COMPARISON OF STEP-BY-STEP KINEMATICS OF RESISTED, NORMAL AND ASSISTED 30 M SPRINTS IN EXPERIENCED SPRINTERS

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The purpose of this study was to compare step-by-step kinematics of resisted, normal and assisted 30m sprints in experienced sprinters. Step-by-step kinematics were measured using infrared mat and laser gun in sixteen subjects during each 30 m sprint under the respective condition. The main findings were that almost all measured kinematics were affected by resisted and assisted sprint conditions. The one exception was that step frequency did not show any marked differences between assisted sprint condition in comparison to normal sprints. It is notable that employing this approach in combination with laser gun and infrared mat over 30 m makes it straightforward to analyse step-by step kinematics under different conditions in training. This approach could provide coaches, researchers and athletes with more detailed information and monitor changes in kinematics during training.

KEY WORDS: step length, step frequency, contact time, flight time

INTRODUCTION: In many sports, sprint-running abilities are highly important. Two broad categories of specific training methods used to enhance sprint performance are resisted and assisted running (Clark et al., 2010; Kristensen et al., 2006; Majdell & Alexander, 1991). These respective approaches provide overload for different portions of the force-velocity curve. Specifically, resisted sprints emphasise force application, whereas assisted sprints provide a velocity focus (van den Tillaar, 2004). A number of different approaches have been employed for resisted sprint training, such as weighted vests, sled towing, parachute and other forms of towing, involving partner-resistance, elastic tubing or a pulley system. Commonly used assisted sprint training modes include running downhill (Paradisis & Cooke, 2001), or some method of towing to provide assistance (Kristensen et al., 2006; Majdell & Alexander, 1991). Few studies to date have investigated step-by-step kinematics during resisted and assisted sprinting.

Based on the studies to date, difference in sprint times between regular sprints and the resisted runs are generally attributed to some combination of a decrease in distance travelled each step and observed decreases in step frequency under the resisted condition (Cronin et al., 2008; Kawamori et al., 2014). When comparing assisted runs with regular sprints, the faster running times under the assisted condition were mainly a result of increased distance travelled per step, produced by longer flight time and shorter contact time (Mero & Komi, 1985).

There are however some practical limitations in the majority of studies that have investigated assisted and resisted running to date. Firstly, the measure of kinematics has involved expensive equipment like high-speed cameras (Cronin et al., 2008) or 3-dimensional motion tracking systems (Nagahara et al., 2014). Aside from issues of cost, the data recorded using these systems is time-consuming to analyse (Cronin et al., 2008) and the field of view for data collection is limited (Cronin et al., 2008; Lockie et al., 2013). There have been attempts to measure the kinematics in different parts of the run placing a force plate or cameras at varying distance to piece together a more complete view over a more extended distance during sprint efforts (Morin et al., 2015). The downside to this approach is that athletes have to run several times, and this may influence the results due to fatigue and variation across multiple efforts. Such limitations make it difficult to use these approaches during regular training and intervention studies to monitor and provide feedback following each run.

Therefore, the aim of this study was to employ an alternative approach to assess step-by-step kinematics and compare the acute effects of resisted and assisted conditions using a towing system during single 30 m sprint efforts in experienced sprinters.

METHODS: Sixteen male (n=11, age 27.7±10.0 years, body mass 83.2 ± 6.6 kg, body height 1.80 ± 0.06 m) and female (n=5, age 23.8±6.7 years, body mass 60.1 ± 4.2 kg, body height 1.68 ± 0.03 m) experienced sprinters with 100m personal best ranging from 10.3-12.5 (men) and 11.8-12.2 (women), were recruited for the study. Following a warm-up, all participants performed 3 maximal 30-metre sprint efforts under normal, assisted and resisted sprints conditions in an indoor facility wearing sprint spike shoes. The towing system used for the assisted and resisted runs was similar to the set up described previously in the studies of Kristensen et al. (2006). The loads employed provided 50 N resistance, and 82 N assistance, respectively. Sprint times were measured with two pairs of wireless photocells (SmartSpeed Timing Gate System, Fusion Sports, Australia). Participants initiated each sprint 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. Speed measurements were recorded continuously during each attempt using a laser gun (CMP3 Distance Sensor, Noptel Oy, Oulu,Finland) sampling at 2.56 KHz, and an infra-red mat of 30 m length recorded contact and flight times throughout the run (Ergotest Technology AS, Langesund, Norway), sampling at 500 Hz. These recordings were synchronised with the Musclelab 6000 system (Ergotest Technology AS, Langesund, Norway). This made it possible to measure contact and flight time directly with the infra-red mat, while step frequency and step length were calculated for each step by the formulas: Step frequency = 1 / (contact time + flight time) Step length = velocity * (contact time + flight time). The velocity for each step was derived from the laser gun. These parameters were calculated and available straight after each sprint. The best attempt for each condition was used for further analysis. Since not every participant took the same number of steps to cover the distance in each condition, only the initial 15-16 steps of the 30 m attempts were analysed.
To compare the step-by-step kinematics of the three conditions a two-way ANOVA (condition, steps) for each kinematic variable was use. The level of significance was set at $p<0.05$ and all data are expressed as mean ± SD. Statistical analysis was performed using SPSS 22.0 for windows (SPSS, inc., Chicago, IL).

