THE EFFECTS OF ASSISTED SPRINT TRAINING ON SPRINT RUNNING PERFORMANCE IN WOMEN

Beata Makaruk, Paweł Stempel, Hubert Makaruk

Jozef Pilsudski University of Physical Education in Warsaw, Faculty of Physical education and Health, Biala Podlaska, Poland

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Abstract
The purpose of this study was to assess the effects of assisted and free sprint training on the kinematics of 20 m flying sprints. Thirty-six physically active female sports college students participated in a randomized controlled study. An assisted sprint training group (AST, n=12) and free sprint training group (FST, n=12) completed a 5-week periodized training program, while a control group (CON, n=12) did not perform any regular speed exercises. Mean running velocity, stride length, stride frequency, knee angle at toe off and footstrike, ground contact time, and flight time were recorded pre-training, post-training and detraining (3 weeks after the program). The speed test involved 20-m flying sprint using a run-in distance of 20 m from a standing start. Both the AST and FST groups improved running velocity ($p<0.05$), increased stride frequency ($p<0.05$) and decreased ground contact time ($p<0.05$) after the training programs. In addition, the AST group reduced flight time and showed a decrease in knee angle at toe off ($p<0.05$). Only the AST group maintained changes induced by training in running velocity and ground contact time after the detraining period. These results suggest that assisted and free sprint exercises may enhance speed during a 5-week training period in physically active women but speed gains after assisted sprint training are more persistent.

***Key words**:* overspeed, supramaximal sprint training, residual training effect, stride length, stride frequency

Introduction

Sprint running is a crucial component of many sports, including athletics and team sports (Baechle & Earle, 2006). From a biomechanical point of view, sprint running depends on an integration of stride length and stride frequency that corresponds with ground contact time and flight time (Mero, Komi, & Gregor, 1992). Research showed that sprint training programs improved speed running by utilizing different patterns of stride kinematics changes. For example, Makaruk, Sozański, Makaruk and Sacewicz (2013) investigated the training effects of a resisted sprint program in physically active women and demonstrated that increasing running velocity during the acceleration phase was accompanied by an increase in stride length and a decrease in stride frequency. In turn, the second experimental group in their study trained under free sprint training program (with no external load or forms) and increased their locomotion speed and stride frequency but their stride length did not change. Interestingly, Zafeiridis, Saraslanidis, Manou, Ioakimidis, Dipla and Kellis (2005) reported that resisted sprint training resulted in a significant improvement in running velocity in the acceleration phase but male participants of this study had no effect on running velocity in the maximum velocity phase. There were reverse trends in participants who completed free sprint training. Stride frequency increased only in the resisted training group in the acceleration phase, whereas step length increased in the free training group in the maximum velocity phase.

Assisted or supramaximal sprinting (overspeed condition) is another effective method of running speed enhancement. This method includes downhill sprinting, high-speed treadmill running, towing using a harness or stretch elastic tubing. Upton (2011), who used speed harness, observed that maximum 36.6-m velocity increased in female soccer athletes after a 4-week intervention period. Assisted sprinting appears to be an effective method to induce changes in stride frequency and running speed due to great neuromuscular stimuli induced by the overspeed condition (Mero, Komi, Rusko, & Hirvonen, 1987). It has was demonstrated by Paradisis and Cook (2006) that a 6-week downhill sprinting training was substantially more effective in improving 35-m maximum running speed when compared to free sprinting. This training also increased stride frequency with no changes in stride length. Murray, Harris, Adams, Berning and DeBeliso (2017) investigated a possible long-term use of combined assisted training (downhill running, towing, sprint ladders and single leg bounds) on the kinematics of 30 m, 60 m, and 120 m sprint distances in female and male collegiate sprinters and hurdlers. A 6-week program led to the improvement in running speed, stride length and stride frequency for all measured distances. In turn, Majdell and Alexander (1991) showed an increase in 40-yd (36.6 m) dash time after 6 weeks of supramaximal sprinting but noted no significant changes in stride length and stride frequency.
Stretch tubing is one of the most popular methods of assisted sprint training. Because current studies are mainly associated with acute effects of stretch

