KINEMATICS OF SPRINTING IN DIFFERENT ASSISTED CONDITIONS COMPARED TO NORMAL FREE SPRINTING IN TRAINED ATHLETES

Jürgen Birklbauer, Sascha Kratky, David Kreuzhuber and Erich Müller

Department of Sport Science and Kinesiology, University of Salzburg, Austria

The purpose of this study was to examine the kinematics of sprinting under different assisted conditions as compared to free sprinting in the top-speed phases. 13 trained athletes performed one trial of each of 4 conditions: with a rope-and-pulley towing device (TD); with a special sprint parachute causing a lift effect (SC); with both training devices combined (TD+SC) and in a normal free sprinting condition (FS). Average and maximum speed were measured with light barriers and a laser system. Stride length, stride frequency, contact time and flight time were collected with an optical acquisition system for eight strides. Statistical analysis found significant differences in TD, SC and TD+SC compared to FS for running speed (except TD+SC) and stride length, whereas stride frequency was significantly altered only in SC condition. Contact time significantly changed exclusively in TD+SC, shortened by 5 ms (4.5%). Further research is needed to clarify neuromuscular adaptations and controlled training studies have to be done to prove the usefulness of these training devices.

KEY WORDS: speed training, assisted training, towing device, sprint chute

INTRODUCTION: According to Carl (1983), special training devices include all equipment used in training allowing a systematic development of performance. Therefore, its use is indispensable in a goal-oriented training process. In both motor and action approach, the application of motor constraints is particularly recommended for technique and speed training; it allows the direct realization of the purposeful exercise and even enforces it respectively. According to the theory of elemental speed training (Bauersfeld & Voß 1992), set-ups reducing body weight (e.g., elastic-cord jumping device) are used to enable goal-oriented neuromuscular structures. In differential learning (Schöllhorn 1999) similar additives are applied to create differences in perception and movement which are relevant for learning. Thus, complex speed training includes methods that provoke a different neuromuscular activation at (supra)maximal running speeds. Commonly used in sprint training are elastic-cord towing, electrical winches, pulleys (Hücklekemkes 2002), or paragliders with a high lift effect to reduce body weight (Burger & Fehr 2005). The resulting biomechanical impacts are largely unexplained.

Mero and Komi (1987) investigated electromyography (EMG) and ground reaction forces (GF) during sprinting from sub- to supramaximal speeds achieved by a towing system. The results showed augmentations in preactivity and forces in the braking phase when running speed increased to supramaximum. In the propulsion phase non-significantly decreased forces, but significantly lowered integrated EMG were found at supra-maximal speed as compared to maximal running. Corn and Knudson (2003) examined selected kinematics in the acceleration phase of sprinting during towing with an elastic-cord. In contrast to free sprinting they detected significant increases in horizontal velocity, stride length and foot placement relative to the center of gravity, but no significant differences in stride frequency. They came to the conclusion that towed sprinting in the acceleration phase using an elastic cord may not be a sprint specific training method. LeBlanc and Gervais (2004) studied the kinematics of sprinting under assisted (AS) and resisted (RS) conditions during the acceleration and top-speed phases of trained sprinters. They didn't find significant differences between AS and normal free sprinting in the kinematic parameters stride frequency, contact time, trunk angle, thigh and knee range of motion, even though the sprinters were significantly faster caused by increased strides lengths in AS condition. It should be taken into consideration that LeBlanc and Gervais (2004) operated with a relatively low sampling frequency of 60 Hz.

In a case study with three male athletes, Burger and Fehr (2005) studied the consequences of two different parachutes and a cargo sledge in selected kinematic parameters compared to free sprinting. Besides a parachute with a round point of attack used in traditional resistance training, a sprint chute (Nasa-Sprint 170 by Co. SpoMess), developed at the University of Mainz, was analyzed as this one produces a lift effect similar to paragliders. Although this special sprint chute led to the biggest decrease in horizontal running speed, contact time was held constant or even reduced in two of the three athletes. The produced vertical force, causing a reduction of body weight, seems to compensate the negative aspects of conventional chutes and cargo sledges as used in resistance training (cf. Wild et al. 1999). Perhaps the effects resulting from lifting could be increased by compensating the occurring horizontal braking force through towing assistance.

