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BRIEF NOTE

Effect of lower body explosive power on sprint time in a sled-towing exercise☆

Effet de la puissance explosive des membres inférieurs sur la performance en sprint avec traîneau résistif

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Biomechanics;
Countermovement jump;
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Summary
Introduction. — This study investigated the correlation between lower body explosive power and the rate of increase in sprint time with increasing sled weight in a sled-towing exercise.
Synthesis of the facts. — Eight male sprinters performed tests of lower body explosive power. The rate of increase in sprint time showed a strong correlation with countermovement jump height ($r = -0.73$) and with normalized peak power in a countermovement jump ($r = -0.81$) and a squat jump ($r = -0.80$).
Conclusion. — Inter-athlete differences in the rate of increase in sprint time might be due to differences in the athlete's power-to-weight ratio.

MOTS CLÉS
Biomécanique ;
Contre-mouvement saut ;
Sprint

Résumé
Introduction. — Cette étude examine la relation entre la puissance explosive des membres inférieurs et la pente de l'augmentation du temps de course en fonction du poids du traîneau dans un exercice de sprint avec traîneau résistif.
Synthèse des faits. — Huit coureurs masculins ont effectué des tests de puissance explosive des membres inférieurs. La pente de l'augmentation du temps de course a montré une forte

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corrélation négative avec la hauteur du saut en contre-mouvement ($r = -0,73$) et avec la puissance maximale normalisée lors du saut en contre-mouvement ($r = -0,81$) et du saut en squat ($r = -0,80$).
Conclusion. — Les différences inter-athlètes dans la pente de l'augmentation du temps de sprint avec traîneau résistif pourraient être dues aux différences de puissance musculaire des membres inférieurs des athlètes.

1. Introduction

Sled-towing exercises are used to develop an athlete's sprinting ability, especially the ability to accelerate rapidly off the mark. When training with a sled, the coach will often time the athlete over a distance of 20 m or 30 m and the increase in the athlete's sprint time relative to the time in unloaded sprinting is an indicator of the intensity of the exercise.

Many coaches use a trial-and-error approach when setting the weight of the sled. However, recent scientific studies have produced a deeper understanding of the relationships between the weight of the sled and the intensity of the exercise. For example, studies have shown that sprint time increases in proportion to the weight of the sled and that an athlete's sprint time increases on running surfaces with a greater coefficient of friction [1]. This work suggests that knowledge of an athlete's rate of increase in sprint time with increasing sled weight (on a given surface) should be useful to the coach when deciding upon the load for the athlete.

Many coaches set the weight of the sled to a percentage of the athlete's body weight so as to account for the fact that larger athletes tend to generate greater anaerobic muscular power. However, Linthorne and Cooper [1] found that even when the sled weight is scaled for body weight in this way, athletes can still show substantial differences (up to 25%) in their rate of increase in sprint time with increasing sled weight. Here, we suggest that inter-athlete differences in the rate of increase in sprint time are due to differences in the athlete's power-to-weight ratio. We suggest that when the sled weight is scaled for the athlete's body weight, athletes who possess a greater than average power-to-weight ratio have a lower relative stress placed on their sprint capabilities and so produce a faster sprint time than would otherwise be expected. This time advantage is expected to be even greater at higher normalized sled loads and therefore the athlete's rate of increase in sprint time with increasing sled weight should be lower than for an average athlete. That is, among a group of athletes we expect to see differences in their rate of increase in sprint time with increasing sled weight, with the lowest rates produced by athletes with a high power-to-weight ratio and the highest rates produced by athletes with a low power-to-weight ratio. The aim of the present study was to test whether measures of lower body explosive power were related to the athlete's rate of increase in sprint time in a sled-towing exercise.

2. Methods

Eight male sprinters with experience in sled-towing volunteered to participate in the study. The mean (± SD) age, stature, and body mass of the participants were 18.6 ± 3.7 years, 1.79 ± 0.07 m, and 73.4 ± 9.8 kg, respectively. This study was approved by the Human Ethics Committee of the Catholic University of San Antonio, the participants were informed of the procedures and inherent risks prior to their involvement, and written consent to participate was obtained.

