unusual symptoms (e.g. discomfort, queasiness) and were allowed to stop the vibration at any time.

The sprint-specific warm-up exercises involved a 450 m jog, 20 upper body windmills (hands touching left and right feet), 20 sit-ups, 20 push-ups, 20 half squats, 20 lunges (10 for each leg), 20 high knee raises with skips (10 per leg), 20 high knee raises with leg extension and skip (10 per leg), 20 high knee lifts with hamstring flicks (10 per leg) followed by three 40 m sub-maximal sprints (increasing speed with each repetition) not exceeding 95% of maximal speed (16). This protocol was selected since it is recommended that an active or sprint-specific warm-up should involve submaximal intensity aerobic exercise followed by dynamic exercises and sport specific drills (3).

After completing a warm-up, the athletes performed 6 × 40 m maximal sprints. The same starting block setup was used across the treatments. Participants started the sprint when ready; that is, without a cue or trigger. The first sprint was completed within 2 minutes of the warm-up. Subsequent sprints were completed within two minutes of the previous sprint. During the latter, the participants walked back to the start position, markers were checked by investigators and then they organised their start position.

The outcome measures were initial stride length, stride time and stride velocity (front and rear leg) during the start. Initial stride for each leg was defined as the time period from the foot (front or rear) leaving the starting block to next foot-ground contact of the same foot (front or rear). Stride velocity was derived from the quotient of stride length on stride time. Sprint time over 0-4 m, 5-10 m, 10-20 m, 20-40 m and 5-40 m were recorded. The Vicon System recorded the 0-4 m sprint time. This time was extracted from a virtual marker located in the centre of the pelvis through the use of Vicon Body Builder software version 3.6.1 (Oxford Metrics Group, United Kingdom).

Table 1. Sprint times over distance intervals for all trials, fastest trial and 1st trial.

Interval (trial)	Sprint-Specific Warm-up Mean ± SD (s)	VbX Mean ± SD (s)	p
0-4 m (all trials)	0.83 ± 0.17	0.84 ± 0.16	0.27
5-10 m (all trials)	0.79 ± 0.05	0.79 ± 0.05	1.00
10-20 m (all trials)	1.36 ± 0.10	1.37 ± 0.10	0.12
20-40 m (all trials)	2.55 ± 0.22	2.56 ± 0.22	0.54
5-40 m (all trials)	4.70 ± 0.38	4.71 ± 0.38	0.51
5-40 m (fastest trial)	4.64 ± 0.15	4.65 ± 0.14	0.54
5-40 m (1st trial)	4.69 ± 0.42	4.78 ± 0.37	0.05

5-40 m sprint time and 5-10 m, 10-20 m, 20-40 m intervals measured by electronic timing gates; 0-4 m interval measured by Vicon measurement system.

It represents the time from the start of movement until 4 m past the start line. A Speedlight TT wireless timing gates (Swift Performance Equipment, Queensland, Australia) recorded sprint time over the 5 to 40 m intervals. A timing gate could not be positioned at the zero metre or start line due to the fact that it occluded marker recognition by the Vicon system; that is, markers were occluded by the timing gates.

Statistical Analysis

Data were extracted from all trials. The following data were extracted for analysis: (i) the mean value of each participant's stride length, stride time and stride velocity for the 6 trials for each treatment; (ii) each participant's fastest 5-40 m sprint time over the 6 trials for each treatment; (iii) each participant's 5-40 m sprint time for the 1st trial for each treatment; (iv) the participant's mean sprint time for the 6 trials over the 0-4 m, 5-10 m, 10-20 m, 20-40 m and 5-40 m distance intervals for each treatment. Descriptive statistics were calculated for all outcome measures and normality assessed by measures of skewness and kurtosis (26). Statistical analyses were conducted with SPSS (version 19.0) for Windows (IBM, Armonk, NY). Treatment outcomes were investigated by repeated measures multivariate analyses of variances (RM MANOVAs). Bonferroni adjustments were not made but an adjustment was made to the alpha level. A more conservative alpha level of 0.01 was used to determine statistical significance.

RESULTS

No significant sprint time differences were found between the warm-up modalities (refer to Table 1 and Figure 1). Average sprint times for the six trials of each participant remained unchanged over the distance intervals. Although no significant differences in the 5-40 m fastest sprint trial times or 1st sprint trial times were found, the latter almost achieved significance (p = 0.05) where the time after VbX was 0.09 s slower than the time after the sprint-specific warm-up. The effect size of 0.21, however, represents a small difference. No

Table 2. Descriptive statistics (all trials) for basic spatiotemporal gait data (front and rear leg) during the sprint start.

	Sprint-Specific Warm-up	VbX	
Measure	Mean ± SD	Mean ± SD	*p*
Front Stride Time (ms)	380 ± 27	379 ± 24	0.76
Rear Stride Time (ms)	316 ± 36	318 ± 38	0.66
Front Stride Length (cm)	213.7 ± 23.2	211.5 ± 26.1	0.83
Rear Stride Length (cm)	134.9 ± 14.9	131.5 ± 16.3	0.59
Front Leg Stride Velocity ($m \cdot s^{-1}$)	5.64 ± 0.60	5.59 ± 0.63	0.85
Rear Leg Stride Velocity ($m \cdot s^{-1}$)	4.32 ± 0.70	4.19 ± 0.69	0.56

significant differences in average initial stride length, stride time and stride velocity were found for the front and rear legs (Table 2).

