COMPARISON OF DIFFERENT SPRINT TRAINING SESSIONS WITH ASSISTED AND RESISTED RUNNING: EFFECTS ON PERFORMANCE AND KINEMATICS IN 20-M SPRINTS

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ABSTRACT

Purpose. The purpose was to examine whether there is a positive acute effect of resisted and assisted sprinting on the kinematics and performance of regular 20-m sprints.
Methods. The total of 15 female team handball players were involved in a counterbalanced crossover design three sprint sessions consisting of (1) seven normal 20-m sprints, (2) seven sprints alternating normal and resisted sprints, and (3) seven sprints alternating between normal and either resisted or assisted sprints in a single session.
Results. The main finding was that only resisted sprints had an effect on the first normal 20-m sprint. However, this was only the case after one resisted run (from 3.59 to 3.54 s; 2% improvement). Using several resisted sprints did not have any positive effect upon the normal sprints, but probably caused fatigue, as shown in the increased contact times and decreased vertical stiffness, step length, and rate. Assisted running did not cause any changes to the normal sprints.
Conclusions. Resisted sprints can cause a positive effect in normal 20-m sprint performance (2%) after the use of one resisted effort in team handball players. However, the small positive effect is negated if several resisted efforts are performed, causing more fatigue than a positive response. Therefore, it is recommended that multiple resisted sprint efforts are not performed when seeking to enhance 20-m sprint performance in these athletes.
Key words: warm-up, step length, step frequency, vertical stiffness

Introduction

In numerous team sports, like soccer, rugby, and team handball, short sprints are very important [1]. They occur several times during matches and are most often associated with critical match-related skills like the fast-break in team handball [2]. Commonly, to enhance sprint performance in athletics, soccer, and other sports, resisted and assisted running is applied. These two training methods are based on the principles of overload by force or velocity [3]. The objective of the overload is to increase the recruitment of the fast-twitch muscle fibres and to elicit a greater neural activation [1]. Most studies that used these training methods to enhance sprint performance did so over several weeks [4–6]. Earlier studies suggested that resisted and assisted sprints increased muscular power output of the gluteus maximus, and the hip and knee extensors, and thereby stride length in normal sprints [7–10]. It is unclear whether resisted and assisted sprints can be effective as a part of complex training methods [11, 12]. Complex training alternates

biomechanical similar high-load weight training (e.g. resisted sprints) with a ballistic exercise (normal sprints) in order to potentiate the ballistic exercise performance [11, 12], which is referred to as post-activation potentiation (PAP) [13, 14]. PAP has been defined as the muscles' ability to develop force, which is dependent on what happened earlier within the muscle and on improvements in performance that follow a submaximal or a maximal contraction [15]. In short sprints, few studies were performed in which PAP was induced [16–19]; however, a PAP effect was found mainly after using heavy back squats (85–90% of one repetition maximum (1-RM) [16–18]. Nevertheless, in competition, it is very difficult to use those exercises as conditioning stimuli owing to logistical limitations (access to squat lifting equipment near the track).

Applying resisted sprints, such as sled towing, results in submaximal or maximal muscle contraction [8, 20] and thus, by including resisted sprints in a warm-up protocol, normal sprint performance afterwards could be enhanced [19]. Smith et al. [19] found that 20-yard

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sled sprinting with a load of 10, 20, and 30% of body weight during warm-up had a positive effect on 40-yard sprints. However, they only tested the effect of one resistance run and not the effect of multiple efforts on normal sprint performance. In addition, athletes who warm up with resisted sprints anecdotally have a subjective perception that they can run faster in a normal sprint as they experience less load.

In assisted sprints, it is also suggested that a potentiation effect occurs that could enhance the normal sprint performance [4]. However, to the best of our knowledge, no study has investigated the acute effect of resisted or assisted sprinting on regular 20-m sprints, a distance that is very important for many sports, such as athletics and team sports [21].

Therefore, the main purpose of this study was to examine whether resisted or assisted sprints could increase performance on normal 20-m sprints by changed kinematics and possible initiated PAP response. In addition, the kinematics of the resisted and assisted sprints were compared with the normal sprints to investigate where, and to what degree, the kinematic changes occurred during these sprints, in order to gain a better insight into what eventually causes PAP to occur in normal sprinting.

Material and methods

To examine whether resisted or assisted sprints could initiate an acute change in the kinematics and performance of normal 20-m sprints, a counterbalanced cross-over design with repeated measures was applied. Each subject was tested in three conditions: (1) seven normal 20-m sprints, (2) seven sprints alternating normal and resisted sprints, and (3) sevens sprints alternated between normal and assisted sprints with at least 48 hours between each testing day. Each subject completed the three conditions in a randomized counterbalanced order.