The purpose of this study was to examine basic kinematic parameters of sprinting under different assisted conditions as compared to free sprinting in the top-speed phases. It was hypothesized that the application of the sprint chute in combination with towing would differ significantly, whereas towing or sprint chute assistance alone would not.

METHOD: 13 trained sprinters (1 female, 12 male; age 20.6 ±3.7 yrs; mass 77,0 ±7,9 kg) with an average 100-m-seasonbest of 11.49 s (10.64-12.85 s) took part in the study. All athletes were experienced with assisted and resisted sprint training or were instructed in the usage of the training devices in appropriate training sessions before.

The data collection took place at the indoor track facility at the University of Salzburg. Subjects performed 2 × 2 sprints over a distance of 30 m in their top speed zone. The time between runs was 30 min, time between sets was 120 min. Each of the four sprints was done in a different test condition (i.e., free sprint, towing sprint, sprint chute and combination of the last two). The order of the conditions was arranged in a Latin-square design to reduce any order effect. In all four test conditions, subjects were given a 30 m acceleration zone prior to the measuring area to reach top running speed and were instructed not to change their sprinting technique intentionally.

In the normal free sprinting condition (FS) neither assistance nor resistance was given. In the towing device condition (TD), the athletes were towed with a rope-and-pulley overspeed system including two deflection pulleys. One pulley was fixed at the wall 25 m behind the finish line; the second unfixed pulley was towed by a certified coach in the opposite running direction of the athletes. Individual counterweights of 15 % bodyweight on a cargo sledge were attached at the end of the rope to ensure similar relative towing forces. In the sprint chute condition (SC) a special parachute (Nasa-Sprint 170 from Co. SpoMess) developed at the University of Mainz was used. Due to properties like a paraglider and an accordingly dominant vertical force vector, the chute has a lift effect reducing the athletes' bodyweight during running. In the fourth condition the towing device and the sprint chute were applied simultaneously (TD+SC), aiming to compensate the horizontal deceleration force.

Running time was measured with two infrared light barriers at the beginning and at the end of the 30-m-'flying' sprint. To assess the maximum speed, a laser measurement system (LDM 300C-Sport) with a sampling rate of 100 Hz was used. The reproducibility of distance measurements stated by the producer is 1 cm, resulting in an accuracy of about 0.1 m/s around velocities of 10 m/s. To determine maximum speed, the original distance data were smoothed with a moving window of 500 ms; velocity was calculated as $\Delta s/\Delta t$ (Δt=250ms). Contact time, flight time, and stride length in the 30 m top speed phase were measured by an optical acquisition system (OptoJump from Co. Microgate) at a sampling rate of 1000 Hz. Eight strides prior to the last of each run were analyzed and averaged for further statistical analysis. The towing forces were recorded by a force transducer between the wall and the pulley of the rope-and-pulley system.

The statistical analysis of the kinematic parameters was done by using simple contrasts in an ANOVA for repeated measures (holding FS constant). The effect size partial eta-squared (η^2) was calculated to point out the degree of association between effect and dependent variable. In order to identify trends in relation to the speed performance level, the subjects were divided into two groups, one consisting of the six fastest and the other of the seven slowest athletes based on the 30-m-times in the free sprinting condition. Additionally, 2 × 4 ANOVA (group × test condition) as well as effect size were calculated.

RESULTS: Mean values and standard deviations of the relative towing forces and kinematic parameters of all 13 sprinters in FS and the three assisted conditions are presented in Table 1. The mean values of relative and absolute changes of stride length, stride frequency, contact time and flight time in all three assisted conditions in relation to normal free sprinting are shown in Figure 1.

