KINEMATIC CHARACTERISTICS OF RESISTED SLED SPRINTS UNDER DIFFERENT LOADING CONDITIONS

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The purpose of this study was to identify the kinematic characteristics of resisted sled sprinting under different loading conditions (0%, 10%, 20% and 30% velocity decrement (Vdec)) and in different sporting populations. Thirty-three healthy athletes (Sprinters n=10; Invasion team sport athletes n=23) were recruited and completed 3 days of testing. Kinematics were captured with high-speed cameras and processed using Dartfish Software. Loads of 20% and 30% Vdec resulted in a significant increase in trunk lean relative to unloaded sprinting, during both acceleration and maximum velocity phases, with no difference between groups (sprint & team sport athletes). This increase in trunk lean with load (20% and 30% Vdec) appeared to prevent athletes transitioning into upright maximum velocity mechanics, and therefore extended the distance of the acceleration phase. The trunk lean increase was related to the heavy loads and athletes were not able to reach mechanics that were truly reflective of maximum velocity (maxV) sprinting. However, heavy loading extended the distance over which it is possible to train acceleration.

KEYWORDS: resisted sprinting, kinematics, training specificity.

INTRODUCTION: The ability to improve sprint performance is a central training goal in numerous sports. With this in mind, coaches target increased force characteristics, and/or improved technical execution (Petrakos et al., 2016). Resistance training exercises such as squats are regularly employed to target improved force characteristics (Suchomel et al., 2018). However, the extent to which an increase in performance of these movements transfers to improved sprint performance may be limited (de Villarreal et al., 2013). The principle of specificity dictates that training should correspond to the functioning of the neuromuscular system in the specific event an athlete is training for and may explain the limited transfer from traditional resistance training to improved sprint performance (Haff et al., 2012). Considering this, the addition of an external load to the action of sprinting (using a weighted sled) may offer a more specific form of resistance training for athletes. However, the kinematic characteristics, and therefore specificity, of resisted sled sprinting is currently unclear. To elucidate this, the purpose of this study was to identify the kinematic characteristics (trunk lean) of resisted sled sprinting (RSS) under different loading conditions and in different sporting populations.

METHODS: Thirty-three athletes were recruited (Sprinters n=10; Invasion team sport athletes n=23; age (yrs)=21.4±3.3; height (cm)=185± 8.2; mass (kg)=80.2±11.8). Participants were recruited if they (a) had experience with resistance and sprint training (minimum of 18 months), (b) were currently strength training and had history of strength training for a minimum of two years, (c) were currently participating in sprinting, Rugby or Gaelic football and (d) were injury free (for at least 6 months). Participants were required to complete 3 testing days. Day 1 was a familiarization session. On day 2 participants completed 12 40 m sprints at different loads (unloaded and 10%, 20%, 30% velocity decrement, three sprints with each load), and on day 3 a battery of strength and power tests were completed. A first estimation for the loads was calculated with the equation from Lockie et al (2003).

After all familiarization trials were finished an individual load–velocity relationship was established for each participant and checked for linearity. The linear regression of the load–

velocity relationship was then used to establish the load that corresponded to a velocity decrement of 10%, 20% and 30% Vdec. Timing gates (Brower Timing Systems, Draper, UT USA) were set up at 5-meter intervals. Sprint time and average velocity was measured with the electronic timing system. Kinematics were measured using two high-speed cameras (HSC) (Sony DSC-RX10 IV, 500fps). The HSC were placed at a distance of nine meters from the middle of the athlete's lane (figure 1a). The optical axis of the HSC was perpendicular to the direction of running. Each of the 2 cameras had a field of view of 5 m. The first camera captured the first 5 m (0-5 m), which was considered the acceleration phase and the second camera captured 5 m between 30-35 m, which was considered the maximum velocity phase.

