

## THE ACUTE AND POST-ACTIVATION POTENTIATION EFFECTS OF THE SPEEDMAKER™ ON STEP-BY-STEP KINEMATICS, MUSCLE ACTIVATION AND PERFORMANCE IN 30-M SPRINTS

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### ABSTRACT

The purpose of this study was to examine the acute effects of using the SpeedMaker™ on step-by-step kinematics and muscle activity in 30-m sprints and if it is possible to elicit a post-activation potentiation stimulus with the SpeedMaker™ upon subsequent 30-m sprint performance. Thirteen male soccer players (age:  $22.8 \pm 1.8$  yr, body mass:  $75.1 \pm 11.9$  kg, height:  $1.80 \pm 0.08$  m) participated in a repeated measure and cross-over design consisting of two conditions: three normal 30-m sprints (control) and two normal 30-m sprints divided by one 30-m sprint with the SpeedMaker™ (intervention). Kinematics were measured for each step together with the peak muscle activity of the hamstrings, quadriceps and gluteus during each stride of each 30-m sprint. The main findings were that sprinting with the SpeedMaker™ increased sprint times by 1.7% compared to normal 30-m sprints. However, no occurrence of a post-activation potentiation (PAP) response was found when performing a 30-m sprint with the SpeedMaker™ prior to a normal 30-m sprint in male soccer players. Furthermore, no detectable differences in step-by-step analysis on kinematics and muscle activity were found between the sprints with and without the SpeedMaker™. Only hamstrings and gluteus activity increased per stride over 30-m. It was concluded that the SpeedMaker™ did influence sprint times, but only in a small way that kinematics and muscle activity did not change detectable. Furthermore, that the SpeedMaker™ did not elicit a PAP effect. In addition, increased hamstring and gluteus maximus activation during the 30-m sprints suggests that these muscles are very important for acceleration, and that it is likely that acute

hamstring strains occur when a soccer player is close to maximal velocity, as hamstring activation is maximal at that point.

**Keywords:** *resisted sprint, EMG, PAP, team male soccer players*

## INTRODUCTION

Sprint performance is an important factor in individual and team-based sports such as soccer, handball, football and rugby. In most of these sports, only distances of 10 to 30 m are performed, which is mainly based upon acceleration. The ability to quickly accelerate towards maximal speed and obtain maximal speed over short distances is often related to critical match-related skills such as breakthroughs, interceptions and counter-attacks in team sports [14, 15]. The first ten meters of an acceleration seems to be the most important phase in team sports [26]. Acceleration is determined by the following kinematic parameters: step length, step frequency, contact time and flight time [26]. There are several ways to enhance acceleration by training. Based on training principles and physiological responses, post-activation potentiation (PAP) has been identified as a component related to sprint performance enhancement.

PAP is defined as an enhancement in the contractile ability of a muscle after a conditioning contraction, which manifests itself as elevated performance in a subsequent task [19]. This acute and temporary enhancement is dependent on the contractile history following a high intensity stimulus [5, 19, 25]. This effect mainly occurs when performing a certain type and amount of conditioning contraction at maximal or near-maximal intensity [19]. To elicit a PAP response by increasing muscle power output of subsequent activity, a complex training protocol is often used [5]. Complex training involves pairing a conditioning contraction consisting of a heavy-load activity or a multi-joint large mass and an explosive subsequent activity with biomechanical similarities to each other [5, 19]. Several types of conditioning contraction are presented in the literature, e.g. back squat, power clean, weighted sled tow, towing system, alternated leg bounds and resistive harness [26], suggesting that PAP may be dependent on the movement pattern, i.e. an activity within the contractile history should have some biomechanical similarities to the subsequent explosive activity. However, a complex pair often involves heavy back squats at 85–90% of one repetition maximum (1RM) before sprints to evoke PAP [10, 17, 28]. Thus, the question arises as to whether the movement pattern of squats is similar enough to sprints. In recent studies, resisted sprints have been used to evoke a PAP

effect, as these have similar movement patterns as sprinting. In general, it was found that including one resisted sprint could have a positive PAP effect upon the subsequent sprint when the load is heavy enough 10–75%, [9, 18, 25], but not too heavy [27] and the resisted sprint is not too long to induce fatigue [22].