tubing training on speed performance and stride kinematics and the results from these studies are inconsistent (Clark, Sabick, Pfeiffer, Kuhlman, Knigge, & Shea, 2009; Corn & Knudson, 2003), there is a gap in the literature with regard to sprint performance enhancement in response to chronic training with the use of the stretch tubing method. The findings of the previous research (Paradisis & Cook, 2006) indicated that sprint assisted methods are the most beneficial to enhancing speed in the maximum velocity phase. The purpose of the present study was to assess the effectiveness of assisted and free sprint training measured by the changes in speed performance and stride kinematics in 20-m flying sprints. There is only one study reporting residual training effects in specific sprint training (Makaruk et al. 2013). Residual training effects are defined as the retention of changes induced by training loads beyond a certain period after the cessation of training (detraining) (Issurin, 2008). From the theoretical and practical point of view, short-term (up to 4 weeks) training residuals are very important for designing training programs (Issurin, 2010; Mujika & Padilla, 2000). Therefore, the second aim of this study was to examine if assisted and free sprint training would produce similar short-term training residuals.

Methods

The study included female physical education students who did not do any sports professionally. However, due to the specificity of their university studies (8-10 hours of sports classes per week), they could be defined as physically active persons. The students were randomly assigned into one of the three groups. The first experimental group performed sprints with the help of the stretched tubing (AST, n = 12). The second experimental group performed runs in standard conditions (free sprint training, FST, n = 12), whereas the control group (CON, n = 10) participated in the tests only. Detailed characteristics can be found in Table 1. All the study participants were requested to refrain from taking part in any extracurricular physical activities. Prior to the experiment, the subjects were informed about the study protocol and the study aim. The research was approved by the Ethics Commission for Scientific Research of the University of Physical Education in Warsaw.

Table 1. *Detailed characteristics of the study participants*

Group	Age (years)	Body height (m)	Body mass (kg)
AST (*n* = 12)	21.5±0.8	1.70±0.06	63.3±6.4
FST (*n* = 12)	21.2±0.7	1.67±0.06	61.9±6.2
CON (*n* = 10)	21.0±0.6	1.67±0.08	62.8±6.1

AST – assisted sprint training group; FST – free sprint training group; CON – control group

Testing protocol

The test involved performing 20-m flying sprints using a run-in distance of 20 m (R_{20+20}) from a standing start, i.e. front foot forward just behind the starting line with the rear foot 30 cm in the back (Makaruk, Makaruk, Sacewicz, Makaruk, Kędra, & Długołęcka, 2009). Legs were slightly bent at the knees and the subject's trunk was slightly leaned forward. The participants were asked to perform the sprint at maximum speed. After taking the starting position, they began the sprint at any moment they liked and ran towards an easily visible finish line. Each study participant performed two attempts. The best result (higher mean running velocity) from two attempts was used for the analysis. The subjects had a 7-8-minute interval between the runs (Makaruk, Kędra, & Makaruk, 2008). During this period, they first rested passively for 4 minutes and afterwards they spent 3-4 minutes preparing for the test repetition. These preparations involved performing dynamic stretching exercises followed by muscle relaxation, according to the study protocol. Each participant performed the runs wearing sports clothes (a T-shirt and shorts). During a warm-up, they were dressed in a T-shirt and tracksuit bottoms. The tracksuit bottoms were taken off just before the run. A warm-up routine consisted of 5-minute light jogging followed by dynamic stretching exercises (7-8 mins) that engaged muscles which are the most crucial ones in sprints, i.e. hip, knee and ankle extensors and flexors. Consecutive exercises were separated by intervals lasting 10-15 s. After a general warm-up, the participants performed forward running with knee lifts (1x20 m) and heel kicks (1x20 m) as well as submaximal-intensity running (1x40 m). All the tests took place at an athletics track, with air temperature of 24°C and slight wind speed (0.2-0.5 $m \cdot s^{-1}$) measured with an electronic anemometer (Slandi 2000, Poland). The tests (R_{20}) were preceded by a pilot study which aimed to determine test reliability (R_{20}) and to apply proper towing force magnitude. Theraband® tubings were employed in the study. Their stiffness was defined by the producer in the following manner: stretching the tubing from 0.3 m to 0.6 m is equal to applying 22 N (www.thera-band.com). The subjects performed three runs in a random order: without the band and with a 10-metre tubing stretched over 30 m and 35 m. At the beginning of the runs, the towing force was equal to 34 N and 42 N, respectively. In the case of track and field athletes, the literature of the subject pointed to approx. 30-40 N (Clark et al. 2009). In the present study, the following criterion of adjusting the towing force was used: the subjects were supposed to reach the speed 4% higher than maximum running speed achieved in standard conditions. The participant who pulled the other participant had the band attached to the back of the belt, while the one being pulled had it attached to the front of the belt. Both participants began to run on two adjoining lanes at the same time. The pulling participants covered the distance of 40 m at a constant pace (10 m per 5 sec.). The pulled subject was asked to accelerate gradually in order to reach the maximum speed at 20 m (where a visible mark was placed) and maintain it for the rest of the distance to the finish line at 40 m (speed measurement in the phase of relative run stabilisation).

