A NEW METHOD FOR MEASURING KINETICS AND KINEMATICS IN FIELD RESISTED RUNNING: COMPARISON TO LABORATORY TETHERED RUNNING

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The current investigation compared results of a resisted sprint device to measure running kinetics and kinematics in the field with those measured by tethered running on a treadmill. Ten male students underwent two sessions comprising two 35m tethered sprints in laboratory or track. Step length and frequency, velocity, force and power were measured for each stride and averaged at each 5m interval. Variables reliability was attested by significant ICC-A between test-retest (between 0.60 and 0.88). Kinematic variables did not present a significant difference (P between 0.09 and 0.72). Despite force and power were systematically higher in laboratory condition (P < 0.001), track condition presented higher correlations between force and velocity at each stride. Track tethered running may be a useful to monitor kinetics and kinematics in track resisted running drills.

KEYWORDS: Performance; Resistance; Technology.

INTRODUCTION: Resisted running is a sprint training technique consisting of sprinting while towing usually a weighted sled, but also a parachute or weighted vest, or even running uphill (Alcaraz, Palao, Elvira, & Linthorne, 2008). Despite existing evidence of velocity improvement (Harrison & Bourke, 2009), some studies do not present beneficial effects when compared to traditional sprint training (Clark, Stearne, Walts, & Miller, 2010). The controversy surrounding these training outcomes may be explained by the poor understanding of force exertion during resisted running.

Because of the difficulty to measure force during running, it is common to use unspecific methods to investigate the resisted running effect in force, such as squats or jumps (Harrison & Bourke, 2009). Using force platforms is an alternative to evaluate force during sprint running, but it is usually performed evaluating some footsteps at a time since to evaluate an entire sprint would need several force platforms in series. For example, Kawamori, Newton, Hori, & Nosaka (2014) show an improvement in 10 m time trials after resisted sprint training, but without ground reaction force differences at the 8m mark. This result could arise from the small space covered by force platforms (2.7 m).

Continuous measurement of force during sprint running could help to better understand force behavior and adaptations during training. Laboratorial tethered running (Lakomy, 1987) is a procedure that measures force continuously, irrespective of sprint duration, but must be performed on a treadmill. Recently, some adaptations have been presented to enhance force evaluation during track sprinting, using the same basic principles as laboratorial tethered running (Lima et al., 2011; Sousa, Reis, Ribeiro, Martins, & Gobatto, 2015). Despite concurrent validity with cycle ergometry and performance, up to date there are no comparisons of such field adaptations to laboratorial measurements.

The current investigation aims were to thoroughly investigate reliability from a track running device recently presented (Sousa et al., 2015), and compare its kinematic and kinetic results with those measured using laboratory tethered running on a treadmill over entire sprints.

METHODS: Ten male active students (age: 19.8 ± 2.1 yrs; mass: 72.3 ± 6.8 kg; height: 179 ± 19 cm; and 9.8 ± 5.1% body fat) volunteered to participate in this investigation. Volunteers were instructed to use the same shoes and lightweight clothes for all test sessions, as to refrain from strenuous exercise and maintain hydration and eating habits. All procedures comply with the ethics standards set at Declaration of Helsinki and was approved by an ethics committee.

An intra-subject, cross-sectional design with a randomized session order was employed to compare track resisted sprint running (TRA) to a similar laboratory model (LAB). Two sessions were performed two to seven days apart, one in each condition. Both sessions comprised of warm-up and two 35 m sprints separated by a period of 30 minutes.

The non-motorized treadmill used in LAB and the resisted running tricycle used in TRA are well described in other studies (Pereira et al., 2015; Sousa et al., 2015), and a graphic example is given in Figure 1. The amount of resistance was set to equalize mean velocity between conditions, and were 7.59 ± 0.43% BW for the treadmill and 9% BW for the track device.

For both ergometers, displacement signals were obtained using a Hall effect sensor, while force signals were recorded from a load cell, both sampled at 1 kHz. Velocity was obtained as the first derivative of displacement, while force was directly measured. Power was calculated as the product of horizontal velocity and force at each millisecond. Stride length and frequency were calculated based on the oscillations in the force signal.