Average and maximum speed significantly increased in TD with 5.9 % and 5.4 % compared to free sprinting ($v_{\varnothing 30}$: $p<0.001$, $\eta^2=0.89$; v_{max}: $p<0.001$, $\eta^2=0.85$), whereas SC led to a significant decrease of 6.4 % and 6.3 % ($v_{\varnothing 30}$: $p<0.001$, $\eta^2=0.98$; v_{max}: $p<0.001$, $\eta^2=0.96$). An increase of speed (+0.9 %) was also observed in TD+SC, however not significant ($v_{\varnothing 30}$: $p>0.05$, $\eta^2=0.19$ bzw. v_{max}: $p>0.05$, $\eta^2=0.37$).

The higher speed in towing assisted runs was due to a significant increase in stride length (Ø +5.4 %, $p<0.005$, $\eta^2=0.89$) with stride frequency remaining fairly unchanged ($p>0.05$, $\eta^2=0.00$). The reduction of speed during chute sprinting resulted from a shorter stride length (-3.9 %, $p<0.001$, $\eta^2=0.92$) and a lower frequency (-2.9 %, $p<0.001$, $\eta^2=0.81$). TD+SC led to a change in stride length (+2.3 %) only, as stride frequency remained nearly unchanged (1.4 %, $p>0.05$, $\eta^2=0.24$).

Contact time significantly altered exclusively in TD+SC, shortened by 5 ms (4.5%, $p<0.001$, $\eta^2=0.75$). 1.7 % shorter and 2.0 % longer contact times in TD and SC were slightly above the $p=0.05$ significance level (TD: $p=0.08$, $\eta^2=0.23$; SC: $p=0.06$, $\eta^2=0.27$). Mean values for flight time increased in all three conditions with the increase in towing remaining unsystematic. (TD: 1.3 %, $p>0.05$, $\eta^2=0.17$; SC: 3.8 %, $p<0.01$, $\eta^2=0.58$; TD+SC: 6.3 %, $p<0.001$, $\eta^2=0.71$).

Table 1 Means (standard deviations) of the relative towing forces and the kinematic parameters

Condition	Towing Force (% BW)	Average Speed (m/s)	Maximum Speed (m/s)	Stride Length (m)	Stride Frequency (n/s)	Contact Time (s)	Flight Time (s)
Free Sprint		9.49 (0.51)	9.61 (0.56)	2.19 (0.11)	4.35 (0.17)	0.105 (0.009)	0.126 (0.008)
Towing Device	4.2 (1.2)	10.05 (0.62)	10.13 (0.68)	2.31 (0.12)	4.35 (0.18)	0.103 (0.008)	0.128 (0.008)
Sprint Chute		8.88 (0.48)	8.91 (0.48)	2.10 (0.12)	4.22 (0.18)	0.107 (0.008)	0.131 (0.008)
Towing+Chute	4.3 (0.8)	9.56 (0.56)	9.66 (0.56)	2.24 (0.11)	4.29 (0.17)	0.100 (0.008)	1.134 (0.008)
Overall	4.3 (1.0)	9.46 (0.55)	9.52 (0.58)	2.20 (0.12)	4.29 (0.18)	0,105 (0.008)	0.129 (0.008)

In all conditions the significantly higher running speeds of the six fast sprinters compared to the slower ones result primarily from a lengthening in stride length of 7.7 % ($p<0.01$, $\eta^2=0.58$), with no significant 2.5 % increase in stride frequency ($p>0.05$, $\eta^2=0.11$). Although flight times were nearly identical in both groups ($\Delta_{slow\text{-}fast}<1$ %, $p>0.05$, $\eta^2=0.00$), contact time of the fast sprinters decreased by 6 %, being significant not until double sample size ($p=0.17$, $\eta^2=0.16$). No significant results were found for time × group interaction for all four kinematic parameters ($p>0.05$, $\eta^2_{SL}=0.03$; $\eta^2_{SF}=0.02$; $\eta^2_{FT}=0.03$; $\eta^2_{CT}=0.04$).

