Improved temporal sequencing of high – intensity muscle contractions prior to the sprint start may maximize motoneuron excitability and may enhance fast twitch fiber recruitment and sprint start effectiveness. The aim of the study was to assess a) the electromyographic activity of the gastrocnemius lateralis, biceps femoris and vastus femoris muscles under exposure to specific voluntary, dynamic actions (quick skipping or tuck jumps that sometimes sprinters perform after the “on your marks” command) and to an external involuntary stimulus (WBV-whole body vibration) and b) the effectiveness of the above stimuli applied on the activation level of lower limb muscles in order to produce neuromuscular activation the very last moment just behind the blocks, as this is measured by the RT and time in 1.5m and 3m after the sprint start.

Ten male sprinters executed sprint starts under 4 experimental conditions after the “on your marks command”: 1st condition – without performing any action, 2nd performing tuck jumps, 3rd performing quick skipping and 4th after being exposed to vibration stimuli. No significant difference in average muscle activity was observed after evaluation of the EMG raw data for the tuck jumps and quick skipping actions. No significant differences were, also, observed for RT and time in 1.5m and 3m in conditions 2 to 4.

Key Words: Sprint start, Neuromuscular activation, Warm up drills
INTRODUCTION

The starting action in sprinting, as this is defined by the reaction time (RT) and the initial acceleration after block clearance, is a complex motor action which critically affects sprint performance. It requires high neuromuscular activation and explosive force production and its efficiency depends on the execution of explosive and powerful movements exerted on the blocks (23, 34, 37). The warm-up procedures conducted by the sprinter in order to increase muscle and body temperature, flexibility and mobility have a crucial effect on sprint start performance (4-6). Sprinters, from amateur to professional level, commonly perform explosive and powerful movements (tuck jumps, dynamic stretching, quick skipping, etc.) after the starter’s “on your marks” command, as a last chance to make themselves “feel ready” for starting. These actions are associated with neuromuscular activation and force-power development and may produce a post-activation potentiation effect, enhancing warm-up effectiveness (28).

The ability of muscle to generate an expected level of force, which is reflected by its contractile history, has been examined in many studies (24, 33, 35). The physiological maximization of acute power development is referred to as post-activation potentiation (PAP). During this process the pre-loaded high-intensity neuromuscular actions elicit force-power output through phosphorylation of myosin light chains and/or changes in pennation angle and/or increased motoneuron excitability (39). There are many studies in the literature that deal with the PAP effect (3, 10, 19, 21). Güllich and Schmidtbleicher (20) reported that maximal isometric voluntary contractions induced short-term potentiation on countermovement jump and drop jump. Furthermore, Chatzopoulos and colleagues (9) indicated improvement in sprint performance after a bout of heavy resistance exercise, while a decrease in sprint performance was observed by Deutsch and Lloyd (17) when unloaded countermovement jump were preceded.

Therefore, neuromuscular activation can be generated voluntarily or passively (involuntarily) by altering either the type of contraction (isotonic/isometric) and/or other stimulus variables (intensity and/or volume, repetitions and rest intervals) via different forms of actions (18, 39). Electromyographic (EMG) evidence during the execution of movements concur that the compartments of a motor unit are used differently, depending on the specific task performed (42) and they are influenced by many physiological, anatomical and related to technique factors (16).

Wakeling (40) reported that the recruitment of motor units during locomotion such as running is related to muscle spindle excitation and may differ between functioning muscles. Voluntary movements that incorporate a stretch-shorten cycle (SSC) seems to be related to the level of pre-activation of the involved muscles, the velocity of shortening or lengthening of muscles, the rate of
tension build-up and the time elapsed between the eccentric (lengthening) and concentric (shortening) phase. Kossev and Christova (27) found that when muscle contractions were involved with joint movements the recruitment threshold was decreased. Schmidtbleicher (36) further examined two types of SSC that were differentiated with respect to the way in which the angular displacements and the ground contact were performed. Movements that involve extensive angular displacements and ground contact time >250 ms are characterized as slow SSC and is observed in maximal effort vertical jumps (countermovement jumps). In contrast, movements that have a short time delay <250 ms during the ground contact time, such as running and hopping, are classified as fast SSC.