RESULTS: The resisted (4.78±0.41 s) and assisted 30m times (4.01±0.26 s) were on average 12% slower and 6% faster, respectively, in comparison to the normal sprints (4.26±0.30 s). During the resisted sprints step velocity, step length, flight time and step frequency were decreased, and contact time was longer than the normal sprints. During the assisted sprints step velocity, step length and flight times increased and contact times significantly decreased in comparison to the normal sprints (Fig. 1).
Differences in step velocity were mainly a result of differences in contact times and step length that were apparent during almost all steps under the respective sprint conditions. Conversely, whereas flight time was different in most steps during the resisted condition, differences were only apparent in three steps during the assisted sprints when compared with the normal sprints (Fig. 1). The progression in step characteristics was approximately the same for the resisted and the normal sprints. An interaction effect was found with the assisted condition for step velocity, contact times and step length. Essentially, step velocity increased at each step during the normal condition, whereas in the assisted condition it was observed to plateau in the last two steps for most participants. A final notable finding was that the step length increased more from step 4 to 11 for the assisted condition in comparison to the normal condition (Fig. 1).

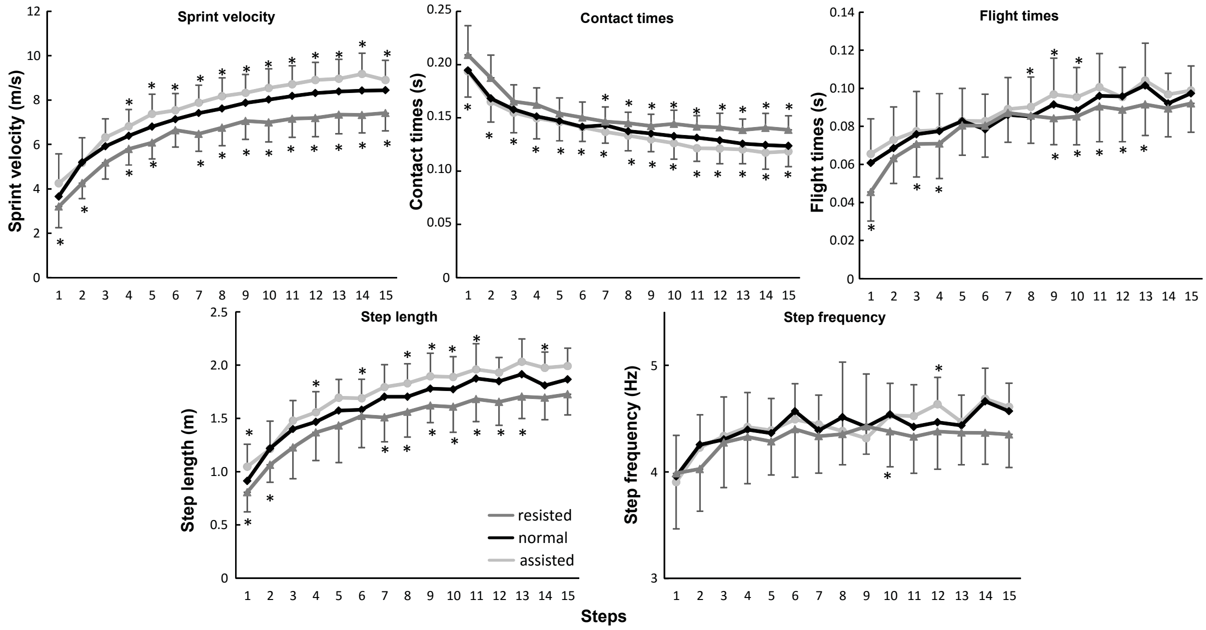

Figure 1: Average step velocity, length and frequency, contact and flight time (± SD) over all subjects for the resisted, normal and assisted 30m sprints. * indicates a significant difference with the normal sprints.

DISCUSSION: The majority of the measured kinematics were affected by the resisted and assisted sprint conditions employed in this study. The only exception to this was that step frequency did not show any marked differences for the assisted sprint condition in comparison to normal sprints. Differences in running time (+12.2%) and velocity measured at each step (-11.2%) under the resisted sprint condition were mainly caused by a decrease in step length (-10%) and flight time (-3.6%), longer contact times (+7.1%), and overall decrease in step frequency (-2.9%) over the resisted sprint. These changes were particularly evident from step 7 onwards during the resisted sprint (Fig. 1). These findings are broadly in line with previous investigations employing resisted sprints (Alcaraz et al., 2008; Cronin et al., 2008). The faster sprint times in the assisted condition (-5.9%) were mainly a result of increases in distance travelled per step (+5%), reflected in longer flight times (+4.5%) and shorter contact times (-2.8%). These findings are broadly in agreement with the investigation by Mero and Komi (1985) on elite sprinters (8.5 % faster in assisted runs). In the assisted condition, the differences in step velocity with the normal condition occurred after step 3. This was mainly caused by the difference in development of the step length between the two conditions. That it occurred from this point upon is in accordance with the 'first transition' during the acceleration phase when sprinting (Nagahara et al., 2014).