The SpeedMaker™ is a harness in which two elastic bands are attached at the front of the upper legs to the waistband (Figure 1). These elastic bands add resistance to the hip extensors, aiming to increase muscle activity in the gluteus and hamstrings, while the hip flexors are put into full stretch when the hip extensors are contracting. This provokes the hip flexors to contract, raising the knee into a higher running position, which may result in a decreased angle of velocity. This higher knee posture allows for exerting more force onto the ground. According to the manufacturer, this device bridges the gap between speed, agility, and strength training, increases the stretch-shortening cycle and elicits a PAP response of subsequent activity while used as a condition contraction [4].

There are already two studies that have examined the use of the SpeedMaker™ with the aim of inducing PAP with the device. Jensen et al. [8] investigated the effect of sprints with and without the SpeedMaker™ upon jumping performance, whereas the study by Meidinger et al. [11] assessed three 50-m sprints at 80, 90 and 100% of maximal effort either wearing the SpeedMaker™ or not, along with one control test. In both studies, no positive effect was found. However, the rest period between the runs was only 1 min, and as both authors suggested, fatigue seemed to be more prominent than the possible PAP response due to insufficient recovery. van den Tillaar and Von Heimburg [25] found that a PAP effect could be elicited after a 5-min rest period between a PAP induced sprint and normal 30-m sprint. However, they used a towing system to introduce resistance during sprints. They also investigated the step-by-step kinematics during different sprints to get a better understanding of what happens after inducing PAP but failed to include electromyographic (EMG) measurements to investigate what happens with muscle activation as a mechanism of the differences in sprint kinematics.

Therefore, the purpose of this study was two-fold. First, we investigated the acute effect of the SpeedMaker™ on step-by-step kinematics and muscle activity in 30-m sprints and secondly, we assessed whether it was possible elicit a post-activation potentiation stimulus with the SpeedMaker™ upon the subsequent 30-m sprint performance.

## **MATERIALS AND METHODS**

To examine the acute effect of the SpeedMaker™ upon step-by-step kinematics and muscle activity and if it causes a PAP response in a subsequent 30-m sprint, a repeated measure and cross-over design was used. Each subject completed two conditions: (1) three normal 30-m sprints and (2) two normal 30-m sprints divided by one 30-m sprint with the SpeedMaker™. Reliability was maintained by applying condition (1) as a control test.

### **Subjects**

The research process included in total 13 male soccer players ( $22.9 \pm 1.8$  years old, body mass  $75.1 \pm 11.9$  kg, body height  $1.80 \pm 0.08$  m) who primarily participate in the fifth division in the national division system. All participants were currently attending soccer practice, with an average of three training sessions per week (range 2–4). Soccer players were selected as subjects because they perform many short sprints during training and competition [1]. The subjects were informed orally and in writing about the aim and methods of the study before participation. Written informed consent was obtained prior to all testing from all subjects according to the current ethical regulations for research. Approval to use the data and conduct the study was given by the NSD.

### **Procedures**

In the two weeks before testing, each subject attended training sessions in which he ran several 30-m sprints while wearing the SpeedMaker™ to get familiar with the device. Sprint performance was tested on two testing sessions, which were separated by at least 48 hours. Subjects were also informed not to undergo hard training 24 hours before testing and to not to do anything unusual in their day-to-day routine. On one session, the subjects performed three normal 30-m sprints used as a control, while on the other session two normal 30-m sprints were conducted, separated with one 30-m sprint wearing the SpeedMaker™ (intervention). Half of the subjects started with the control condition, while the other half started with the intervention condition.