In antithesis to voluntary contractions, which are controlled by the performer, involuntary actions (spinal reflex/automatic responses) are fast responses to an external stimulus, and they are controlled by the spinal cord (18). A common involuntary mechanical method that could be used as a training aid to enhance muscle activation is the whole body vibration (WBV) (2, 8, 12). WBV elicits involuntary reflex contraction via the tonic vibration reflex (TVR), inducing changes in the level of muscle function caused by the frequency and/or amplitude displacements generated by the vibration platform (1, 7, 41).

High-intensity contractions prior to the performance of an athletic activity may maximize motoneuron excitability, which is also expected to enhance the performance of a sprint start (34). In this study, we tried to determine the best voluntary pre-condition task that is commonly performed by sprinters after the “on your marks” command and the impact of a non-conventional involuntary sprint-related actions such as WBV, just before a sprint start performance. The target point of these specific actions was the virtually instantaneous activation of the neural and musculotendinous system using different training “aids” and neuromuscular pathways and the transfer of this activation to sprint start performance. To our knowledge, no previous study has attempted to quantify muscle activity during brief, explosive, specific actions that could be executed by an athlete prior to the sprint start. In this study, two major objectives of scientific and practical interest were considered. The first was to assess the EMG activity of the gastrocnemius lateralis (GA), biceps femoris (BF) and rectus femoris (RF) muscles under the specific actions /“quick skipping”, “tuck jumps” and WBV, which were performed after the starter’s “on your marks” command and also their potential effect on the activation level of lower limb muscles in order to be “ready to respond”. The second was to investigate the effectiveness of all the above-mentioned specific voluntary and involuntary actions on sprint start performance. We hypothesized that “triggering” sprinter’s lower extremity muscles via specific pre-conditioning actions, executed after the starter’s command, could positively influence the level of neuromuscular activity and thus the “final outcome” of a sprint start performance.
MATERIAL AND METHODS

Participants

Ten male sprinters, active members of track and field clubs who competed at the regional level and had trained at least 2 years in a sprint-specific training program (age = 20±1.8 yrs; mass = 69.38 ± 8.52 kg; height = 1.73 ± 0.08 m), participated voluntarily in the study. All individuals gave their written informed consent and all procedures were fully explained. The research protocol was approved by the university ethics committee. Subjects were asked to refrain from vigorous exercise and caffeine consumption for 24-48 hours prior to testing. All individuals had no history of any disease or musculoskeletal abnormality and none of them was under pharmacological treatment.

Procedure

All participants performed a standardized warm-up protocol (26) of 5min low-intensity running, followed by static and activity-specific, dynamic stretching exercises (10-12min) (4, 6), 2×20-30m acceleration runs and 2 sprint starts. A crossover design was applied sequentially to the same subject. After 5 to 7min of resting, each subject was randomly assigned to perform the 4 different conditions after the “on your marks” command, followed by a sprint start: 1st condition- without action behind the blocks, 2nd condition- tuck jumps, 3rd condition- quick skipping, 4th condition- WBV. Each experimental condition from its start to the gun signal lasted less than 40 sec. The duration of the stimulus applied was determined by the time in which two tuck jumps were performed, approximately 300ms; thus, the quick skipping and WBV stimuli were also applied for 300ms. A recovery period 5 to 7min was provided between conditions to minimize any bias due to fatigue and any carry-over effect of one condition to the next (28). No feedback was applied before, during or after each sprint start trial.
The sprint start was initiated by a signal given from a starting device (ReacTime, Lynx System Developers, Inc.) mounted on the sprint block. The ReacTime unit recorded and displayed the athlete’s gun-to-motion times (RT) to an accuracy of 1/1000th sec. It was operated using commands from a digitized internal starter triggered by the researcher through a signal input cable with start button attached. The ReacTime unit was also connected with two photocell gates (Polifemo Radio Light-Microgate, Italy) which were triggered by the gun signal of the ReacTime device. Photocells were placed at 1.5 and 3m to record the time after block clearance.

**Tuck Jumps**

Tuck jumps are active, dynamic actions, in which extensive hip and knee angular displacements are performed and are commonly used in plyometric training (32). To tuck jumps, the athlete jumps high, trying to tuck the legs up to the chest, with both feet placed shoulder-width apart. Subjects were instructed to jump vertically, as high as possible, without pausing in the bent knee position, tucking their knees up to their chest. Once they landed on their feet, they repeated the procedure immediately.