A reason that step frequency per step did not change between normal and assisted sprints could be that the athletes were simply not able to increase limb velocity to the degree required to achieve greater step frequency under the assisted sprint condition. Whilst the kinematics of lower limb joints and limb segments were not investigated in the present study, Mero and Komi (1985) previously reported altered shank (lower leg) and knee joint angles at touchdown during assisted sprinting in comparison to unloaded sprint efforts, which may be indicative of greater braking occurring at each step under the assisted sprint condition. Despite this assertion, distance travelled each step was greater under the assisted sprint condition, which indicate that any additional braking is compensated for by the added propulsion provided by the pulley. Similarly, the propulsion provided by the towing system allows participants to decrease the length of the contact phase at each step. The shorter contact times under the assisted sprint condition were accompanied by a longer flight phase

during step 8-10. It might be that the longer flight phase was due to more vertical oscillation of the participant's centre of mass, which may be the imitation for increasing step frequency. We might speculative that with greater exposure to the assisted sprint condition athletes may learn to make the necessary adjustments to allow them to increase step rate alongside the increases in step length. Some athletes did not have experience with the assisted sprint and perhaps a training period of several weeks could change the kinematic pattern positively by increasing flight time and the step frequency as Kristensen et al. (2006) showed after 6 weeks of assisted training. In general, step-by-step kinematics comparison measured with the infrared mat and laser gun were easy to perform. The results were direct available after each run and it was easy to measure possible difference in kinematics, which makes it easy to use as feedback in training. In future studies, kinetic and kinematic analysis of the different body segments during the sprints should be included to get a better understanding of the effects of assisted and resisted sprint conditions on these transitions.
A potential limitation of the study was that we used men and women of varying performance levels, which could cause possible differences in the kinematics. However, the main purpose was to investigate the acute effect on step-by-step kinematics of resisted and assisted sprints in experienced sprinters, which in general was similar for all athletes. More subjects from the same level or gender should be included before making statements about the effects of these conditions on different athlete populations.

CONCLUSION: Based upon the findings of the present study we can conclude that the majority of the sprint parameters measured were affected by the resisted and assisted sprint conditions. In terms of practical application, it is notable that employing this approach in combination with laser gun and infrared mat over 30 m makes it very easy to analyse step-by step kinematics in resisted, normal and assisted sprints in training.

REFERENCES:

Alcaraz, P. E., Palao, J. M., Elvira, J. L., & Linthorne, N. P. (2008). Effects of three types of resisted sprint training devices on the kinematics of sprinting at maximum velocity. *Journal of Strength and Conditioning Research,* 22, 890-897.

Clark, K. P., Stearne, D. J., Walts, C. T., & Miller, A. D. (2010). The longitudinal effects of resisted sprint training using weighted sleds vs. weighted vests. *Journal of Strength and Conditioning Research* 24, 3287-3295.

Cronin, J., Hansen, K., Kawamori, N., & McNair, P. (2008). Effects of weighted vests and sled towing on sprint kinematics. *Sports Biomechanics,* 7, 160-172.

Kawamori, N., Newton, R., & Nosaka, K. (2014). Effects of weighted sled towing on ground reaction force during the acceleration phase of sprint running. *Journal of Sports Sciences,* 32, 1139-1145.

Kristensen, G. O., van den Tillaar, R., & Ettema, G. J. (2006). Velocity specificity in early-phase sprint training. *Journal of Strength and Conditioning Research,* 20, 833-837.

Lockie, R. G., Murphy, A. J., Jeffriess, M. D., & Callaghan, S. J. (2013). Step kinematic predictors of short sprint performance in field sport athletes. *Serbian Journal of Sports Sciences,* 7, 71-77.

Majdell, R., & Alexander, M. J. L. (1991). The effect of overspeed training on kinematic variables in sprinting. *Journal of Human Movement Studies,* 21, 19-39.

Mero, A., & Komi, P. V. (1985). Effects of Supramaximal Velocity on Biomechanical Variables in Sprinting. *International Journal of Sport Biomechanics,* 1, 240-252.

Morin, J., et al. (2015). Acceleration capability in elite sprinters and ground impulse: Push more, brake less? *Journal of Biomechanics,* 48, 3149-3154.

Nagahara, R., Matsubayashi, T., Matsuo, A., & Zushi, K. (2014). Kinematics of transition during human accelerated sprinting. *Biology Open,* 3, 689-699.

Paradisis, G. P., & Cooke, C. B. (2001). Kinematic and postural characteristics of sprint running on sloping surfaces. *Journal of Sports Sciences,* 19, 149-159.

van den Tillaar, R. (2004). Effect of different training programs on the velocity of overarm throwing: a brief review. *Journal of Strength and Conditioning Research* 18, 388-396.