On each testing day, before executing the first 30-m sprint, each subject carried out a standardised warm-up protocol consisting of  $8 \times 40$  m sprints separated by a 60 s recovery period. The first 40 m was performed with a self-estimated intensity of approximately 60% of estimated maximal sprinting velocity. Each 40 m sprint effort thereafter increased self-estimated

intensity by 5% until 95% maximal sprinting velocity was reached. Each rest period involved one of seven dynamic flexibility exercises for the shoulder, hip, knee and ankle joints, starting with shoulders and working downwards to increase the range of motion of different joints, as described in detail by van den Tillaar and co-workers [23, 24]. After executing the warm-up protocol, each subject had a 5 min active recovery period before performing the first 30-m sprint. Each sprint was separated by a 5 min recovery period as suggested by previous studies [19]. The SpeedMaker™ device (Speed-Maker™ Athletics, San Diego, USA) is a harness consisting of a waist belt connected to shoulder and leg straps (Figure 1) and three pairs of resistance bands. Only the heaviest elastic bands (green) were used for the second attempt of the intervention condition. The resistance bands were attached to the waist belt and leg straps to give extra resistance to the hip extensors during the push phase of sprinting. During all other attempts, including the ones during the control condition, the SpeedMaker™ harness was worn without the resistance bands to avoid differences in sprinting due to just wearing the harness.

To measure performance in the 30-m sprint, two pairs of wireless photocells (Brower Timing Systems, Draper, USA) were used. Each subject initiated each sprint attempt from a standing start in a split stance, with the lead foot behind a line taped on the floor 0.3 m from the first pair of photocells. The optical contact grid sampled at 500 Hz continuously from the first



**Figure 1.** Set up of the SpeedMaker™ with the shoulder straps and waist belt connected by resistance bands with the leg straps.

step to 32 m during all attempts with the Muscledab 6000 system (Ergotest Innovation, Porsgrunn, Norway), allowing measures of contact and flight time as well as step frequency to be derived for each step of the 30-m sprints.

Muscle activity was measured by using a wireless EMG with a sampling rate of 1 kHz (Ergotest Innovation, Porsgrunn, Norway) with electrodes (Zynex Neurodiagnostics, 9990 Park Meadows drive, Lone Tree CO 80124, 572 cm in diameter) on the muscles of the right leg. The skin to which the electrodes was fastened had been shaved and washed with alcohol before fastening the electrodes. The

electrodes (11 mm contact diameter and 2 cm centre-to-centre distance) were placed along the presumed direction of the underlying muscle fibres on the vastus lateralis, rectus femoris, biceps femoris, semimembranosus, gluteus medius and maximus muscles according to the recommendations of SENIAM [6]. The EMG raw signal was amplified and filtered using a pre-amplifier located as close as possible to the pickup point with the intention of minimising the noise induced from external sources through the signal cables. The preamplifier had a common mode rejection ratio of 100 dB. The EMG raw signal was then bandpass filtered (fourth-order Butterworth filter) with cut-off frequencies of 20 Hz and 500 Hz. The resulting EMG signals were converted to root mean square (RMS) signals for the contact and flight phases. The highest average RMS during one of the phases during each stride cycle (one left and right step) for each muscle was used for further analysis. All sensors were synchronised using Musclelab version 10.5.69 (Ergotest Innovation, Porsgrunn, Norway), which made it possible to measure and analyse kinematics and muscle activity for each step cycle and stride during the 30-m sprint. Each step cycle consisted of contact and flight time for either the left or right foot. One stride cycle involved the contact and flight time for both feet. In total, 15 step cycles and eight strides were included for further analysis.