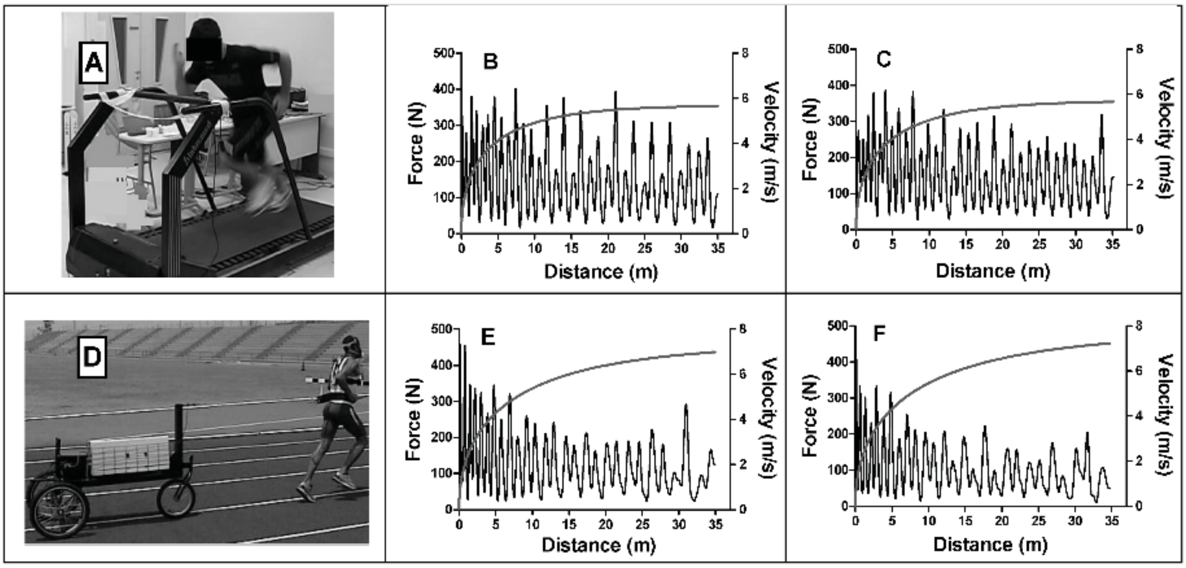

Figure 1: Test performed in LAB (A), with signals of force (oscillating lines) and velocity (straight lines) for test (B) and retest (C). Test performed in TRA (D), with signals of force and velocity for test (E) and retest (F).

Data were averaged for each stride, and the intervals between 0m to 5m, to 10 m, 15 m, 20 m, 25 m, 30 m and to 35 m were averaged to compare sprint distances between LAB and TRA. For between conditions comparison, the two sprints of each condition were averaged. In each sprint the relationship between the force exerted in each stride and the respective development of velocity (delta between end velocity and initial velocity at a given stride) was investigated.

Data normality was tested (Lilliefors) and two way ANOVAs for repeated sprints with ergometer and sprint distance as main factors. Scheffé post-hoc was applied when significance was shown, and percentage difference was calculated (%diff). Intra condition absolute agreement was tested for reliability via ICC-A, and consistency between conditions was tested using ICC-C. Pearson’s correlation coefficient were applied between the exerted force per stride and the velocity development. Statistical significance was accepted at $P < 0.05$.

RESULTS: Regarding reliability in the test-retest analysis, ICC-A were significant ($P < 0.001$) for all measured variables irrespectively of running condition. Kinematic variables as velocity (ICC-A = 0.98 for both LAB and TRA), stride frequency (ICC-A = 0.80 and 0.86, for LAB and TRA) and stride length (ICC-A = 0.87 and 0.88 for LAB and TRA) presented the higher ICC-A. Kinetic variables also had significant ICC for both power (ICC-A = 0.85 and 0.60, for LAB and TRA) and force (ICC-A = 0.88 and 0.79, for LAB and TRA).

Kinematic variables did not present a significant main effect between running condition (P between 0.09 and 0.72). The %diff between conditions for each 5m interval from 0 up to 35m were usually low between 1 and 6%, reaching 9% for stride length at the sprint end (Figure 2).

For all three kinematic variables, ANOVA presented significant main effect for sprint distance (P < 0.001; statistic power > 0.99) and post hoc analysis revealed a significant improvement in velocity and stride length over each distance increase, but stride frequency levelled off at 15 m in relation to longer distances.