The measures of lower body explosive power that were used in the study were the athlete's unloaded sprint time, jump height in a vertical jump, and normalized peak power in a vertical jump [2]. Three types of vertical jump were tested: a countermovement jump; a squat jump from an initial knee angle of 90°; and a squat jump from an initial knee angle of 120°. All jumps were performed with the participant's hands placed firmly on his hips (i.e., arms akimbo). The vertical force profiles of the jump trials were measured using a force platform that was sampled at 500 Hz. The participant's vertical velocity, v, at any instant during the ground contact phase of the jump was calculated from the force-time data using the impulse-momentum method, and the flight height of the jump (h) was calculated from the participant's vertical velocity at the instant of take-off (v_{to}) using $h = v_{to}^2/2g$, where g (9.81 m/s^2) is the acceleration due to gravity. The external mechanical power, P, generated by the participant at any instant was calculated using $P = Fv$, where F is the vertical ground reaction force at the corresponding instant. The participant's peak power was defined as the greatest instantaneous power that was generated during the ground contact phase of the jump, and this power was normalized by dividing by the participant's body weight.

The sprint trials and sled-towing trials were 30-m sprints at maximum effort from a crouched start and were conducted on a Mondo Sportflex Impronta athletics track. The participant's 20-m and 30-m sprint times were taken as the elapsed time obtained from sets of timing gates. For the sled-towing trials, a weighted sled (Power Sled; Power Systems, Knoxville, TN, USA) was attached to the participant by a 3.6-m cord and waist harness. The participants performed one unloaded sprint and three sled-towing sprints with the sled loaded to 8%, 13%, and 18% of the participant's body weight. The coefficient of friction of the sled when sliding on the running surface was 0.32.

The strength of the linear dependence between the variables was calculated using the Pearson product-moment correlation coefficient (r). An r value that is close to zero is usually designated as a ''negligible'' correlation, and the threshold r values for ''weak'', ''moderate'', ''strong'', and ''very strong'' correlations are ± 0.1, 0.3, 0.5, and 0.7, respectively. The 90% confidence interval of the correlation coefficient was calculated using the Fisher z transformation. However, with a sample size of eight the 90% confidence interval of a correlation coefficient is about ± 0.6. That is, in the present study we were not able to reliably distinguish between the categories of the correlation coefficient. Instead, we designated the correlation coefficient as ''unclear'' if the 90% confidence limits of the correlation coefficient spanned both weak negative and weak positive values, and otherwise the magnitude of the correlation coefficient was taken as the observed value [3]. Therefore, in this study a correlation coefficient was only considered to be ''clear'' if it was less than −0.56 or greater than +0.56.

3. Results and discussion

As expected, the participant's 20-m and 30-m sprint times when towing a weighted sled increased linearly with increasing sled weight, and there were substantial differences between the participants in the rate of increase in sprint time with increasing sled weight (Fig. 1). For the 20-m times, the rate of increase in sprint time ranged from 1.5 to 3.0 s per body weight, and for the 30-m times, the rate of increase in sprint time ranged from 1.9 to 4.1 s per body weight.

The correlations between the rate of increase in sprint time and the measures of lower body explosive power were similar for sled-towing over 20 m and 30 m (Table 1). As predicted, the rate of increase in sprint time showed a clear strong negative correlation with the flight height and normalized peak power in a countermovement jump and in a squat jump with an initial knee angle of 90°. However, the 120° squat jump showed an unclear but possibly weak or moderate correlation. Likewise, the rate of increase in sprint time showed an unclear but possibly moderate positive correlation with the participant's unloaded sprint time (over 20 m and 30 m).