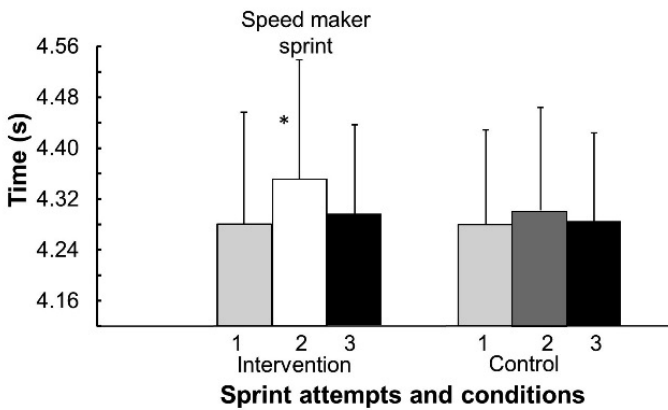
### **Statistical analyses**

To assess the differences in 30-m sprint times for conditions and attempts, a 2 (condition: intervention and control)  $\times$  3 (sprint attempt: 1–3) repeated measures analysis of variance (ANOVA) was used. When assessing kinematics, a 3 (sprint attempt: 1–3)  $\times$  15 (step cycle: 1–15) repeated measures ANOVA was applied on the intervention condition. A 3 (sprint attempt: 1–3)  $\times$  8 (stride: 1–8) with repeated measures ANOVA was used to assess muscle activity for each muscle. If significant values were found, a Holm-Bonferroni post hoc comparison was applied to locate the differences for attempts and step cycles/strides. The level of alpha was set to  $p < 0.05$ . When the assumption of sphericity was violated, the Greenhouse-Geisser adjustments of the alpha level was reported. Effect size was used to determine the strength of the level of significance. Effect size was evaluated with  $\eta^2$  (partial eta square) where  $0.01 < \eta^2 < 0.06$  constitutes a small effect,  $0.06 < \eta^2 < 0.14$  constitutes a moderate effect, and  $\eta^2 > 0.14$  constitutes a large effect [3]. The reliability of the sprint kinematics and EMG variables was based upon the three sprints in the control condition and tested by the intraclass correlation coefficient (ICC) based upon the using Cronbach's alpha. Statistical analysis was performed using SPSS 25.0 for Windows (SPSS, Inc., Chicago, IL).

## RESULTS

The ICC of the different variables were on performance (0.98), contact time (0.99), flight time (0.99), step frequency (0.98), gluteus maximus (0.99), gluteus medius (0.99), rectus femoris (0.88), vastus lateralis (0.99), biceps femoris (0.99) and semimembranosus (0.99).

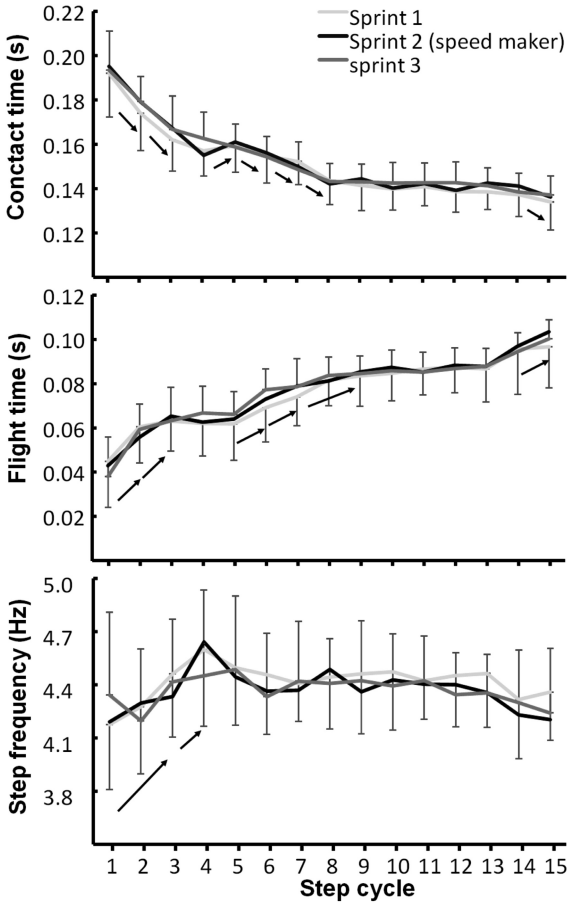
The subjects sprinted on average significantly 1.7% slower when wearing the SpeedMaker™ ( $F = 6.2$ ,  $p = 0.007$ ,  $\eta^2 = 0.34$ ) compared to the other two 30-m sprints, while no significant differences were found between normal sprint 1 and 3 in the intervention condition and between the three sprints in the control condition (Figure 2).



**Figure 2.** Average 30-m sprint times (SD) in each sprint for both conditions (intervention and control).

\* indicates a significant difference with the other two sprints in this condition at the  $p \leq 0.05$  level.