Kinematic analysis of the run

Kinematic parameters of the run were registered with the use of two digital cameras (Basler piA640-210gc, Germany) operating at a sampling frequency of 100 Hz. Moreover, StreamPix 3.34.0 software (Norpix, Canada) was used. The cameras were set perpendicular to the track 24 m away from it (fig. 1). The workspace of each camera covered a 10 m section of the track as well as 1 m before and 1 m after this space. The image overlapped at a distance of 2 m in the middle part. Strides 3 and 4 were analysed in the measurement field of each camera.

Five markers were placed on the body of the examined subject: at the height of the anterior superior iliac spine, trochanter major, lateral condyle of the tibia, malleolus lateralis and the fifth metatarsal (Makaruk et al. 2013). A 2-D cinematographic analysis was performed with the use of System APAS XP software (USA). The film was scaled using a flat calibration system. The following kinematic parameters of the stride were analysed:

1. *Mean running speed in the phase of relative stabilisation of the run between 20 m and 40 m* expressed with $m \cdot s^{-1}$. It was calculated on the basis of the following formula: stride length ÷ (ground contact time + flight time).
2. *Stride length* - was determined based on the distance (expressed in metres) from the tip of the front shoe at toe off to the tip of the opposite shoes at footstrike.
3. *Stride frequency* - was calculated based on the ratio of the number of strides to the time it took to perform them.
4. *Knee angle at toe off and footstrike* - was measured on the basis of the angle between the thigh and the shank, which was determined by the straight line running through the trochanter major and the lateral condyle of the tibia as well as by the line running through the lateral condyle of the tibia and the malleolus lateralis. The measurements were performed on the right lower limb.
5. *Ground contact time* - was measured on the basis of the time between footstrike and toe off.
6. *Flight time* - was measured based on the time between toe off of one foot and footstrike of the opposite leg.

Reliability of particular parameters, determined by means of the interclass correlation coefficient (ICC), was high and ranged between 0.79 and 0.92 (Makaruk et al. 2009).

Speed training programme

The main training protocol was preceded by a 4-week remedial training programme (realised twice a week). During training sessions no. 6 and 7, the study participants were being acquainted with the rules of stretch tubing training. Due to sprint training intensity, sessions were held twice a week for five weeks. The main training task involved running at an increasing speed over a distance of 20 m and trying to maintain this speed over the next 20 m. The subjects were asked to cover the second section of the distance (from 20 m to 40 m) at maximum intensity and the first part of it at a gradually increasing speed. Both training groups performed the same number repetitions and distances but in different conditions (Table 2). The AST group performed runs with the assistance of the stretched tubing (towing force was selected individually prior to the main experiment), whereas the FST group did their running tasks without the use of the band. The control group only attended curricular classes at university without performing any extra activities.

Table 2. *Sprint training performed by both experimental groups*

Week	Repetition x distance [m]*
1	3 x 20 (with 20 m run-in)
2	4 x 20 (with 20 m run-in)
3	5 x 20 (with 20 m run-in)
4	6 x 20 (with 20 m run-in)
5	4 x 20 (with 20 m run-in)

*- 5-minute rest periods, according to the protocol used by Corn and Knudson (2003)

Statistical analysis

Values of the parameters under investigation are presented with the use of mean and standard deviation (*SD*). Assessment of the normality of statistical distributions of the investigated variables was carried out using the Shapiro-Wilk test. Significance of differences between the analysed kinematic parameters of the stride was determined with the use of a two-way analysis of variance with repeated measures ANOVA 2 (groups) x 2 (time). When the result was significant, Tukey's test was employed. Statistical significance was set at $p<0.05$. Statistica v. 13.1 PL software was used for calculations.

