COMPARISON OF KINEMATICS ON 30 M SPRINTS WITH 0, 10, 20, 30 AND 40% BODY WEIGHT OF ACTIVE RESISTANCE IN EXPERIENCED SPRINTERS

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The purpose of this study was to compare kinematics of un-resisted and active resisted 30m sprints with different loads in experienced sprinters. kinematics were measured using laser gun, contact mat and IMUs integrated with a 3-axis gyroscope in fourteen participants during an un-resisted 30 m sprint and sprints with a 10, 20, 30 and 40% of body weight (BW) active resistance. The main findings were that 30m times increased with resp. 16, 31, 51 and 77% from 3.95±0.28 (un-resisted) to 6.99 ±0.85 s (40% BW resistance). These increases were caused by lower maximal velocity reached earlier in the 30m sprints. The lower maximal velocity was a result of shorter step length, flight time and longer contact times. These changes were accompanied with lower maximal knee and hip extension, and plantar flexion velocities with increasing resistance.

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

INTRODUCTION: Sprinting is imperative for success in many sports, such as athletics, football and rugby. Therefore, improving sprint performance is one of the most important goals of training in these sports. Sprint training is primarily focused either on increasing strength and power, or on improving the efficiency of a certain movement (Petrakos et al., 2016). A widely used training method for increasing the sprint performance is resisted sprints (Alcaraz et al., 2018; Petrakos et al., 2016). In resisted sprints most often an external load is used such as weighted sled pulling/pushing (Bachero-Mena & GonzaLez-Badillo, 2014; Cronin et al., 2008; Petrakos et al., 2016). The challenge with weighted sled sprinting is friction, inertia of the sled and passive resistance. At the start an additional force is required initially, to overcome the effects of friction between the sled and the track surface, also called static friction (Cronin et al., 2008; van den Tillaar, 2018). When this force is overcome the sled will begin to move and then the friction between the track surface and the sled determines the total friction and load that has to be pulled. The resistance will become lower. Differences in friction due to this interaction (Linthorne & Cooper, 2013) makes it also difficult to compare different studies with each other (van den Tillaar, 2018).
Nowadays there are also pulley systems such as the 1080Sprint™ and Dynaspeed™ that can give a constant active resistance during the whole sprint by using a motor to employ a constant pulling force. van den Tillaar (2018) showed that with an active force equal to 10 and 20% of body weight employed with the DynaSpeed™ increased 30m times with resp. 13 and 27%, which was much higher than with weighted sled sprints with similar weights (Cronin et al., 2008).
Although many studies have discussed various biomechanical aspects of sprinting (Bezodis et al., 2008; Lockie et al., 2003), only a few have investigated these parameters in resisted sprints (Alcaraz et al., 2008; Cronin et al., 2008; Simperingham & Cronin, 2014). Almost all these studies based their results on analyses at the specific spot of sprinting and have not investigated the development of the kinematics per step. Furthermore, none of these studies has combined joint kinematics with running kinematics over the whole acceleration phase of resisted sprints with several different loads.
Therefore, the aim of the study was to investigate the effect of different active resisted sprint loads (10, 20, 30 and 40% of BW) upon spatiotemporal and joint kinematics during 30 m sprints in experienced sprinters.

METHODS: Fourteen male experienced sprinters (age 27±6 years, body mass 76.6 ± 8.8 kg, body height 1.80 ± 0.07 m, 100m: 10.81±0.45 s) performed, after an individualised warm-up,

two un-resisted 30 m, followed by 2x30 m with 10, 20, 30 and 40% of body weight in active resistance employed by dynaSpeed (Ergotest Technology AS, Langesund, Norway) in a random order. 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. Contact time and flight time was also recorded using an infra-red device covering 35 m in length, sampling at 1000 Hz. In addition three wireless 9 degrees of freedom inertial measurement units (IMU) integrated with a 3-axis gyroscope, sampling rate of the gyroscope was 200Hz and maximal measuring range of 2000 degrees/second±3% (Ergotest Technology AS, Langesund, Norway) were attached on the right lower limb to measure peak angular joint velocity of hip, knee and ankle during each stride. All recordings were further synchronised with the Musclelab 6000 system (Ergotest Technology AS, Langesund, Norway), allowing measures of contact and flight time, step length and step frequency to be derived for each step of the 30 m sprint efforts. These parameters were calculated and made available directly after each sprint bout. The best attempt for each condition was used for further analysis. To account for the difference in number of steps between the conditions, the data was interpolated to calculate the values at every ten (spatiotemporal kinematics) and twenty percent (joint kinematics) of total the distance.
To compare the kinematics of the resisted sprint a two-way ANOVA (resistance, distance) for each kinematic variable was used. When significant differences were found, 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).

