COMPARISON OF STEP-BY-STEP KINEMATICS OF NORMAL AND ASSISTED 60 M SPRINTS WITH DIFFERENT LOADS IN EXPERIENCED SPRINTERS

Roland van den Tillaar

Department of Sports Sciences, Nord University, Levanger, Norway

The purpose of this study was to compare step-by-step kinematics of normal and assisted 60 m sprints with different loads in experienced sprinters. Step-by-step kinematics were measured using inertial measurement units integrated with a 3-axis gyroscope and a laser gun in eleven participants during a normal 60 m sprint and sprints with a 3, 4, or 5kg pulling force. The main findings were that using increased assisted loads resulted in faster 60 m times, which was a result of a higher step velocity caused mainly by longer step lengths. In terms of practical application, it is notable that employing this approach, when using a 5 kg assisted load can help athletes reach higher step velocities and maintain these velocities longer, which could be a training impulse to move the speed barrier upwards.

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

INTRODUCTION: In many sports, sprint ability is highly important. There are different training methods used to enhance sprint performance. One of these methods is assisted running (Mero & Komi, 1985; van den Tillaar & Gamble, 2018). Assisted sprints are used to overcome the speed barrier, which is defined as the maximal running velocity that an athlete could reach. Different ways are used to create this assisted condition like downhill running (Paradisis & Cooke, 2001), running behind a car, or by using a pulley system (Kristensen et al., 2006; Majdell & Alexander, 1991). Some pulley systems, like elastic bands or be pulled by a partner (Mero & Komi, 1985), are not easy to control and are therefore, not easy to standardize the pulling force for research purposes.

Only a few studies have investigated the kinematics during assisted sprints (Kristensen et al., 2006; Mero & Komi, 1985; van den Tillaar & Gamble, 2018; van den Tillaar & Von Heimburg, 2017). In assisted runs, higher step velocities were found, which were caused by a longer step length and shorter contact times (van den Tillaar & Gamble, 2017, 2018; van den Tillaar & Von Heimburg, 2017), whereas Mero and Komi (1985) found a higher stride rate when performing assisted sprints.

However, van den Tillaar and colleagues (2017, 2018) have only investigated the effect of assisted sprints upon kinematics for the first 20-30m, while Mero and Komi (1985) has investigated kinematics during 10 m between 35 and 45 m. Moreover, these studies compared only one assisted sprint condition with the normal sprint. Furthermore, none of these studies investigated the whole development of kinematics from start to maximal velocity and the acute effect of assisted runs with different loads.

Therefore, the aim of the study was to investigate the effect of different assisted sprint loads upon step-by-step kinematics during a 60 m sprint in experienced sprinters. It was hypothesised that step velocity increases with increased assisted sprint loads and that this increase in step velocity causes a higher maximal velocity. This higher maximal velocity would be the result of longer step length and shorter contact times and higher step rate as found in earlier studies (Mero & Komi, 1985; van den Tillaar & Gamble, 2017, 2018).

METHODS: Eleven male (age 22.3±5.8 years, 74.8 ± 7.6 kg, 1.82 ± 0.08 m) experienced sprinters with 100m personal best ranging from 10.27-11.30 were recruited for the study. After a warm-up, all participants performed one normal 60m sprint followed by one 60 m sprint with 3, 4, or 5 kg pulling force employed by dynaSpeed (Ergotest Technology AS, Langesund, Norway). Thus, in total four sprints. Sprint times were measured with two pairs of wireless photocells (Brower Timing Systems, Draper, USA). 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 re-sampled at a rate of 10 Hz with a moving average of 100 msec to calculate step velocity. Contact and flight times throughout the run were derived from using wireless 9 degrees of freedom inertial measurement units (IMU) integrated with a 3-axis gyroscope. Sampling rate of the gyroscope was 200Hz with maximal measuring range of 2000 deg/s±3% attached to the dorsal side of each foot (Ergotest Technology AS, Langesund, Norway). Foot contact and flight time were recognized by the pattern that the angular velocity of plantar flexion/extension of both feet showed, which was determined in an unpublished pilot study that compared contact and flight time data measured with infrared contact mat over 30 m (Ergotest Technology AS, Langesund, Norway) with the patterns of the angular velocity of plantar flexion/extension (ICC=0.94). This made it possible to measure contact and flight time directly with the IMU per step, 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). All recordings were synchronised with the Musclelab 10.57 (Ergotest Technology AS, Langesund, Norway).
To compare the step-by-step kinematics of the three conditions a two-way ANOVA (condition, 30 steps) for each kinematic variable was use. When significant differences were observed, post hoc comparison with least mean difference were performed for pairwise comparison. The level of significance was set at $p<0.05$ and all data are expressed as mean ± SD. Statistical analysis was performed using SPSS 24.0 for windows (SPSS, inc., Chicago, IL). Reliability of the sprint times and kinematics was tested by intraclass correlation coefficient (ICC) based on Cronbach's alpha of the electronic timing was 0.94, while the ICCs of the measured kinematics were varying from 0.87 (step length) to 0.97 (contact times) measured in a previous study of van den Tillaar and von Heimburg (2017).