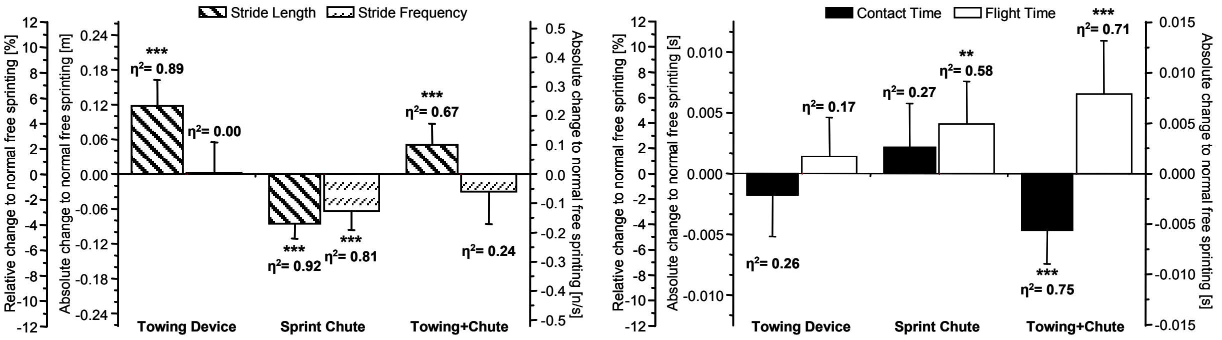

Figure 1: Relative and absolute changes of stride length and stride frequency [left] as well as contact time and flight time [right] to normal free sprinting (*p<0.05; **p<0.01; ***p<0.001; Effect size partial eta-squared=$SS_{condition}/(SS_{condition}+SS_{error})$).

DISCUSSION: Results of this study confirm the findings of previous research about towing assisted sprints, showing that supramaximal speed is caused by a bigger stride length but not to a change in stride frequency. This opinion is contradictory to the coaches' belief that overspeed training positively influences neural adaptations beneficial to higher stride frequencies. The small and non-significant reduction in contact time affirms the results by LeBlanc and Gervais (2004).

While in the case study by Burger and Fehr (2004) maximal running speed was reduced by 9.6 % to 12.3 % when using a sprint chute, the speed loss resulting from horizontal braking forces was only about half as much (4.6-7.7 %). Changes in contact time observed in towed runs could be largely compensated with the sprint chute, as demonstrated by Burger and Fehr (2004): 4 sprinters realized shorter, 9 athletes longer support times. The chute's lift effect and the resulting body weight reduction allow, despite slower running speed, contact times such as seen in free sprinting. Because of higher running speeds compared to SC, the combination of towing and sprint chute (TD + SC) causes a bigger lift effect as well. With this combined training devices the duration of the support phases was reduced most plainly in comparison to towing or sprint chute only: the test condition accounts for 75 % of contact time variance. A reduction of contact time was found in all athletes except one. The minimal and non-significant decline in stride frequency seems to avoid negative effects on central nervous time structure compared to SC.