Results

Mean ± SD values of kinematic parameters are given in Table 3. The following significant interactions were found for group (AST, FST, CON) x time (before and after the training program as well as in the detraining period): mean running velocity ($F_{4,66}=6.38$; $p<0.001$), stride frequency ($F_{4,66}=4.92$; $p<0.01$), knee angle at toe off ($F_{4,66}=2.84$; $p<0.05$), ground contact time ($F_{4,66}=3.69$; $p<0.01$) and flight time ($F_{4,66}=2.52$; $p<0.05$). After the training programs, the AST and FST groups improved their mean running velocity significantly ($p<0.05$) by 6.7% and 4.3%, respectively. Also, stride frequency increased and ground contact time decreased significantly ($p<0.05$) in both experimental groups. In addition, the AST group decreased ($p<0.05$) knee angle at toe off and increased ($p<0.05$) flight time after training. Three weeks after the completion of the program, mean running velocity was higher ($p<0.05$) and ground contact time was still shorter ($p<0.05$) compared to the values of these parameters attained prior to the program. In the FST group, mean running velocity and stride frequency decreased ($p<0.05$) after the detraining period compared to post-training results

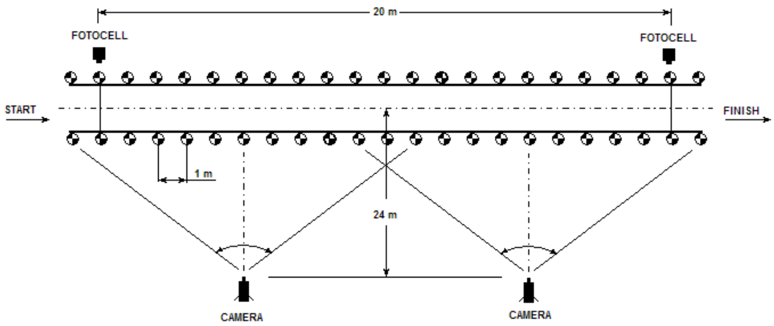

Figure 1. Graphic representation of testing condition

Table 3. Effects of sprint running training on sprint kinematics (mean± SD) in flying sprint test*

	AST	FST	CON
Running velocity (m·s^{-1})			
Pre-training	6.74±0.48	6.76±0.39	6.67±0.46
Post-training	7.17±0.47#	7.08±0.48#	6.75±0.67
Detraining	7.02±0.51#	6.80±0.45$	6.80±0.63
Stride length(m)			
Pre-training	1.78±0.08	1.73±0.07	1.75±0.07
Post-training	1.76±0.07	1.75±0.06	1.75±0.09
Detraining	1.78±0.07	1.74±0.06	1.76±0.09
Stride frequency (HZ)			
Pre-training	3.83±0.18	3.89±0.21	3.81±0.22
Post-training	4.04±0.18#	4.06±0.23#	3.84±0.25
Detraining	3.96±0.22	3.93±0.25$	3.88±0.33
Ground contact time (s)			
Pre-training	0.131±0.012	0.129±0.009	0.129±0.015
Post-training	0.120±0.012#	0.121±0.010#	0.131±0.012
Detraining	0.122±0.011#	0.127±0.008	0.130±0.015
Flight time (m·s^{-1})			
Pre-training	0.132±0.014	0.128±0.010	0.133±0.012
Post-training	0.125±0.011#	0.127±0.014	0.131±0.014
Detraining	0.127±0.013	0.130±0.011	0.130±0.014
Knee angle at toe off (degrees)			
Pre-training	167±6	165±8	166±8
Post-training	163±8#	168±10	167±10
Detraining	164±9	165±8	167±10
Knee angle at footstrike (degrees)			
Pre-training	148±8	151±7	153±8
Post-training	151±9	152±6	152±7
Detraining	149±9	152±6	152±6

*AST = assisted sprint training group; FST = free sprint training group; CON = control group.
#Significantly different ($p<0.05$) from pre-training measurements.
$Significantly different ($p<0.05$) from previous measurements.

Discussion

The main findings of the study indicate that assisted sprint training and free training are effective methods in increasing running speed. Both training groups increased stride frequency and reduced ground contact time. However, an increase in flight time and a decrease in knee angle at toe off were only observed in the AST group. Additionally, an increase in running velocity and contact time was maintained over 3 weeks after completing training (the detraining period) relative to baseline measures in the AST group, while the FST group demonstrated a decreasing tendency for running velocity and stride frequency. These observations have some useful implications for the implementation of assisted sprint training in the periodization of speed training.