Participants

The total of 15 experienced female team handball players (age 19.2 ± 1.2 years, body mass 68.4 ± 9.1 kg, body height 1.74 ± 0.04 m) playing in the first national division level participated in the study. Team handball players were involved since they experience a lot of 20-m sprints during their team handball matches [22] and therefore it is important for them to be fast over the distance. Furthermore, all subjects regularly perform 20-m sprints as part of their regular tests during the season. The local committee for medical research ethics approved the study and all participants provided their written informed consent prior to testing, which complied with the current ethical standards in sports and exercise research.

Procedures

The subjects performed the tests always at the same time of a day (between 4 and 6 p.m). On each test occasion, they carried out a standard warm-up protocol, consisting of 8 × 40-m sprints with a 60-second rest between the efforts (10 minutes in total). The first 40-m effort was at a self-estimated intensity of approximately 60% of estimated maximal sprinting velocity; each 40-m effort thereafter increased by approximately 5% until they reached 95% of maximal self-estimated intensity. In each rest period, one of seven dynamic flexibility exercises for the shoulders, hip, knee, and ankle joints was completed, starting with the shoulders and working downwards to increase the range of motion of the different joints, as described in detail by van den Tillaar et al. [23] and van den Tillaar and von Heimburg [24]. After the warm-up, the participants had 5 minutes of active rest (easy walking and standing) before they performed one of the three protocols. The three testing protocols were: (1) seven normal 20-m sprints, (2) seven sprints alternating between normal and resisted sprints, (3) seven sprints alternating between normal and assisted sprints. The assisted and resisted sprints were executed with the use of a towing system similar to that applied by Kristensen et al. [25]. The towing device provided extra resisted or a propulsion force, depending on the running direction. The system used a 5-mm non-stretch rope fastened to the roof (5 m above the floor) and passed through seven castors (three fixed to the ceiling, one at the wall at the height of 1.5 m, and three on a movable fixation bar), creating a 1:6 gearing system between the load and the subject. The rope was fastened to the subject's hip with a belt (Figure 1). In the pilot study, resisted and propulsive forces were recorded by a load cell mounted on the rope close to the subject. The total movable loads attached to the system were 5 kg (resisted) and 40 kg (assisted), leading to additional forces, while standing still, of approximately 32 N and 80 N, respectively. These absolute loads were used, and not those expressed by individualized percentages of body weight, since this was more practical, and Kristensen et al. [25] showed that these loads had a longitudinal effect on 20-m sprint performances.

Between each sprint, an approximately 5–6-minute rest was applied to avoid fatigue and to achieve the best PAP effect, as earlier studies have proved [26]. The 20-m times were measured with two pairs of wireless photocells (Brower Timing Systems, Draper, USA), with the subjects starting from a standing split start 0.3 m behind the first pair of photocells. The kinematics were measured by a 20-m long infrared mat, sampling at 500 Hz (contact and flight time) and a laser gun (running velocity, step length), sampling at 2.56 KHz. The laser gun signals were re-sampled at the rate of 10 Hz with a moving average of 100 ms. These sensors were all synchronized by the Musclelab 6000 system (Ergotest Tech-
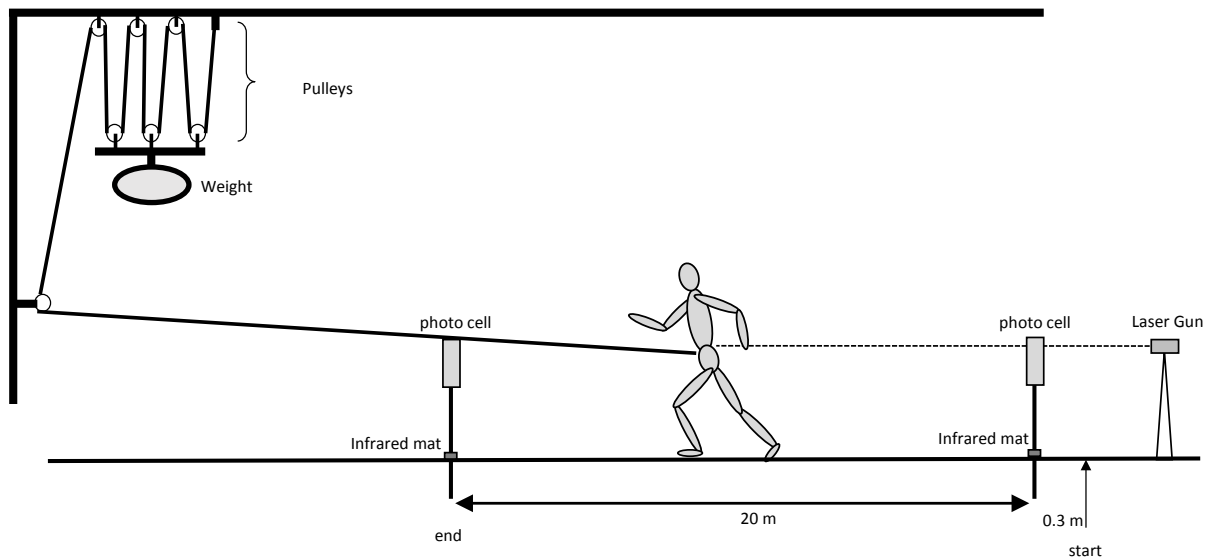
Figure 1. Experimental set-up; the towing system and a subject running in assisted conditions. For resisted sprints, running direction was the opposite. Running performance was measured between the two photocells (20-m) with a laser gun and infrared mat