During piloting, it was observed that maxV occurred between 25 and 40 meters depending on athlete and load. From split times it could be determined when the athlete started decelerating. The cameras were used to compute trunk lean (angle between trunk axis and vertical axis), which can be seen in figure 1b. Before commencing the sprint trials, the participants performed a sprint-specific warm-up lasting approx. 15 minutes. The weighted sled was attached to each participant by a 3.6-m cord and waist harness to minimize lateral displacements during sprinting. All participants started 20cm before the first timing gate with a two-point stance to ensure gates were not triggered with hand or head. Exact foot position was marked out with tape. All subjects were given standardized verbal encouragement during their sprints. The athletes started with unresisted sprints (free sprints), then completed the rest of the loads in randomized order. A minimum 5-minute rest period was provided in between each sprint. Trunk lean angles were measured at toe-off (TO). Using the first frame in the video where the foot had left the ground, and at touch down (TD), using the first frame in the video where the foot had contact with the ground. Statistical analysis between and within groups was evaluated using a mixed-model ANOVA, followed by Bonferroni post-hoc tests. The first two steps of the acceleration phase and only one step of the maxV phase were assessed because early acceleration is known to demonstrate more changes in kinematics compared to the maxV phase, which is more constant (von Lieres und Wilkau et al., 2020). The significant level was set at 5%.

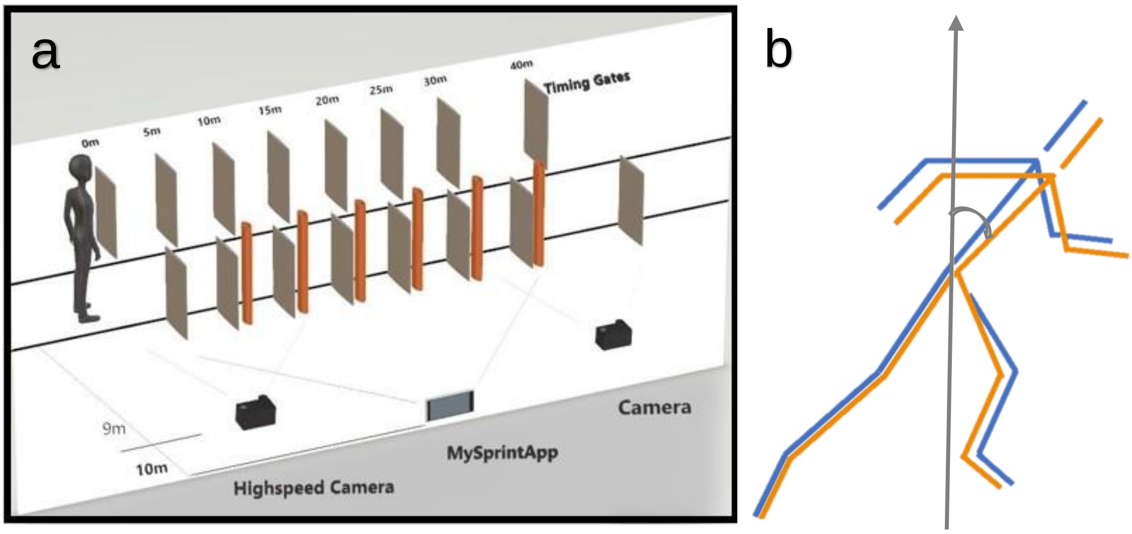

Figure 1: a) Experimental Set Up, b) Demonstration of how trunk lean was calculated.

RESULTS: Using the mixed-model ANOVA, no significant load group interactions were identified. In addition, there was no main effect for group for both acceleration and maximum velocity phase and no significant main effect for load for acceleration phase step one TD

(F(1.811, 50.704) = .436, p = .629, ηp^2 = .015) and TO (F(1.155, 32.340) = .219, p = .578, ηp^2 = .008). However, there was a statistical significant main effect for load in the findings for step two: at TD (F(1.994, 55.843) = 10.716, $p<0.05$, ηp^2 = .277), at TO (F(2.371, 66.389) = 21.165, $p<0.05$, ηp^2 = .430) and for maxV at TD (F(3, 60) = 13.831, $p<0.05$, ηp^2 = .409 and at TO (F(3, 60) = 22.476, $p<0.05$, ηp^2 = .529). The trunk angle was significantly greater (more forward lean) for all loading conditions for the acceleration phase TD and TO second step, as well as for 20% and 30% Vdec for the maxV phase, than in unloaded sprinting. Table 1 shows data of trunk lean at TD and TO for all athletes and sprint conditions, as there were no differences between groups.