Considering Burger and Fehr (2004), who measured vertical and horizontal forces with the sprint chute at the speeds of 4, 5, 7, and 9 m/s, body weight reduction and braking force in SC and TD+SC can be estimated with a trend calculation based on running speeds. Vertical unloading was found at 126 N (±7 N) in SC. Because of significantly higher running speeds in TD+SC, vertical forces increased by about 8 %, which is equivalent to a relative body weight reduction of approximately 18 % (±2 %). The thereby occurring horizontal braking effect of the chute was 52 N (±3 N), whereas the measured pulling force (32.7 N ±7.3 N) was clearly below this value. Despite the devices' missing horizontal force equilibrium in favour of braking forces, which were almost two thirds above the pulling forces, the sprinters achieved the same running speeds as in free sprinting. This can be interpreted as a consequence of the sprinters' reduced weight. The decline in contact time supports the demand of Ralph Mann (1999): he developed a movement model ('Elite Athlete Program') based on kinematic analyses of over 1000 competition sprints of a large number of elite sprinters, and proposed contact times as the key to success. Stride frequency, by definition, would increase with flight time remaining the same. Čoh et al. (1999) affirmed this postulate after analyzing the Slovenian female national sprint team with kinematic and electromyographic methods. The importance of support times is also confirmed by the comparison of the two advanced groups in our study: the faster sprinters realized clearly shorter contact times in all conditions than the slower sprinters, whereas flight time showed hardly any differences between the two groups. The reduction in support time, provoked by the combination of TD+SC, was alike for the whole inhomogeneous range of speed performance. Even the fastest sprinter (100-m-

SB: 10.64 s) reduced contact time by an average of 6 ms compared to free sprinting. Still, the direction of cause-effect-correlation between speed performance and contact time remains unclear without a training study and therefore must be judged with caution.

CONCLUSION: The results of this study pointed out that the combination of a special sprint chute (causing a lift effect) and a towing system (causing a decrease of the braking forces), as well as the consequential body weight reduction, lead to a positive change in fundamental kinematic sprint parameters. The isolated application of each training device does not result in the changes expected by coaches and predicted by producers. The decline of bodyweight and the resulting decrease in contact time in the top speed phase, obtained through the combination of both devices, could induce a force reduction in braking and propulsion phase. In the case of limited strength abilities, central nervous and neuromuscular adaptations could be positively influenced. The examination of those speculations through kinematic and electromyographic methods is a research objective for the future, keeping in mind that the benefit of any training device can only be clarified with the help of controlled training studies.

REFERENCES:

Carl, K. (1983). Training und Trainingslehre in Deutschland. Schorndorf: Hofmann.

Bauersfeld, M. & Voß, G. (1992). Neue Wege im Schnelligkeitstraining. Münster: Philippka.

Čoh, M., Milanovič, D. & Dolenec, A. (1999). Biomechanische Merkmale des Sprintschritts von Sprinterinnen der Spitzenklasse. *Leistungssport*, 29, 41-46.

Corn, R. J. & Knudson, D. (2003). Effect of elastic-cord towing on the kinematics of the accleration phase of sprinting. *Journal of Strength and Conditioning Research*, 17, 72-75.

Burger, R. & Fehr U. (2005). Theoretische Herleitung und erste Erprobung eines neuen Fallschirms als Trainingsmittel für Sprinter. In P. Wastl (Ed.), *Leichtathletik in der Diskussion* (pp 201-214). Hamburg: Czwalina.

Hücklekemkes, J. (2002). Den Speedy richtig einsetzen. *Leichtathletiktraining*, 13, 32-39.

LeBlanc, J. S. & Gervais, P. L. (2004). Kinematics of assisted and resisted sprinting as compared to normal free sprinting in trained athletes. *Proceedings of the XXII ISBS Congress* (p.536). Ottawa.

Mann, R. (1999). Biomechanische Grundlagen des Kurzsprints. *Leichtathletiktraining*, 10, 24-31.

Mero, A. & Komi, P. V. (1987). Elektromyographic activity in sprinting at speeds ranging from submaximal to supra-maximal. *Medicine & Science in Sports & Exercise*, 19, 266-274.

Schöllhorn, W. (1999). Individualität – ein vernachlässigter Parameter? *Leistungssport*, 29, 5-12.

Wild, S., Burger, R. & Letzelter, M. (1999). Fallschirmläufe im Training der Sprinter. Leistungssport, 29, 23-28.