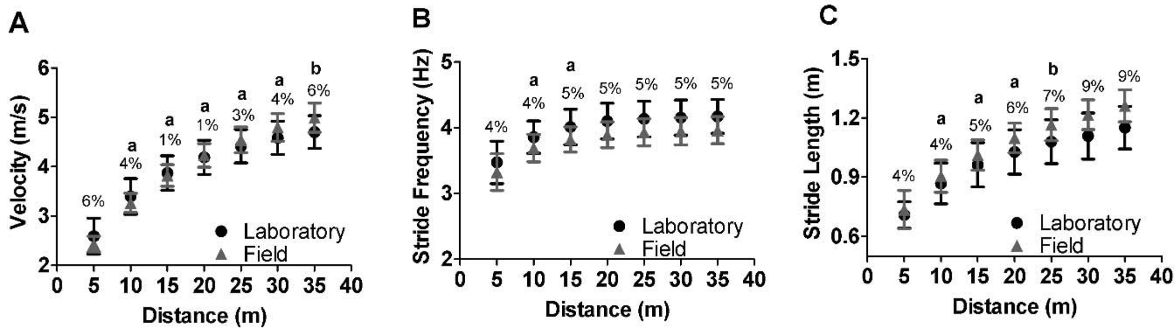

Figure 2: LAB (black circles) and TRA (grey triangles) means and SD for velocity (A), stride frequency (B) and stride length (C) for 0 to 5m, to 10m, to 15m, to 20m, to 25m, to 30m and to 35m tethered sprints. a – Post hoc difference from previous distance in the same condition at both conditions; b – Post hoc difference from previous distance only for the field condition (for all significant differences, P was < 0.001; statistical power ≥ 0.99).

For mean power and force, ANOVA revealed significant main effects for both running condition and sprint duration (P < 0.001). Further, %diff between conditions for each distance presented a mean of 20% for force and 25% for power, which is detailed in Figure 3.

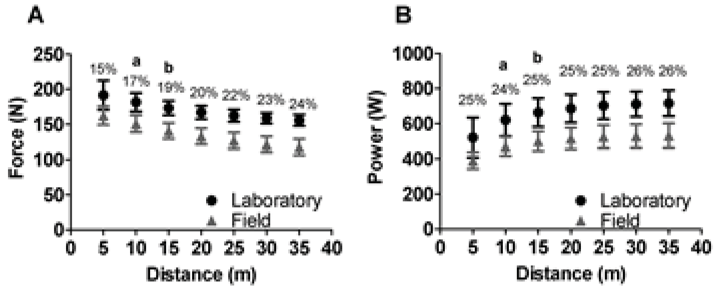

Figure 3: LAB (black circles) and TRA (grey triangles) means and SD for force (A) and power (B) for 0 to 5m, to 10m, to 15m, to 20m, to 25m, to 30m and to 35m tethered sprints. a – Post hoc difference from previous distance in the same condition at both conditions; b – Post hoc difference from previous distance only for the field condition; (for all significant differences, P < 0.001; statistical power > 0.96).

Despite the differences in force and power, the type C ICCs between conditions were significant not only for kinematic variables (ICC-C between 0.87 and 0.93), as for power (0.67) and force (0.81). This demonstrates a consistency between conditions even in variables when a difference appeared, suggesting a generally systematic bias.

Finally, analyzing each sprint individually, force exerted for each stride was significantly correlated to the respective development of velocity in all cases, with higher correlations in TRA (r = 0.75 ± 0.10, P always < 0.05) than in LAB (r = 0.60 ± 0.15, when P < 0.05). Further, in LAB this relationship was not significant for four sprints including test and retest.

DISCUSSION: Overall, all measured parameters from TRA and LAB presented significant reliability. In comparison between methods, kinematics presented a good level of agreement for all sprint durations, but kinetic parameters were significantly different. However, %diff was similar over each sprint distance, which together with significant relationships between the two methods suggests a systematic difference.

Despite being consistent between conditions, the significant effects and high %diff between conditions for mean power and mean force is an unexpected result. The consistency between these variables attests a similar ranking capacity when evaluating runners. However, the reason why force is so much lower in TRA is still unknown. It is plausible to speculate, based on the tendency of lower end velocity and stride length in LAB, more dissipation of force may be happening for purposes other than to propel the body forward. Higher relationships between force and velocity at each stride are in line with this assumption, supporting a more effective force application towards enhancement of velocity in TRA than in LAB. Mechanical properties of running surfaces are among the possible explanations for differences between running on a treadmill and on track, together with familiarization, air resistance and disruption of the velocity caused by the treadmill belt (Schache et al., 2001). Besides, it is also expected force decrease with attainment of higher velocities (Kawamori, Nosaka & Newton, 2013), probably because of smaller ground contact time. One of the limitations of this study and the proposed device is the measurement of kinetic variables only in the horizontal plane. However, it is also common to see (as in Kawamori et al., 2013) better relationships between horizontal kinetics and performance when compared to total or vertical kinetics.

CONCLUSION: The proposed TRA alternative presents similar kinematics to LAB, suggesting an analogous running technique in the studied sprint duration. Differences in kinetics are large but systematic, reinforcing the usefulness of both methods to rank runners in such variables. Differences in kinetic variables magnitude between LAB and track running must be taken into consideration when using LAB to infer about performance. TRA may be a useful tool to monitor force and power in track resisted running drills.

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Acknowledgement

Support grant numbers: FAPESP: 2009/08535-5; 2013/16710-7 and 2015/19241-3. CNPq: 461559/2014-5. Authors would like to thanks all members of LAFAE who helped in any way.