nology AS, Langesund, Norway), which made it possible to measure and analyse contact and flight time, step length and frequency, and vertical stiffness [27] for each step during the 20-m sprints. The average of each left- and right-foot step created a step cycle, resulting in six step cycles in each 20-m sprint, and these step cycles were used in further analysis.

Statistical analyses

To assess the differences in the normal 20-m sprint times and kinematics during the cycles, attempts and conditions, a 3 (condition: resisted, normal, and assisted) × 4 (sprint attempt: 1, 3, 5, and 7) × 6 (step cycle 1–6) repeated analysis of variance (ANOVA) was used. In addition, a 3 (condition: resisted, normal, and assisted) × 3 (sprint attempt: 2, 4, and 6) × 6 (step cycle 1–6) repeated analysis of variance (ANOVA) was also applied to compare the kinematics when running with resisted and assisted 20-m sprints with normal 20-m sprint. When significant differences in sprinting times and kinematics were found, a two-way ANOVA (attempts and step cycles) was also conducted to locate the eventual changes for each condition. Post hoc comparisons with the Holm-Bonferroni correction were employed to locate the differences. The level of significance was set at $p < 0.05$ and all data were expressed as mean ± *SD*. When sphericity assumptions were violated, Greenhouse-Geisser adjustments of the *p*-values were reported. The criterion level for significance was set at $p < 0.05$. The effect size was evaluated with η^2 (partial eta squared), where $0.01 \leq \eta^2 < 0.06$ constituted a small effect, $0.06 \leq \eta^2 < 0.14$ constituted a medium effect, and $\eta^2 \geq 0.14$ constituted a large effect [28]. Statistical analysis was performed in SPSS, version 22.0 (SPSS, Inc., Chicago, IL, USA). The reliability

of the sprint times and kinematics was based upon the first three normal sprints in the normal conditions and was tested by the intra-class correlation coefficient (ICC) based on Cronbach's alpha. The ICC of the electronic timing was 0.94, while the ICCs of the measured kinematics were 0.92 (running velocity), 0.97 (contact times), 0.94 (flight times), 0.87 (step length), 0.95 (step frequency), 0.98 (vertical stiffness).

Results

The mean resisted or assisted 20-m sprint times were respectively 7.3% slower and 7.5% faster than the normal sprints. A trend (*p* value between 0.05 and 0.10) was found ($F = 2.8$, $p = 0.094$, $\eta^2 = 0.22$) between the sprints (1, 3, 5, and 7: normal sprints), but not between the conditions ($F = 1.1$, $p = 0.352$, $\eta^2 = 0.10$). The post hoc comparison revealed a significant increase in sprint times from run 1 and 3 with run 5. When a two-way ANOVA was performed per condition, only in the normal ($F = 3.2$, $p = 0.033$, $\eta^2 = 0.19$) and resisted ($F = 4.2$, $p = 0.01$, $\eta^2 = 0.21$) conditions was a significant effect observed; a non-significant medium effect was noted for the assisted conditions ($F = 0.81$, $p = 0.50$, $\eta^2 = 0.07$). The post hoc comparison proved that in the normal conditions, the sprint times increased from run 1 and 3 with run 5, and that in the resisted conditions, the sprint times first decreased from run 1 to 3 (2%) and then increased again from run 3 to 5 to the times that appeared in run 1 (Figure 2).