Based on previous studies (Paradisis & Cook, 2006; Upton, 2011), it was expected that running speed would increase after 6 weeks of sprint training programs. In examining the possible mechanism for speed improvement in the present study, it is logical to suggest that speed gains in both training groups were produced by an increase in stride frequency and shorter contact time when compared to pre-training values of these kinematic parameters. This explanation is in agreement with previous works that examined the long-term effects of sprint training programs (Makaruk et al. 2013; Paradisis, Bissas, & Cook, 2013; Paradisis & Cook, 2006). Similar kinematic changes may suggest that the underlying mechanism of speed enhancement induced by assisted training is close to the mechanism evoked by free sprint training. However, despite the similarities, there were differences in changes in flight time and knee angle at toe off between assisted and free training. Both kinematic parameters changed only in the AST group. We assume that flight time decreased due to a reduced range of motion in the knee joint at the end of the propulsive contact phase. The knee angle at toe off is an optimal value in sprint running; therefore, this observation should be taken into consideration when planning speed training. Weyand, Sternlight, Bellizzi and Wright (2000) found that running speed is determined more by the rate of force development during the propulsive phase than speed of the leg during the flight phase. Thus, decreasing the knee angle at toe off may be associated with undesirable time reduction and a lowered rate of force development in the propulsive phase. This observation was previously confirmed by Mero et al. (1987), who showed that shorter ground contact time in supramaximal conditions was due to in the concentric portion of contact time. It appears that stride length was not significantly altered by either of the training programs. However, there were different tendencies in assisted and free sprinting training programs, which corroborates the assumption that both training programs might develop different sprinting movement patterns. Future studies should address further kinematic factors in sprinting that may be responsible for speed running improvement.

Detraining is the partial or total loss of performance adaptations caused by insufficient training stimuli (Mujika & Padilla, 2000). Training loads are intended to develop athletic performance as well as maintenance of specific performance adaptation after the cessation of a training program. The knowledge of the influence of a detraining period on sports performance is a current issue for planning and programming sports training due to illnesses, injuries, off-season breaks or other factors that result in reduction or training cessation. Therefore, it is important to identify residual effects of each type of training. We found that assisted sprint training contributed to the maintenance of positive post-training changes in running speed and ground contact time (in comparison with baseline values) and no significant changes in stride frequency relative to the post-training results. Conversely, running speed and stride frequency significantly decreased after the detraining period in the FST group. A possible explanation for beneficial residual effects of assisted training in the present study may be integrated with high neural activation of muscles induced by the overspeed condition. Research has documented that supramaximal sprints provided greater loading condition for the neuromuscular system compared to free sprinting (Mero et al., 1992; Mero et al., 1987). Their findings and the current results are consistent because Mero at al. (1992) found a significant correlation between stride frequency and changes in neural activation. It is worth noting that one previous study (Makaruk et al., 2013) investigated short-term training residuals in running speed training and also showed positive residual effects induced by non-specific (resisted) sprint training. However, the researchers revealed only one persistent change for stride length.

One consideration that needs to be investigated in future research is the possibility of a speed running level interaction, which may limit potential positive effects of assisted training. That is, non-athletes may have gains in speed performance by incorporating the stretch tubing method. In contrast, athletes may not display speed performance enhancements from the same characteristics of training program (volume, intensity, density of training loads). Using athletes in a replication of this study would be beneficial in a real sports training condition.

Conclusions

The implications of this study provide insight into the effects of assisted sprint training on critical kinematics in speed running. Specifically, the results indicate that assisted sprint training and free sprinting resulted in similar immediate positive changes in running speed, stride frequency and contact time in physically active women but the persistence of post-training effects was greater in the AST group than in the FST group. Assisted training may be an effective speed training method due to running sprint improvement and at least 3 weeks of beneficial residual training effects. In addition, we indicate that force towing approximately 4% higher than maximum running speed in standard conditions may be recommended in amateur training programs.

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Websites:
www.thera-band.com

Corresponding information:
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Correspondence to: Hubert Makaruk
University: Jozef Pilsudski University of Physical Education in Warsaw,
Faculty: Faculty of Physical education and Health, Biala Podlaska, Poland
E-mail: hubert.makaruk@awf-bp.edu.pl