RESULTS: Thirty-meter times increased with resp. 16, 31, 51 and 77% from 3.95±0.28 (un-resisted) to 6.99 ±0.85 s (40% BW resistance). All running kinematics were affected by resistance and distance. Post hoc comparison revealed that velocity increased every 10% to 90% of the distance in un-resisted sprints, while with increasing resistance the maximal velocity was reached earlier at 60% of the distance. After reaching the maximal velocity it decreased again significantly with the resisted sprints (Fig. 1). Contact time increased, while flight time, step length and step frequency decreased with more active resistance. Furthermore, contact times decreased over a longer distance (until 60% of distance) in the un-resisted sprints than with resisted sprints with increasing active load (only to 10% of distance). Flight time and step length increased over mostly the entire distance in the un-resisted sprints, while in the resisted sprints these parameters only increase until 40% of the distance. In step length it even decreases with resisted sprints with loads more than 20% from 80% of the distance (Fig. 1).
A significant effect of resistance and running distance was found for all peak angular joint movement velocities. Post hoc comparison showed that peak knee and hip extension velocity decreased with each load, while peak plantar flexion velocity decreased significantly from un-resisted to the 20% BW load condition and again from 30% BW to 40% BW load condition. Hip flexion velocity only decreased when the load was increased to 30 and 40% of BW condition (Fig. 2).
Peak plantar flexion and knee extension velocities increase from the first 20 to 40% of 30m distance in every condition, while hip flexion and extension only increased in this phase in the un-resisted and 10% BW conditions. In addition, in the un-resisted condition peak plantar flexion and knee extension velocities increased from 40 to 60 % of the distance and again for plantar flexion from 60 % to 100% of the distance (Fig. 2).

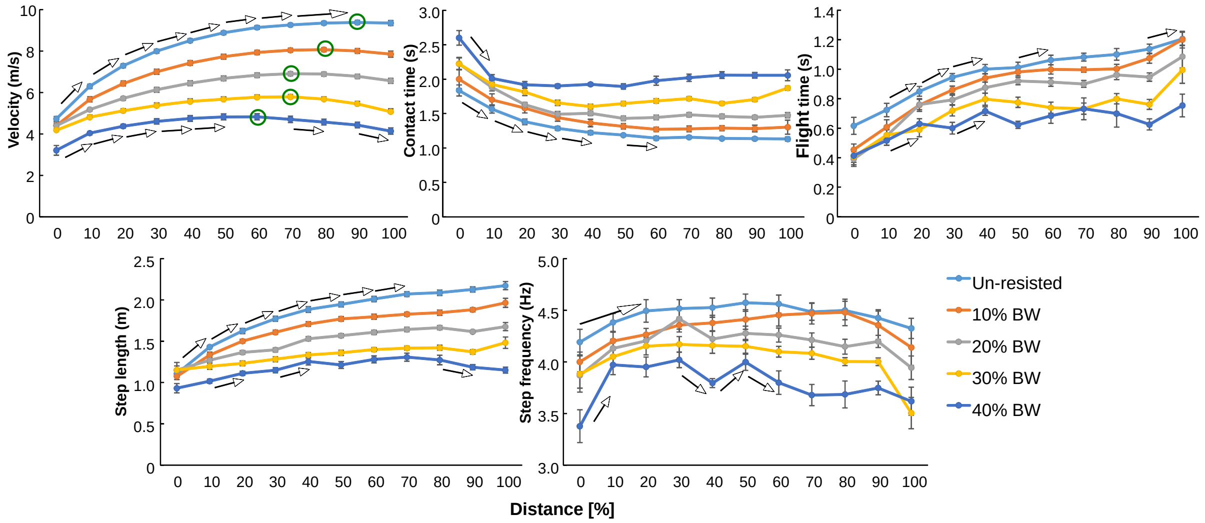

Figure 1. Mean spatiotemporal parameters per 10% of the 30m sprint for all resistances over all participants. → indicates a significant difference from this part (%) of the 30 m to all right of the arrow. ʘ indicates where maximal velocity was reached for this condition.