However, no effect of protocol was observed for any kinematic variable ($F \leq 3.03$, $p \geq 0.076$, $\eta^2 \geq 0.02$). Only two trends were found between protocols: for contact time ($F = 2.80$, $p = 0.088$, $\eta^2 = 0.24$) and flight times ($F = 3.03$, $p = 0.076$, $\eta^2 = 0.28$). The post hoc com-
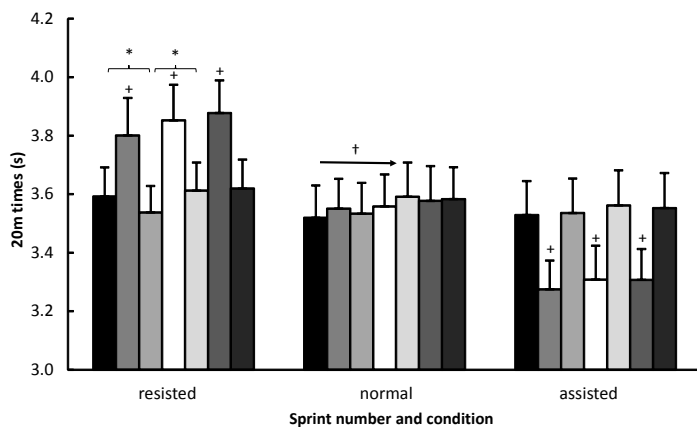
Figure 2. Average sprint times (± 95% confidence intervals) for the resisted, normal, and assisted protocol per run. * – a significant change between the two sprints, † – a significant change between the sprint and all those to the right of the arrow, + – a significant difference with the normal sprints

parison showed that contact times were shorter during the assisted than the normal conditions ($p = 0.004$, Figure 3), while flight times were longer during assisted than resisted conditions ($p = 0.03$, Figure 3).

A significant effect of the running attempt for contact time, running velocity, vertical stiffness, and step frequency ($F \geq 5.06$, $p \leq 0.007$, $\eta^2 \geq 0.36$), but not for flight time ($F = 1.73$, $p = 0.177$, $\eta^2 = 0.18$) or step length ($F = 2.99$, $p = 0.056$, $\eta^2 = 0.33$) was found (Figures 3 and 4). It was shown that, in the resisted conditions, running velocity, contact time, step frequency, and vertical stiffness were affected by running attempts, while for the normal conditions, the same variables were affected except for vertical stiffness. Running attempts only affected vertical stiffness and contact times in the assisted conditions (Figures 3 and 4).