When investigating the step kinematics, no significant differences were found between the three sprints with and without the SpeedMaker™ for contact time ( $F = 1.57$ ,  $p = 0.228$ ,  $\eta^2 = 0.12$ ), flight time ( $F = 0.49$ ,  $p = 0.620$ ,  $\eta^2 = 0.04$ ) or step frequency time ( $F = 2.00$ ,  $p = 0.145$ ,  $\eta^2 = 0.15$ ). Only an effect of step cycle was found for all three kinematic variables ( $F \geq 3.52$ ,  $p \leq 0.001$ ,  $\eta^2 \geq 0.22$ ). The post hoc comparison showed that contact times decreased from step 1 to 8, then stabilised, then decreased again at the last step. The opposite was found for flight time; i.e. an increase in flight time was seen from step 1 to 9 and again in the last step. As a result, only step frequency increased from step 1 to 4, after which it stabilised (Figure 3).

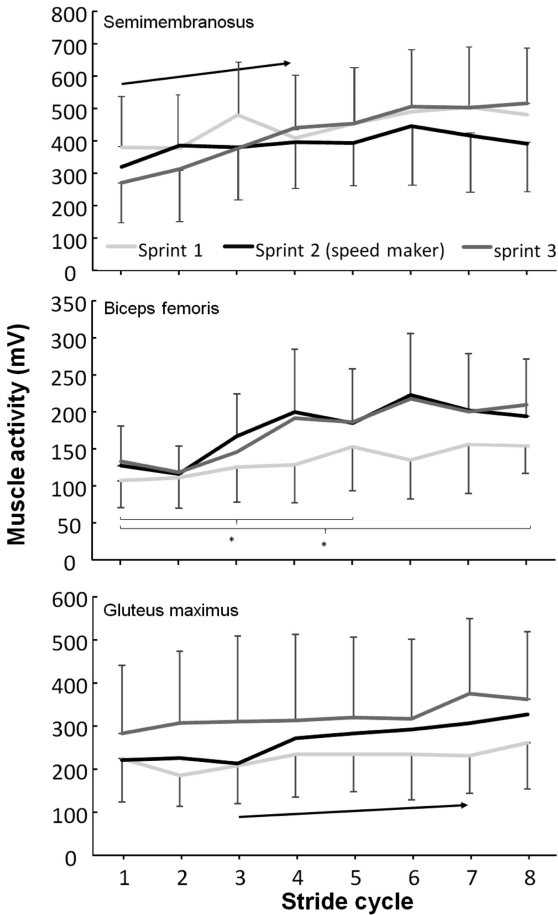


**Figure 3.** Average contact and flight time per step cycle and step frequency for each 30-m sprint attempt for the intervention condition ( $\pm$  SD).

→ indicates a significant difference between this step cycle and all those right of the arrow at the  $p < 0.05$  level.

No significant differences in muscle activity were found between the three attempts within the SpeedMaker™ condition ( $F \leq 1.73$ ,  $p \geq 0.23$ ,  $\eta^2 \leq 0.30$ ). A significant effect of stride was detected (Figure 4) for the gluteus maximus ( $F = 3.08$ ,  $p = 0.012$ ,  $\eta^2 = 0.38$ ), semimembranosus ( $F = 4.54$ ,  $p = 0.002$ ,  $\eta^2 = 0.53$ ) and biceps femoris muscles ( $F = 3.04$ ,  $p = 0.09$ ,  $\eta^2 = 0.28$ ). For the other muscles (Figure 5), no significant effect of stride were found ( $F \leq 1.6$ ,  $p \geq 0.24$ ,  $\eta^2 \geq 0.14$ ). The post hoc comparison indicated an increase in muscle activity from stride 1 to 4 and onwards for the semimembranosus and between stride 1 with 5 and 8 for the biceps femoris. The gluteus maximus increased activity from stride 3 to 7 and onwards (Figure 4).