**Quick Skipping**

Quick skipping is a sprint-related quickness drill. Active dynamic small steps, with a high frequency of leg action without forward movement, were performed. Subjects were instructed to act in a self-determined pace of maximal quickness with the minimum contact time.
WBV

WBV is a passive dynamic activity. A mechanical stimulus was applied to the subject’s body, through a vibrating platform (Power Plate, USA). Low-frequency WBV has been shown to stimulate reflex pathways (involuntary action), leading to acute training adaptations (11). Participants stood unloaded on the platform in a half-squat position with the feet shoulder-width apart, holding onto the handles. No movement was performed on the vibrating platform (isometric contractions). A 30-Hz low frequency with high peak to peak amplitude (4.1-6 mm) was applied (2).

EMG

Surface electrodes used to acquire the EMG activity of the GA, BF and RF muscles of the right leg. The electrodes were placed prior to the warm-up on clean, shaven skin overlying the muscles, according to SENIAM recommendations for surface EMG electrode placement. EMG data were recorded at 1024Hz using rectangular-shaped (19.8mm×35mm) bipolar surface electrodes with 1cm Ag conductors and a 1cm inter-electrode distance. The reference electrode was placed over the iliac crest. The amplified EMG signals were low-pass filtered with a frequency of 10Hz (EMGworks 3.7 Delsys Inc.). The EMG signal magnitude was quantified using the average root mean square (RMS). A 200ms moving window was used to analyze the data between the onset and offset of EMG activities. The EMG data were collected by using the Delsys EMG system, Myomonitor IV wireless Transmission (Delsys Inc.).

Statistical Analysis

Statistical methods were employed, including mean and standard deviation (M±SD). Reaction time (RT), 1.5m time, 3m time and RMS values for the GA, BF and RF muscles were considered for analysis. Two separate MANOVAs were performed: the first was 4 conditions: without action, tuck jumps, vibration, quick skipping × 3 (RT, 1.5m, 3m); the second was 3 conditions: tuck jumps, vibration, quick skipping × 3 (muscles: GA, BF, RF). Significance was set at $p \leq 0.05$. All data were analyzed using SPSS 20.0 (IBM, Chicago, USA).
RESULTS

The first MANOVA did not reveal a significant multivariate main effect for all the conditions on reaction time, 1.5m and 3m (F=0.357, \( p > 0.05 \)). Analysis of the RT between the 4 conditions revealed that tuck jumps and WBV conditions (173±32ms and 172±22ms, respectively) (\( p > 0.05 \)) were related to a shorter RT but without showing any significant difference compared to the without action and the quick skipping conditions (193±33ms and 186±30ms, respectively) (\( p > 0.05 \); Figure 2).

![Figure 2. Reaction time (ms) for the 4 conditions](image)

Time analysis data indicated that the tuck jumps condition was related to a quicker (0.78sec) but not significant time at 1.5m (\( p > 0.05 \)). Furthermore, the 3m time analysis on the quick skipping condition showed a better performance time (1.17sec) but the data revealed no significant changes between conditions (\( p > 0.05 \); Figure 3).
An example of the raw data on the EMG activity pattern of the monitored muscles (BF, GA and RF) during the 3 different conditions is shown in Figure 4. It is evident that these muscles behaved differently in each condition. WBV seemed to increase EMG activity slightly from baseline (0μV).
Figure 4. Examples of raw EMG data recorded from the right leg during 300ms of vibration, 300ms of tuck jumps and 300ms of quick skipping. Note the obvious difference in EMG amplitude recorded on the vibration condition as the condition showing the least activation of the muscles evaluated.

The second MANOVA indicated a significant effect for the type of condition on EMG activity for the GA, BF and RF muscles (F=10.585, p≤0.05). A greater activation was recorded during voluntary actions (quick skipping and tuck jump conditions) in contrast to WBV condition. No significant difference was indicated in EMG activity of the monitored muscles between quick skipping and tuck jumps (p>0.05; Table 1).
Table 1.