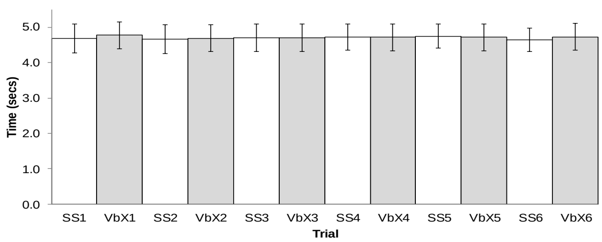

Figure 1. Plot of mean and standard deviation (indicated by bar) for the 5-40 m sprint time for each trial. For example, SS1 is the 5-40 m sprint time for the first trial after the sprint-specific warm-up, whereas VbX1 is the 5-40 m sprint time for the first trial after the VbX warm-up.

DISCUSSION

Studies have shown that VbX elicits a warm-up effect similar to that achieved by a warm-up involving active or competition-specific exercises (10). To our knowledge, however, no study has unequivocally investigated the use of VbX alone as a warm-up modality for maximal sprinting gait. It was hypothesised that VbX alone, that is without simultaneous performance of preconditioning exercises or following a warm-up involving sprint-specific exercises, can be used as an alternative warm-up for maximal sprinting over 40 m.

Vibration exercise has been shown to improve the sprint time of ice-hockey and soccer players over distances of 10 to 40 m when performed simultaneously with half-squats (20, 21). However, when shorter bouts of VbX were performed simultaneously with "high knee" running, the 40 m sprint time of a group of track and field athletes remained unchanged (16). When delivered in isolation, VbX has been shown to improve the sprint time of a group of netball players over 1.5 m but not over distances of 3 and 4 m (11). Furthermore, the 30 m sprint time of a group of skeleton athletes remained unchanged after VbX was delivered in a rest period following a sprint-specific warm-up and a 30 m sprint (6, 7).

This study found sprint times and stride dynamics (length, time, and velocity) remained unchanged across the warm-up modalities. The average difference in the 5-40 m sprint times (all trials) across the warm-up modalities was 0.01 s and the average difference for the fastest 5-40 m sprint time across the warm-up modalities was also 0.01 s. A significant treatment difference was almost achieved for the 1st sprint trial times (p = 0.05) where the average time after the VbX warm-up was 0.09 s slower than the average time for the sprint-specific warm-up (VbX = 4.78 s, sprint-specific = 4.69 s). The effect size of 0.21, however, represents a small difference. It is possible that the athletes may have been unwilling to sprint maximally after VbX. Future work should ensure that athletes are fully familiarised with VbX to the point where it is probably necessary to conduct a VbX familiarisation sprint sessions prior to an investigation.

It is difficult to compare the outcomes of this study to previous research since to our knowledge no study has investigated this issue. Moreover, previous work investigating the effect of VbX on sprint time has involved preconditioning exercises, employed a sprint-specific warm-up before VbX, has primarily involved non-track athletes (e.g. soccer, ice-hockey, netball players and skeleton athletes) or focussed on sprints over short distances (up to 5 m).

Previous research (17) has shown varying responses to different VbX dosages (peak-to-peak displacement, frequency, duration). Whether the dosage and delivery method (side-alternating plate) used in this study is the optimal method is unknown. Moreover, the suggested relatively low metabolic cost of VbX(14) compared to a competition-specific warm-up (1, 19) could be investigated over a competition day or game period to examine possible effects on muscle fatigue and associated injury risks.

There were several limitations to this study that need to be acknowledged. Firstly, only six Vicon cameras were available which restricted the Vicon 3D capture volume to 7000 mm (length) × 1000 mm (width) × 2000 mm (height). Due to the need to capture all markers at the start, this capture volume only allowed 4 m (length) capture volume after the start. This prevented the capture of the time period over the 4 – 5 m interval. The timing gates could not be placed at the start (0 m) since they interfered with the capture of the markers. Secondly, the sprinters did not wear spikes due to the indoor testing environment. Although this is a limitation, the same running surface and footwear were used for both warm-up modalities. Finally, a relatively small sample size was used in this study. This sample size however, is similar to other sample sizes used in sprinting research. It is difficult to recruit large numbers of high-level sprinters due to training loads and competition commitments, and the relatively high injury rates in this population.

Based on the findings of this study, it is reasonable to conclude that VbX alone may be used as an alternative warm-up modality for maximal sprint performance over 40 m and multiple sprint performances over 40 m. The effect of differing vibration dosage (peak-to-peak displacement, frequency, duration) and delivery method (side-alternating or synchronous plate) requires further investigation to ascertain the optimal dose for sprinting activities. Given its time efficiency and suggested relatively low metabolic cost, VbX may be a suitable warm-up for activities requiring multiple sprints over a competition day or game period. Importantly for this study, no musculoskeletal injuries were sustained.

Based on the findings of this study, it is reasonable to conclude the following: VbX delivered with an amplitude and frequency of 4.5 mm and 26 Hz respectively by a rotary vibration platform is a warm-up modality that could be utilized for maximal sprint performance over 40m. The effect of differing vibration dosage (amplitude, frequency, time) and delivery method (rotary or vertical vibration plate) requires further investigation to ascertain the optimal dose for a sprinting warm-up. Importantly for this study, no musculoskeletal injuries were sustained.

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