Apart from the difference in sprint times when running resisted or assisted, no significant effect of running attempt was found ($F \leq 1.71$, $p \geq 0.196$, $\eta^2 \geq 0.02$, Figure 1). All kinematics were significantly affected by the condition (resisted or assisted). Since no significant ef-
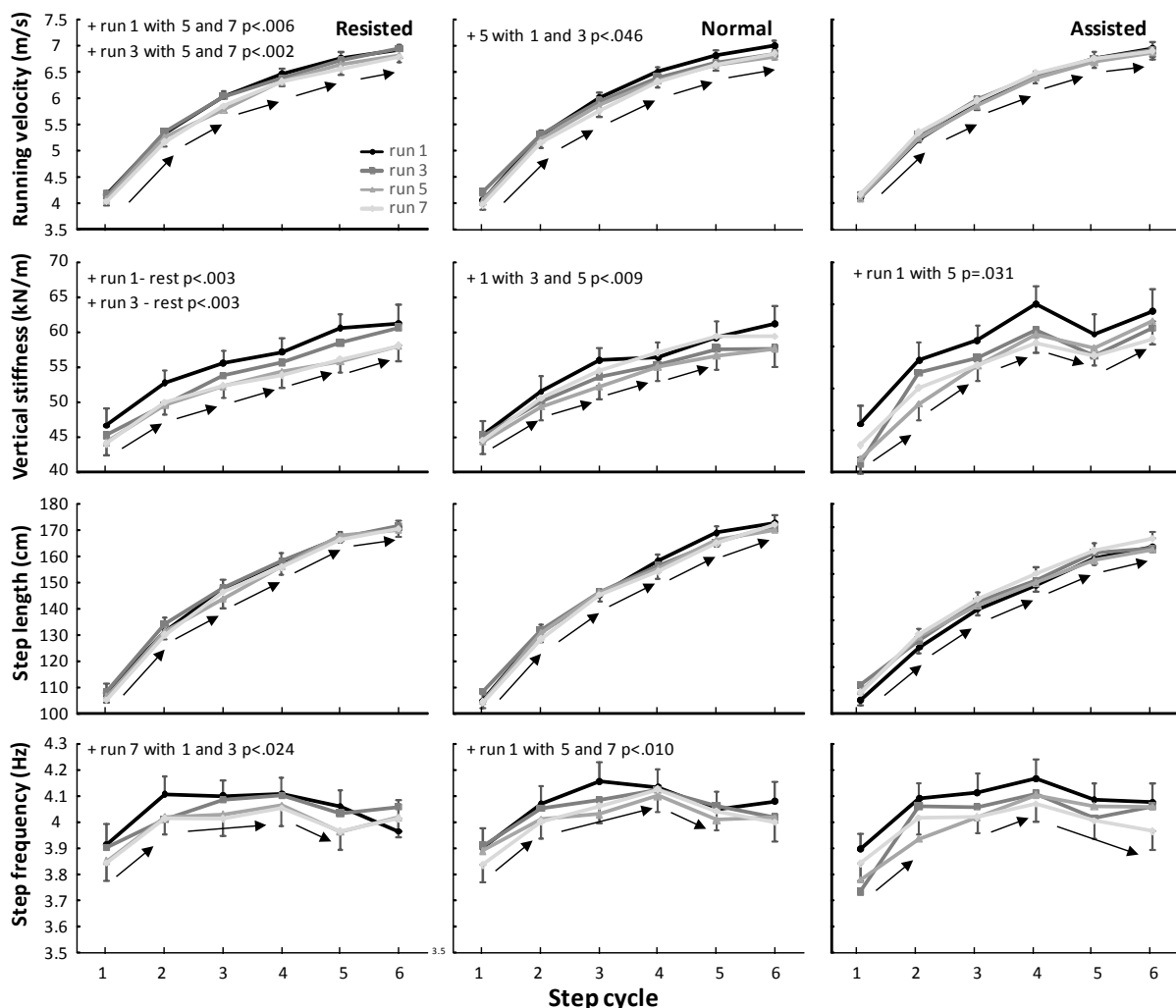

Figure 3. Average velocity, vertical stiffness, step length, and step frequency (± *SD*) per step cycle for the resisted, normal, and assisted conditions from sprints 1, 3, 5, and 7.→ – a significant difference from the previous step cycle, + – a difference between the corresponding sprints
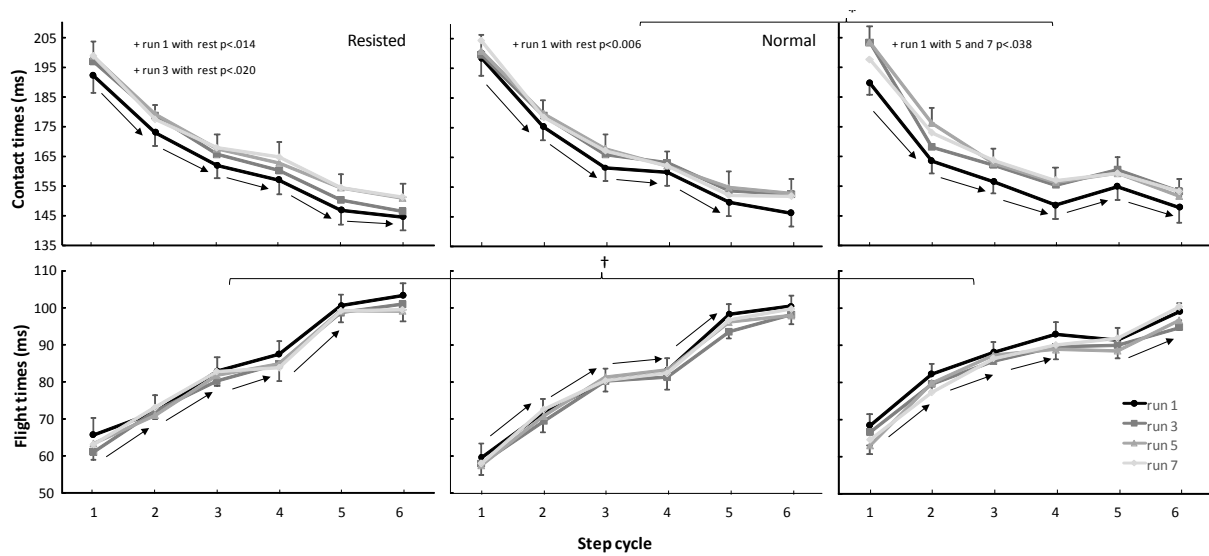
Figure 4. Contact and flight times (± *SD*) per step cycle for the resisted, normal, and assisted conditions from sprints 1, 3, 5, and 7. * – a significant difference from the normal sprint conditions, † – a significant difference between the assisted and resisted conditions, → – a significant difference from the previous step cycle, + – a difference between the corresponding sprints