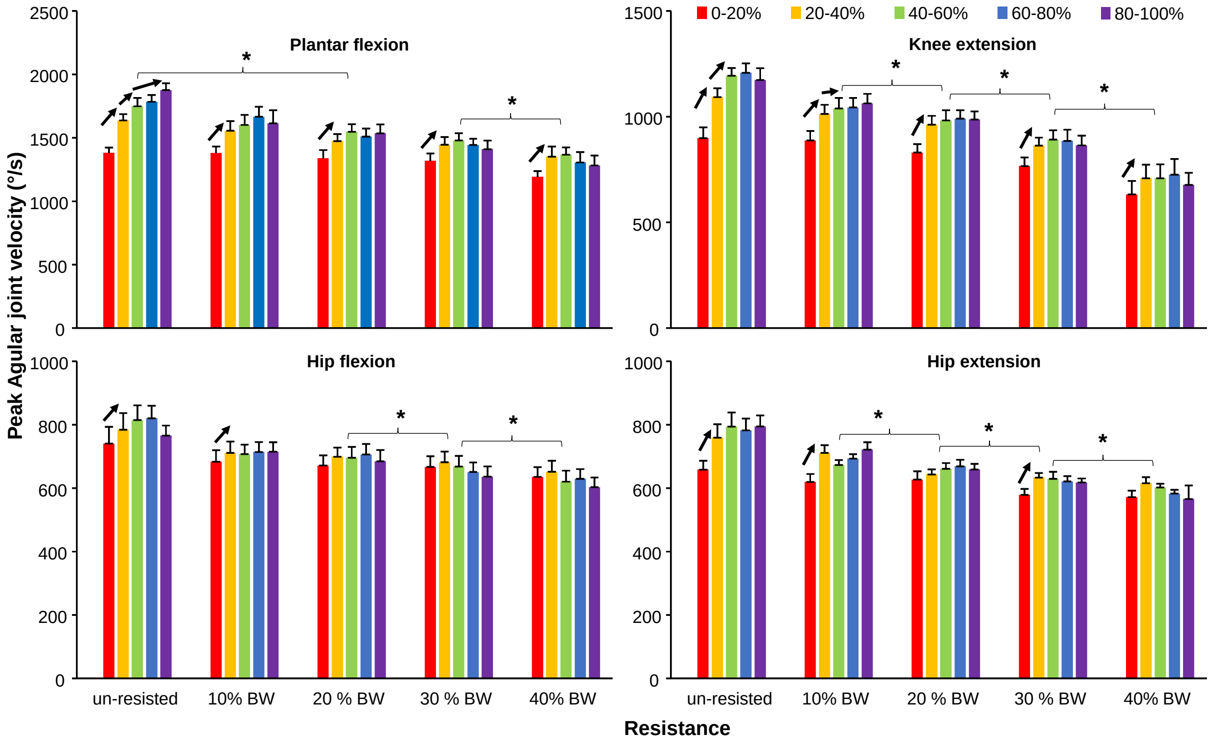

Figure 2. Mean peak angular velocities of the ankle, knee, and hip joint movement averaged per twenty percent of the 30m sprint for all resistances. * indicates a significant difference with between these two conditions. → indicates a significant difference from this part (%) of the 30 m to all right of the arrow.

DISCUSSION: The main findings were that using increased resisted loads resulted in slower 30m times, which was a result of a lower step velocity mainly caused by shorter step lengths and frequencies, flight times and longer contact times. Furthermore, peak joint kinematics also decreased with increasing loads. Sprint times were 30m times increased with 16 to 77%, which was much more than reported in earlier studies on resisted sled running (Cronin et al., 2008; Simperingham & Cronin, 2014) indicating that active resistance employed by Dynaspeed^{TM} causes more resistance than with sled towing. It seems that 40% BW active

resistance is similar to 80% BW with sled towing (Cross et al., 2017). Cross et al. (2017) showed that maximal velocity was reached at 25m while in the present study it is already reached after 18m (60% of distance) indicating that active resistance costs much more effort of the participants than sled towing. The lower maximal step velocity is mainly the result of shorter step length and flight time. Even with longer contact times (could produce more total force over time), contact time already reaches a plateau after just 3m as seen with 40% BW resistance, while step length and flight time reach this after 12m showing that maximal propulsion force is reached very early with active resistance.
These changes in spatiotemporal parameters were accompanied with lower maximal joint movement velocities with increasing resistance. Especially, knee and hip extension seem to be influenced most as peak velocities decreased with each resistance, which indicates that the gluteus maximus and quadriceps are getting targeted very much by increased resistance. Furthermore, it is observed that peak joint velocities increased with step velocity and since step velocity does not increase much with resistance, peak joint velocity only increased the first 12m of the resisted sprints (Fig. 2).
A limitation of the study was that no muscle activation and joint angles were measured that could confirm the statements and changes in patterning. In future studies, kinetic and kinematic analysis of body segments should be included to get a better understanding of the acute effects of active resisted sprint conditions with different loads on sprinters.

CONCLUSION: Based upon the findings of the present study we can conclude that resisted sprint loads employed with Dynaspeed^{TM} have a larger acute effect on running kinematics than sled towing with similar loads due constant active resistance. In terms of practical application, it is notable that employing this approach, it can help athletes to target muscles more at a shorter distance, which could be a training impulse to increase acceleration.

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