RESULTS: The 3 kg (6.94 ± 0.27 s), 4 kg (6.82 ± 0.26 s) and 5 kg assisted 60 m times (6.74 ± .26 s) were on average 1.9, 3.6 and 4.8 % significantly faster in comparison to the normal sprints (7.08 ± 0.26 s). Step velocity was also significantly different between the four conditions. Furthermore, an interaction in step velocity was found. Post hoc comparison showed that step velocity increased each step and that maximal velocity was reached at step 21: 39 m (normal sprint) or 22: 42.2-43.3 m (assisted sprint conditions). Velocity decreased again from step 23 for the normal and 3 kg assisted sprints. With the 4 kg assisted sprints, velocity decreased starting at step 25 and no significant step velocity decrease was observed within the 5 kg assisted sprints (Fig. 1). Significant differences between conditions in step velocity started from step 4.

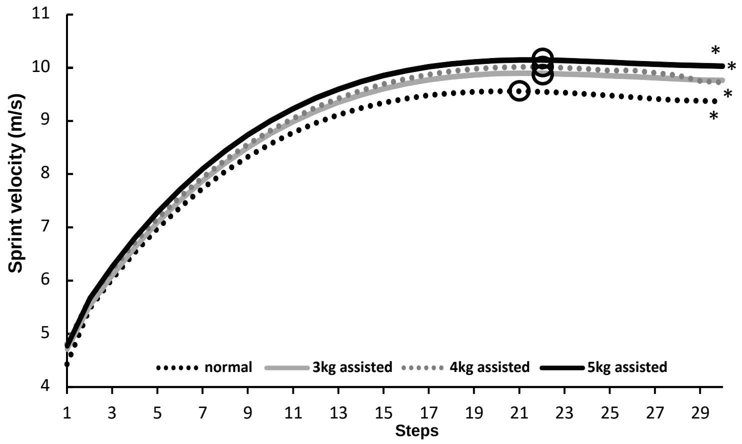

Figure 1. Average step velocity, (± SD) over all participants for the normal and 3, 4 and 5kg assisted 60m sprints. * indicates a significant difference in step velocity with the all other sprints. ʘ indicates step at which maximal velocity was reached for each condition.

Only a significant effect of condition was found for step length, which was significantly shorter in the normal 60 m sprints compared to the assisted sprints. Furthermore, step length was also shorter with the 3 kg load compared with the 5 kg assisted sprint (Fig. 2). Contact time did not change per condition significantly (p = 0.06). No significant effect of condition was found for flight time (p = 0.73) or step frequency (p = 0.63). All variables had a significant step effect (p < 0.001). Post hoc comparison showed that step frequency only increased from step 1 to 6 and then decreased again the last two steps, while contact and flight times respectively decreased and increased until step 17. Step length increased from step to step until it reached maximum at step 20 (Fig. 2).