We also observed a strong positive correlation between absolute peak power in a vertical jump and body weight; no clear correlation between vertical jump height and body weight; a strong negative correlation between sprint time and body weight; a negative correlation between sprint time and jump height; a negative correlation between sprint time and normalized peak power in a vertical jump; and a strong negative correlation between unloaded sprint time and flight height in a countermovement jump. These findings are similar to those from previous studies of

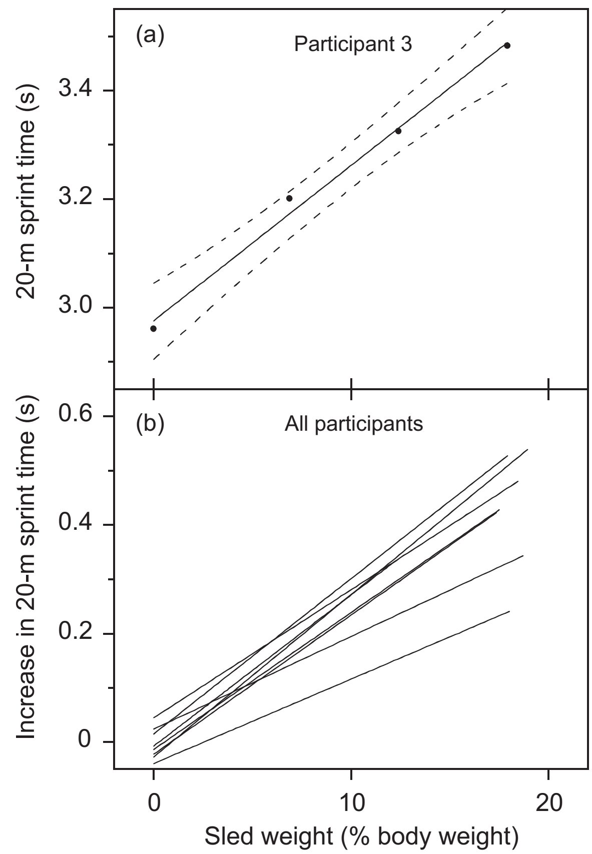

Figure 1 Plot (a) shows the linear increase in 20-m sprint time with increasing sled weight for a male sprinter (Participant 3). The solid line is the line of best fit and the dashed lines indicate the 95% confidence limits. The gradient of the line of best fit gives the rate of increase in sprint time for this athlete. Plot (b) shows that there were substantial differences in the rate of increase in 20-m sprint time with increasing sled weight within this group of male sprinters. Only the line of best fit for each of the eight athletes is shown; data points have been omitted for clarity.

Table 1 Correlation between lower body explosive power and the rate of increase in sprint time with sled weight when towing a weighted sled ($n = 8$).

Measure of lower body explosive power	Correlation with rate of increase in sled-towing sprint time	
	20 m	30 m
20-m sprint time	0.40	0.49
30-m sprint time	0.31	0.27
Flight height in a countermovement jump	**−0.73**	**−0.65**
Flight height in a squat jump from 90°	**−0.65**	−0.40
Flight height in a squat jump from 120°	0.04	0.13
Peak power in a countermovement jump	**−0.81**	**−0.70**
Peak power in a squat jump from 90°	**−0.80**	**−0.66**
Peak power in a squat jump from 120°	−0.35	−0.20

90° and 120° = initial knee angle. Clear correlations are in boldface.

sprinting and jumping [4], and suggest that the result from the present study regarding the strong correlation between the rate of increase in sprint time in a sled-towing exercise and measures of lower body explosive power would be observed in other groups of trained male athletes.

4. Conclusion

The aim of this study was to gain a deeper understanding of the relationships between the athlete's sprint time in a sled-towing exercise, the weight of the sled, and the physical qualities of the athlete. We found that even when the weight of the sled is normalized for the athlete's body weight, athletes can have substantial inter-athlete differences in the rate of increase in sprint time with increasing sled weight. We also found a strong correlation between the athletes' rate of increase in sprint time and measures of their lower body explosive power. This result indicates that inter-athlete differences in the rate of increase in sprint time in a sled-towing exercise might be due (at least partly) to differences in the athlete's power-to-weight ratio. Therefore, when setting the intensity of the exercise for an athlete, the weight of the sled should be scaled for the athlete's power-to-weight ratio, rather than for the athlete's body weight.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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