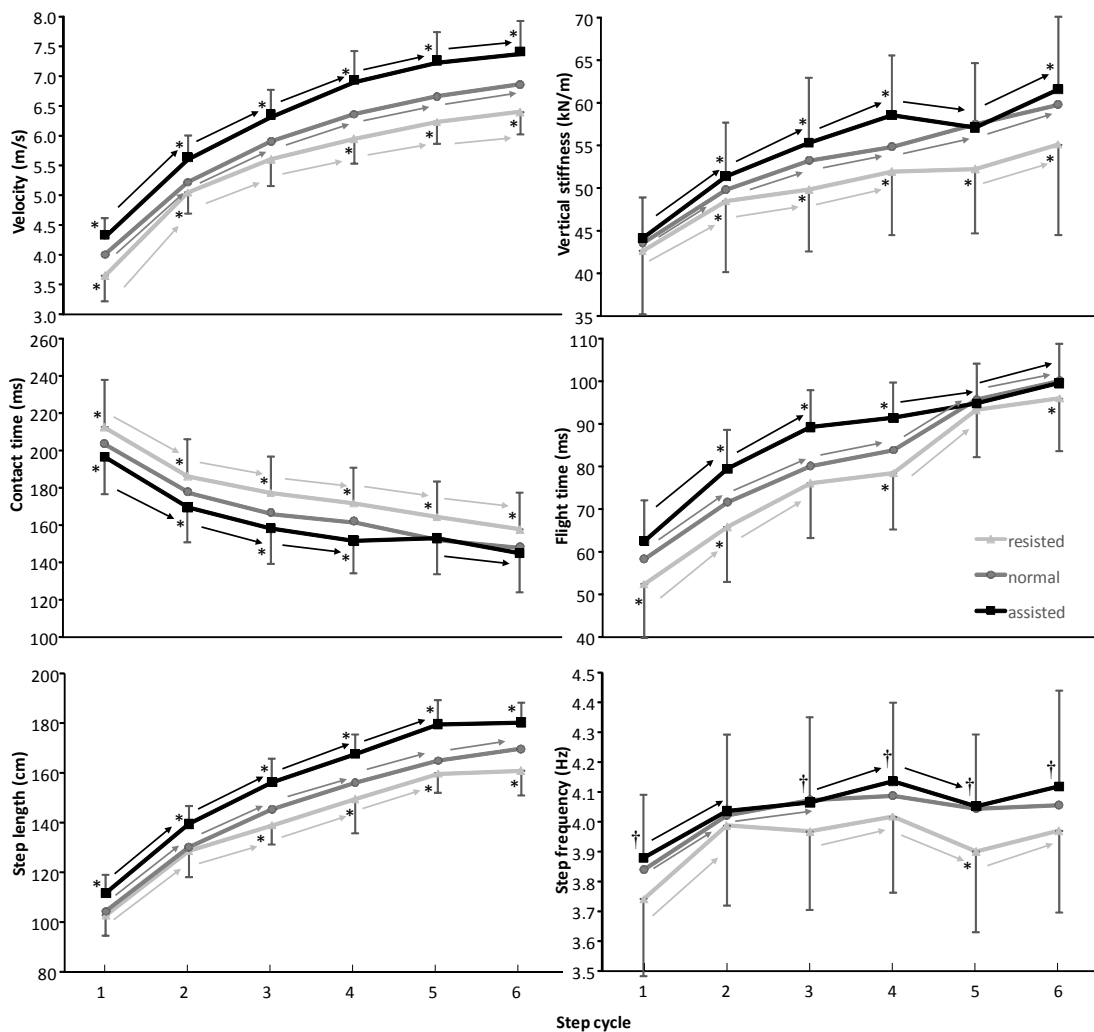Figure 5. Average velocity, vertical stiffness, step length, and step frequency, contact and flight time (± *SD*) per step cycle for the resisted, normal, and assisted conditions, averaged from sprints 2, 4, and 6. * – a significant difference from the normal sprint condition, † – a significant difference between the assisted and resisted conditions, → – a significant difference from the previous step cycle