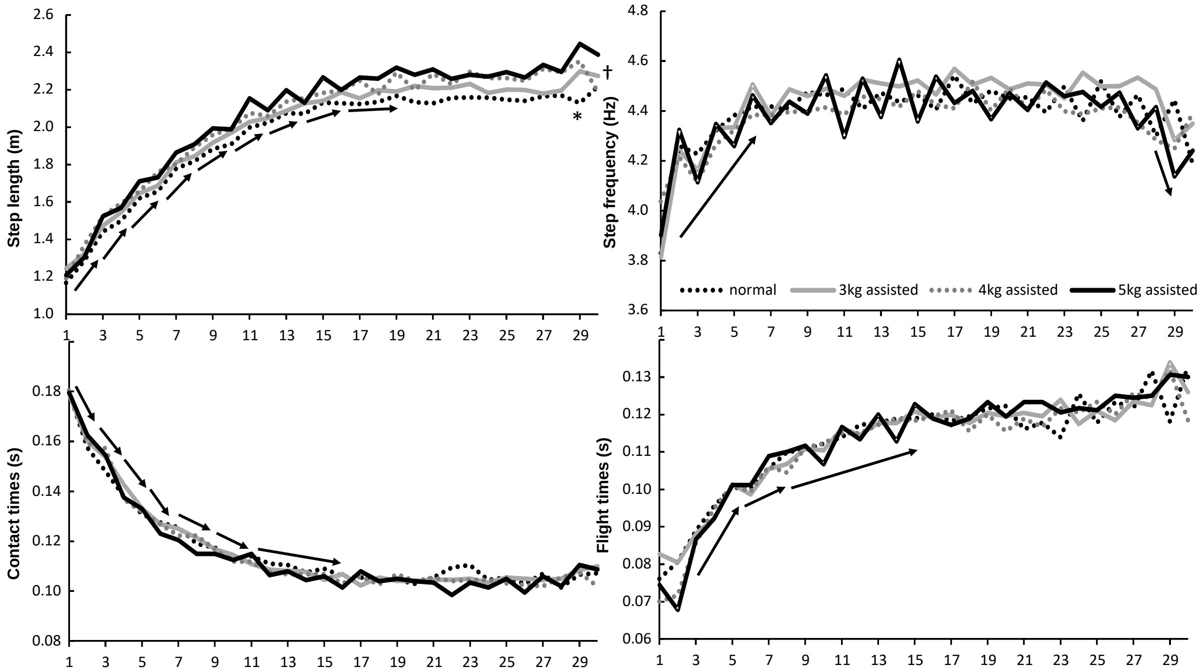

Figure 2. Average step frequency and length, flight and contact time (± SD) over all participants for the normal and 3, 4 and 5kg assisted 60m sprints. * indicates a significant difference with the normal sprints. † indicates a significant difference in step length between 3 and 5kg condition. → indicates a significant difference from this step to all right of the arrow.

DISCUSSION: The main findings in this study were that using increased assisted loads resulted in faster 60 m times, which was a result of a higher step velocity mainly caused by longer step lengths, which was measured during the entire 60 m. Sprint times were only 1.9, 3.6 and 4.8 % faster, which were lower than reported in earlier studies: 6% (van den Tillaar & Gamble, 2017) and 8.5% (Mero & Komi, 1985). These differences can be explained by the fact that van den Tillaar and Gamble (2017) used a higher pulling load (85 N) and that Mero and Komi (1985) only measured 10 m time (35 to 45 m). When comparing data from 35 to 45 m during the normal runs of the present study, step length (2.17 vs. 2.17 m), frequency (4.44 vs. 4.46 Hz) and velocity (9.55 vs. 9.65 m/s) were similar with those of Mero and Komi (1985) who used comparable athletes. The increases in velocity over this distance when pulled with 5 kg were now 6%, which is much more similar to what Mero and Komi (1985) reported.

The faster 60 m times when assisted were caused by reaching a higher maximal step velocity and holding this maximal step velocity longer as indicated by the velocity plateau in the 5 kg assisted sprint from step 22 and onwards, while in the normal and 3 kg assisted sprints, step velocity started to decrease again from step 23 and onwards (Fig. 1). It is interesting to see that the maximal step velocity was reached at almost the same step (step 21-22) for each condition that assistance with these loads did not influence time of occurrence of maximal performance. This maximal step velocity was caused by decreased contact time, increased flight time and step length, which reached their maximal value at steps 17 and 20. It indicates that assisted sprints can help to increase maximal step velocity, but not the time of occurrence of it. The cause of it could be that the athletes were simply not able to increase limb velocity more to the degree required to achieve shorted contact times and longer steps, and that the pulling force is compensated by a greater braking force occurring at each step under the assisted sprint condition. At around this point (step 22), the added propulsion provided by the machine is in balance with the braking force during touchdown caused by putting the foot more in front of the centre of mass. Whilst the kinematics of lower limb joints and limb segments were not investigated in the present study, Mero and Komi (1985) previously reported this at touchdown by altered shank (lower leg) and knee joint angles during assisted sprinting in comparison to normal sprints

Differences in step velocity with the normal condition occurred after step 3, which was similar to earlier studies (van den Tillaar & Gamble, 2017, 2018; van den Tillaar & Von Heimburg, 2017). This was mainly caused by the difference in development of the step length between the two conditions. This is in accordance with the 'first transition' during the acceleration phase when sprinting (Nagahara et al., 2014).

A potential limitation of the study was that we used men of varying performance level and experience with assisted sprints, which could cause possible differences in the kinematics. Perhaps with greater exposure to the assisted sprint condition, athletes may learn to make the necessary adjustments to allow them to increase step frequency 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 step frequency as Kristensen et al. (2006) showed after 6 weeks of assisted 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 sprint conditions with different loads on the step kinematics. In addition, more subjects from the same or higher level 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 different assisted sprint loads mainly affected increased step length, which resulted in faster runs. In terms of practical application, it is notable that employing this approach, when using 5 kg assisted load can help athletes reach higher step velocities and maintain these velocities longer, which could be a training impulse to move the speed barrier upwards.

REFERENCES

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.

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.

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., & Gamble, P. (2017). Comparison of step-by-step kinematics of resisted, normal and assisted 30 m sprints in experienced sprinters. *Conference proceedings of the 35th International Conference on Biomechanics in Sports 14-18 June 2017. Cologne, Germany*, 452-455.

van den Tillaar, R., & Gamble, P. (2018). Comparison of step-by-step kinematics of resisted, assisted and unloaded 20-m sprint runs. *Sports biomechanics*, 1-14.

van den Tillaar, R., & Von Heimburg, E. (2017). Comparison of different sprint training sessions with assisted and resisted running: effects on performance and kinematics in 20 m sprints. *Human Movement,* 18, 21-29.