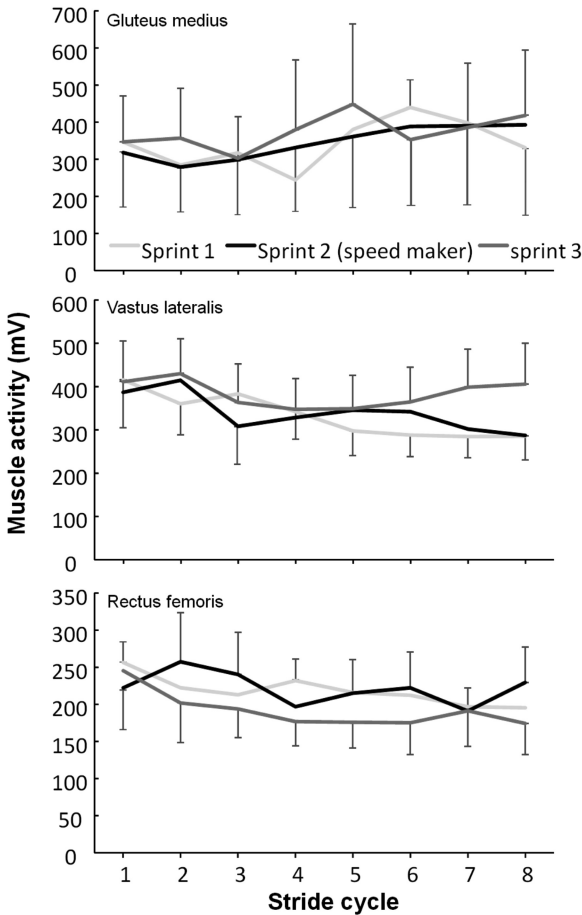




**Figure 4.** Peak muscle activity of the gluteus maximus, biceps femoris and semimembranosus during the flight or contact phase per stride cycle for each 30-m sprint attempt for the intervention condition ( $\pm$  SEM).

→ indicates a significant difference between this step cycle and all those right of the arrow at the  $p < 0.05$  level

\* indicates a significant difference between these two strides at the  $p \leq 0.05$  level.



**Figure 5.** Peak muscle activity of the gluteus medius, vastus lateralis and rectus femoris during the flight or contact phase per stride cycle for each 30-m sprint attempt for the intervention condition ( $\pm$  SEM).

## DISCUSSION

The main findings were that sprinting with the SpeedMaker<sup>TM</sup> increased sprint times by 1.7% compared to normal 30-m sprints. However, no occurrence of an elicited PAP response was found when performing a 30-m sprint with the SpeedMaker<sup>TM</sup> prior to a normal 30-m sprint in male soccer players. Furthermore, no detectable differences were found in the step-by-step analysis on kinematics and muscle activity between the sprints with and without the SpeedMaker<sup>TM</sup>.

Sprinting with the SpeedMaker<sup>TM</sup> caused an increase of 1.7% compared to normal 30-m sprints, which indicated that it costs extra strength for the

subject. The elastic bands probably added resistance to the hip extensors (gluteus and hamstrings) during the push off phase. However, no differences were found in the muscle activity of the hamstrings and gluteus (Figure 4) or in running kinematics (Figure 3), which is in line with the findings of Jensen et al. [8] on vertical jump performance after using the SpeedMaker™. An explanation for this absence is the variability of muscle activation during sprinting, as also shown by Mero and Komi [13] and van den Tillaar and Gamble [20]. They found no differences in the muscle activity of the hamstring and gluteus between sprinting at a maximal or supramaximal level, which was 6–7 % faster than normal due to variability. Furthermore, in resisted sprints that were 12% slower than at the maximal level, no differences were found in muscle activation for these muscles [20]. Furthermore, in these studies [12, 20] detectable kinematic differences were found in contact and flight time and frequency due to the large differences in sprint times. In the present study, the difference between the two conditions was only 1.7% which would obviously not result in detectable differences in muscle activation or sprint kinematics.

No difference in sprint times was found between the first and second normal 30-m sprint after a 30-m sprint with the SpeedMaker™, indicating that no PAP occurred. This is in accordance with the findings of two earlier studies in which the SpeedMaker™ was used as a conditioning stimulus on sprint and vertical jump performance [8, 11]. Although the load applied with the SpeedMaker™ seemed to be insufficient to provoke PAP, intensities and biomechanical similarities were attained according to the recommendations. Whelan et al. [26] suggested that the contractile history should have some biomechanical similarities to the following explosive activity to elicit a PAP response. As opposed to power cleans and back squats, the SpeedMaker™ maintains the biomechanical similarities of sprinting from conditioning contractions to subsequent activity. As suggested by Tillin and Bishop [19], conditioning contractions should be performed at maximal or near-maximal intensities. In fact, van den Tillaar and Von Heimburg [25] showed that one resisted sprint at maximal intensity (7.5% increase in sprint time) caused a PAP response for the subsequent sprint. However, in previous studies with the SpeedMaker™, sub-maximal intensities of 80% and 90% were used [8, 11]. This intensity, in combination with insufficient rest after the sprint with the SpeedMaker™, did not give the PAP stimulus required. In the present study, the subjects performed each sprint at maximal intensity, which was also shown by the same times in the control and intervention condition (Figure 2). Other possible explanations for the absence of PAP, besides the low resistance load, could be subject characteristics such