fect of running attempt (run 2, 4, and 6) per condition was observed, the average of the three sprints per condition was used to investigate the kinematic differences between the three conditions. Running velocity increased with each step cycle for each condition, together with a significant increase in vertical stiffness, step length, and flight time, and a decrease in contact time for the normal sprints (Figure 5). Contact times decreased, while vertical stiffness increased significantly in each step cycle in the resisted and assisted sprints, except for cycle 4 to 5 in the assisted sprints (Figure 5). The step length in the resisted and assisted sprints only increased in each step cycle until cycle 5. Flight times increased significantly from cycle 1 to 2, 2 to 3, and 4 to 5 for both the resisted and assisted sprints, while in the assisted sprints an increase was also observed from cycle 5 to 6 (Figure 5). The step frequency increased significantly in all conditions from cycle 1 to 2, while it increased from 2 to 3 in the normal sprints, and in the resisted and assisted sprints it increased from step cycle 3 to 4; then it stabilized for the normal sprints and decreased and increased again for the resisted and assisted conditions (Figure 4). Between the conditions, running velocity, step length, flight times, and vertical stiffness were significantly higher in generally each step cycle for the assisted sprints and lower for the resisted sprints as compared with the normal sprints (Figure 5). The contact times were significantly lower in the assisted conditions and higher in the resisted conditions as compared with the normal sprints (Figure 5). Step frequency was significantly different between the assisted and resisted conditions, i.e. it was lower per step cycle in the resisted conditions than in the assisted conditions (Figure 5).

Discussion

The main finding was that only resisted sprints resulted in a faster running time in the first normal 20-m sprint after a resisted sprint in experienced team handball players. However, this was only the case after one resisted run. In contrast, assisted running did not cause any performance time changes to normal sprinting. Nevertheless, kinematically, during assisted sprinting, the velocity, step length, flight times, and vertical stiffness were generally higher for each step cycle and lower for the resisted sprints as compared with the normal sprints, while for the contact times the opposite was observed.

Kinematics and sprint time differences were comparable with those reported by Simperingham et al. [29], Lockie et al. [30], and Kristensen et al. [25], who involved respectively experienced field sport athletes [29, 30] and sports science students over 10 [30], 20 [25], and 40 m [29]; this indicates that the subjects in our study were of an experienced field sport athletes level. Only Kristensen et al. [25] applied a similar towing device, making it possible to compare the kinematics between the three conditions. However, they investigated the effect of re-

sisted and assisted training over a 6-week intervention and did not report any acute effects of resisted or assisted running on normal sprints.

To the best of our knowledge, only Simperingham et al. [29] investigated a possible acute effect of different resisted sprints with added lower body load on the kinematics of different phases of 40-m sprint performance in an elite male rugby player. They observed that a loaded warm-up with only 3% of additional load on the lower body during a standardized sprint warm-up decreased the 40-m sprint times by 4%. In our study, sprint times decreased after one resisted run by 2%, which was similar to the findings of Simperingham et al. [29]. However, it is difficult to explain the reported positive effect after the first resisted run by the observed kinematics. In the first normal run, the contact times were lower (Figure 4), and a higher vertical stiffness (Figure 3) was observed than in the later normal sprints. In addition, no higher running velocity per step was identified between the first and second run, while the velocity decreased in the following two normal sprints (Figure 3). One possible explanation for the faster running times in the second normal run could be the longer contact time. It could result in a more propulsive force being produced [9, 30, 31] during the steps, as Simperingham et al. [29] also found. Since the total step time (flight + contact time) did not change significantly ($p = 0.14$), this could increase the step length. However, the average step length over the 20-m sprints (from 1.47 to 1.48 m) did not increase significantly ($p = 0.53$). Furthermore, in the following normal sprints, the contact times increased (Figure 4), while vertical stiffness decreased together with the step frequency (Figure 3). This resulted in a decreased running velocity per step and a total increase in running time (Figure 2).

The observed changes in running kinematics are more likely caused by fatigue, since in the normal conditions the same changes were also observed in running kinematics (increased contact times, decreased step frequency and vertical stiffness), which also resulted in a lower running velocity per step (Figure 2) and increased 20-m times (Figure 2). From sprint 4 (normal protocol) and sprint 5 (third normal run) in the resisted protocol, slower sprinting times were found (Figure 1). They result from a decreased vertical stiffness and stride rate (Figure 3), and increased contact times (Figure 4). Simperingham et al. [29] also found slower sprint times after conducting drop jumps as a possible potentiation stimuli, which was related to a decreased vertical oscillation. These changes in kinematics after the second and third resisted sprints are suggested to result from greater peripheral fatigue.