RMS(μV) amplitude. Mean(±SD) of GA, BF and RF recorded under tuck jumps, vibration and quick skipping

<table>
<thead>
<tr>
<th></th>
<th>Gastrocnemius lateralis</th>
<th>Biceps femoris</th>
<th>Rectus femoris</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuck jumps</td>
<td>160.22±49.2 *</td>
<td>125.23±74.34 *</td>
<td>138.11±40.52 *</td>
</tr>
<tr>
<td>Vibration</td>
<td>34.82±24.73</td>
<td>44.07±12.65</td>
<td>44.27±9.24</td>
</tr>
<tr>
<td>Quick skipping</td>
<td>160.79±73.38 *</td>
<td>129.11±39.59 *</td>
<td>163.75±64.14 *</td>
</tr>
</tbody>
</table>

* Denotes a significant difference from vibration, p<0.05.

**DISCUSSION**

Improved temporal sequencing of high-intensity muscle contractions prior to the sprint start may maximize motoneuron excitability and enhance fast-twitch fiber recruitment. The primary findings of this study indicated that the use of pre-conditioning activities had a positive, but not significant, effect on sprint start performance. Sprint start is a complex motor activity that forces athletes to move from an acyclic movement into a cyclic one, activating a multitude of different motor units to minimize reaction time and maximize block acceleration. Tuck jumps and quick skipping are two dynamic pre-conditioning “task-strategies” that are commonly performed by some sprinters the “very last moment” just behind the blocks before the “get set”command. During the tuck jump task, athletes exert a powerful push upwards with an increased ground contact time and high angular displacements. This function seems to be related to the acyclic movement of a sprint start, where the athlete exerts a high impulse on the blocks by “pushing and tucking” the rear leg until the first step is completed. On the other hand, the quick skipping task is a more sprint-specific drill, which emphasizes more on the high frequency (quickness) of SSC, using the recoil phenomenon of the muscle-tendon system repetitively, minimizing contact time, which almost resembles the cyclic movement of a sprint start (38). The results in this study revealed that
in both the dynamic conditions examined, tuck jumps and quick skipping, the participants showed a slightly positive trend, but not significant time in the 1.5m and 3m, respectively, which might have been dependent on the specificity of the performance task prior to the sprint start. Furthermore, the EMG activity pattern during tuck jumps and quick skipping showed that motor units worked differently on each task, but after the evaluation of the EMG raw data no significant difference in average muscle activity was revealed. This finding indicated that similar muscle activation was produced, regardless of the performed task.

In addition to these conditions, unloaded static squatting on the vibration platform focuses on the eccentric function of lower limb muscles. This task causes a permanent muscle fiber lengthening and seems to produce a higher level of activation via the optimization of cross-bridge length (31). Cochrane and colleagues (13) proposed that 10min of static squatting on the vibration platform increases muscle temperature when it is used as a warm-up procedure. These authors also indicated that the PAP effect, which is induced by WBV, is related more to myogenic rather than neurogenic changes (14). In our study, the EMG data from static unloaded squatting on the vibration platform showed that the muscle activity level of the GA, BF and RF increased slightly from baseline. Thus, WBV for 300ms as a pre-condition stimulus did not seem to enhance muscle electrical activity, resulting in a limited effect on sprint start performance. According to previous studies, the efficiency of a sprint start depends on powerful neuromuscular movements (37) leading to the recruitment of fast-twitch muscle fibers (25), but the WBV task in this study did not seem to be able to produce the appropriate level of neuromuscular activation.

It is difficult to directly compare the results of the present study with those of other studies. To our knowledge, the effect of such a brief stimulus applied just before a complex motor activity such as the sprint start has not been studied so far. A limitation that exists may involve the experimental procedure itself. When sprint start performance is examined, several important factors may, also, affect block clearance efficiency, such as the height of the sprinter’s center of body mass in the set position, the block face angle, the type of the position of and on the blocks (15, 22, 29, 30) etc. However, the lack of significant differences between conditions did not allow us to verify the initial thoughts that led us to design this study and so to proceed with a further analysis. The use of the WBV needs to be further examined under loading conditions for its acute effectiveness at the sprint start.

A “functional” warm-up protocol should include all the proper drills that could prepare the athlete physically and mentally to optimize performance. The execution of specific exercises/actions should be performed by the athletes before the sprint start according to their personal preferences and subjective evaluation of the effectiveness of actions performed.
REFERENCES


*Address for correspondence:*

Athanasia Smirniotou, PhD
Associate professor
41, Ethnikis Antistaseos Str., 172 37 Dafni, Greece
Email: asmirn@phed.uoa.gr