as muscle strength, training level, type of competitive activity and power-strength relation [19]. Lower limb strength plays a major role in improving sprint performance, and the PAP effect has been shown to be most prevalent for fast, strong, predisposed or highly trained individuals who can lift more than two times their body weight in back squats. In addition, they possess a greater ability to resist fatigue compared to less strong individuals [5]. An estimate of the strength level of the recruited subjects was not performed, which perhaps is a limitation of this study.

Another limitation is that we used soccer players and not top sprinters. Soccer players do not usually perform many straight-line sprints. They are more likely to undergo changes in directions during their sprints, which involves a smaller step length and a low centre of gravity and results in a lower knee posture when sprinting. Therefore, this is a possible explanation for why soccer players are not used to this type of sprinting with the SpeedMaker™, even after two training sessions. Yet, the soccer players showed the same development in step kinematics and muscle activity as experienced sprinters. Contact times decreased in the first 8–9 steps, while flight times increased (Figure 3). In experienced sprinters, the same happens, but they continue this development until step 12 [20], probably due to a higher maximal velocity. However, the step frequency showed the same development as in the sprinters in that it increased up to step 4, after which it stabilised (Figure 3).

The present study is one of few studies that have investigated muscle activity per step during maximal sprints. To the best of our knowledge, only one study has reported the stride-by-stride development of muscle activity during acceleration in sprinters [20], and in the present study the same development of muscle activation was found as in sprinters. The muscle activation of the hamstrings and gluteus maximus muscles increased over the strides during the 30-m sprints (Figure 4), while the quadriceps did not change activity during the sprints (Figure 5). These findings provide evidence that the gluteus maximus and hamstring muscles are very important for acceleration. It is likely that acute hamstring strains occur when a soccer player is close to maximal velocity [7, 16] as activation of the hamstrings is maximal at that point.

No joint kinematic measurements were performed in the present study that could indicate if the SpeedMaker™ causes high knee lift and more hip flexion during the flight phase. However, Meidinger et al. [11] indicated that the use of the SpeedMaker™ leads to an acute increase in the range of motion around the knee joint, but it did not affect the angles around the hip joint. Clark et al. [2] indicated that by conducting a training period,

the knee joint range of motion changed positively due to the use of the SpeedMaker™, suggesting that it could be a useful tool to improve sprint technique. However, they had a small sample size (n=5), so they could not make this bold statement. Therefore, for future studies, it is suggested to perform training studies in which a larger number of subjects are involved. Furthermore, sprinters should be used instead of soccer players, because they are trained in sprinting straight ahead under different circumstances and probably have greater strength levels for sprinting than soccer players. In addition, joint kinematics should be included to investigate the use of the resistance bands upon these joint angles, and a radar gun should be employed to gain more insight into how the SpeedMaker™ affects the different steps and step velocity of sprints [20, 21, 25]. When the purpose is to elicit a PAP response, a heavier pair of elastic bands should be used.

Based upon the findings of the present study, it was concluded that the SpeedMaker™ did influence sprint times in male soccer players, but only in a small way, such that kinematics and muscle activity did not change detectably. Furthermore, the SpeedMaker™ does not seem to elicit a PAP effect when measuring 30-m sprints. In addition, the activation of the hamstrings and gluteus maximus increased during the 30-m sprints, which shows that these muscles are very important for acceleration. It is likely that acute hamstring strains are likely to occur when a soccer player is close to maximal velocity, as hamstring activation is maximal at that point.

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