A chain of events involved in muscle excitation contraction coupling, such as induced muscle action potential, reduced CA^{2+} release from the sarcoplasmatic reticulum, and fewer cross-bridge cycles [32], may cause a decrease in force and power and thereby induce kinematic changes, such as decreased vertical stiffness and stride rate (Figure 3), and increased contact times (Figure 4).

However, the increased contact times in the normal sprints after the resisted run could also result from short-term adaptation. During the resisted sprints, the contact time increased, while flight time, vertical stiffness, step frequency, and step length decreased as compared with the normal sprints (Figure 5), which could result in an adaptation for later sprints. In long term adaptation, Kristensen et al. [25] already found that after six weeks of resisted sprint training, step length decreased in normal sprints, owing to the fact that the resisted sprint group trained with a lower step length all the time. Furthermore, a limitation of the study is that we used a towing system with the same resistance and assistance for all subjects. Thereby, the effect of resistance for a strong athlete would differ from that for a weaker athlete. Seitz and Haff [33] suggested that stronger athletes were able to exhibit a greater PAP effect than their weaker counterparts, since they may have a greater percentage of type II muscle fibres and therefore a greater phosphorylation of the myosin light chain [34]. In addition, stronger athletes may have developed fatigue resistance to heavier loads after a near-maximal effort, which might affect the balance between potentiation and fatigue after the conditioning stimulus [33, 35].

Running velocity increased with each step cycle (Figure 5) in all conditions, as expected, since the distance was only 20 m, which is mainly responsible for acceleration. The increased running velocity per step cycle resulted from an increased step length, and decreased vertical stiffness and contact times, as shown in each condition (Figure 5). Step length in the resisted and assisted sprints did stabilize after the cycle 5, which could be an indication that the maximal step length for these conditions had been reached and, probably, the phase of maximal running velocity had started [29, 36]. Step frequency did not show the same pattern, and only increased from step cycle 1 to 2. Then it stabilized for the normal sprints, while during the resisted and assisted sprints it fluctuated, which could result from unfamiliar conditions for the athletes. Other factors indicating that the subjects were not 100% familiar with the resisted and assisted conditions were seen from step cycle 4 to step cycle 5, where a rapid increase in flight time was observed in the resisted sprints, a decrease in step frequency in both conditions, and a decrease in vertical stiffness in the assisted sprints (Figure 5). The decrease in vertical stiffness in the assisted conditions was caused by the increased flight time, while the contact time did not decrease from step cycle 4 to 5 [31].

No positive effect of the assisted sprints on the times and kinematics of normal sprints were found, which was surprising since it was expected that the shorter step time induced by the assisted sprints would have a short term adaptation effect to the normal sprints, as in the resisted condition. In long-term adaptation after a training period, this positive effect was observed [4, 25]. This discrepancy was probably due to the fact that the subjects were not familiar with this type of training. In team handball, resisted sprints are used in training, while it was the participants' first time with assisted sprints. However, some differences in kinematics were revealed between the normal sprints after the assisted sprints as compared with the other two conditions (normal and resisted). Contact times were shorter during the assisted conditions than in the normal conditions, while the flight times were longer during the assisted than in the resisted conditions (Figure 4), which indicates some adaptations due to the assisted sprints. Because of their inexperience with the assisted sprints, the subjects did not fully use the potential of the assisted force to run faster as they did not increase their stride rate as compared with the normal sprints (Figure 5), as Mero and Komi [10] found in overspeed sprints. The subjects probably did not move their legs faster than in the normal sprints, but owing to the pulling force, the flight phase increased and that caused a longer step length with the same lower leg movement. Therefore, it is possible that in the assisted conditions, the subjects did not have to perform at maximal intensity because they were pulled. Thereby, the muscles perhaps contracted not at the maximal effort; the preload stimulus was not high enough to result in any PAP.

Conclusions

The study shows that resisted running caused a positive acute effect in the normal 20-m sprint performance (2%) after the application of one resisted run in team handball players. However, this effect is observed only for one run. Employing several resisted sprints did not have any positive effect on the normal sprints, but caused fatigue, as shown in the increased contact times and decreased vertical stiffness, step length, and rate. Thus, for athletes and coaches it could be interesting to include one resisted sprint in the warm-up to enhance sprinting performance afterwards. However, future studies should be performed in which electromyography (EMG) and kinetics are included to gain more information about the effects of resisted and assisted sprints on normal sprints. The acquired evidence can help researchers, coaches, and athletes in their understanding of these training methods, of whether they should include these types of practice in their regular training and how much they should train to gain the best output.

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