Table 1
Kinematics of trunk angle for the acceleration and maximum velocity phase.

		Acceleration Phase		**Maximum Velocity Phase**
		Step1	**Step2**	
		Mean (±SD)	Mean (±SD)	Mean (±SD)
0% Vdec	**TD**	48.2° (±19.34)	34.3° (±7.16)	10.6° (±4.87)
	TO	45.7° (±19.40)	33.0° (±5.90)	9.9° (±5.52)
10% Vdec	**TD**	51.7° (±14.81)	38.7° (±7.61)*	12.8° (±6.76)
	TO	46.8° (±6.51)	37.3° (±6.71)*	13.5° (±6.97)
20% Vdec	**TD**	49.1° (±7.34)	42.2° (±12.31)*	16.6° (±8.33)*
	TO	47.8° (±5.90)	39.73° (±5.61)*^	19.5° (±6.00)*^
30% Vdec	**TD**	48.6° (±8.15)	41° (±7.49)*	23.3° (±9.95)*^
	TO	46.9° (±5.18)	40.2° (±5.39)*	24.3° (±8.66)*^~

* $p<0.05$significant difference to 0%.
^ $p<0.05$ significant difference to 10%.
~ $p<0.05$ significant difference to 20%.

DISCUSSION: Two groups, team sport athletes and sprint athletes, were chosen for this study because of the different physiological demands of the sport. The analysis indicated that both team sport athletes and sprint athletes respond to RSS in a very similar manner.

However, it appears that the addition of load to sprinting significantly increased trunk lean relatively to unloaded sprinting. Not all loading conditions displayed similar kinematics (trunk lean) and these may be specific for training the different aspects of a sprint based on criteria for specificity. Specificity is essential when designing training and there are many aspects of it. This study used only one of them and based it on movement similarities (joint angles). Trunk lean at acceleration and maximum velocity phase was significantly increased for all loading conditions.

During sprint acceleration the body, and subsequently the trunk, should be at an angle of 45 degrees as this position allows the runner to more easily apply a GRF that is oriented in a more horizontal direction, which is a key performance parameter (Morin et. al., 2011). The addition of load appeared to get athletes closer to this angle, based on trunk lean changes, although increase in trunk lean does not reflect that the lower body is aligned along the same axis. During RSS, an increase in trunk lean, may allow the foot to make contact with the ground closer to the athlete's center of mass (CoM). When leaning forward the CoM shifts away from the hip closer to the knee joint. This results in greater propulsive force, and may therefore reduce braking forces (Kugler et al., 2010). Morin et al. (2017) showed that greater sled load (20%-120% body mass) increased maximal horizontal force production and mechanical effectiveness (i.e. more horizontally applied force), suggesting increased trunk lean may be a positive change in acceleration kinematics. Existing studies (Kawamori et al., 2014a, 2014b, Weyand et al., 2000) have demonstrated that this may transfer back into normal sprinting.

During maximal velocity sprinting however, the body should be relatively upright, with the overall GRF oriented more vertically, to overcome the effects of gravity and so maintain maximum velocity. This does not mean that no horizontal force is applied, but vertical forces may play a more important role (Weyand et al., 2000, Docherty et al., 1988). In order to continue moving the sled with the heavier load (20% and 30% Vdec) it seemed necessary for the athletes to maintain more trunk lean to stay in a position that allowed greater horizontal force production, meaning a more angled position for longer, as it counteracted the weight of the athlete. Although this may indicate that RSS is less specific in terms movement specificity at heavy loads, this may allow athletes to increase the distance over which they can train acceleration mechanics.

CONCLUSION: Although trunk lean changed in the acceleration phase relative to unloaded, this appeared to actually place athletes in a more optimal position to produce horizontal forces. The results suggest that athletes, with the heavier loads, were not able to reach mechanics that are truly reflective of maxV phase. This may support the recommendation (Lockie et al., 2003) that training with lighter loads has an advantage in improving maximum velocity performance, as athletes were able to display maxV positions. However, the question is how kinematics will change over time, as only acute changes have been assessed in the current study. Further research is required to confirm if a heavy load has a negative transfer effect on trunk lean and maximum velocity sprinting mechanics over time.

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