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Running head: Trail training parameter

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Funding: No funding to disclose

ABSTRACT

Trail running is characterised by successive uphill and downhill running sessions. In order to prescribe training intensity, an assessment of maximal running capacity is required. This study compared two uphill incremental tests using the same ascensional speed increment to identify the influence of the slope gradient on performance. Ten subjects (eight men and two women) performed three incremental exercises on various slope (1%: IT01, 10%: IT10, and 25%: IT25), the ascensional speed increment was similar between IT10 and IT25 (100 m/h every minute). Gas exchanges, heart rate, and power were monitored continuously during the tests. Similar VO_{2max} levels were observed in the three conditions: 68.7 ± 6.2 for IT01, 70.1 ± 7.3 for IT10, and 67.6 ± 7.0 for IT25. A greater maximal ascensional speed was reached in the IT25 (1760 ± 190 vs 1330 ± 106 for IT25 and IT 10 respectively, $p<0.01$). A significant relationship was observed between relative VO_2 levels and relative power without any effect of slope. Power should be the parameter used for prescribing training intensity compared to ascensional speed in trail.

Keywords: VO_{2max}, slope, running, performance

INTRODUCTION

Trail running (TR) is defined by the International Trail Running Association as "a pedestrian and off-road race conducted in a natural environment (e.g. mountain) with minimal possible paved or asphalt road (<20% of the total duration race)". TR is challenging, as races are characterised by successive uphill and downhill running sections that are associated with major physiological changes (14). Using the classic endurance running model, maximal oxygen consumption (VO_{2max}) has been shown to account for 90% of TR performance (11).

In order to prescribe adequate exercise intensity, coaches use a test protocol to establish performance levels, and plan training accordingly. The majority of exercise tests are performed by running on a horizontal grade treadmill. Recently, the comparison of an outdoor 16% uphill exercise test has been compared to 1% laboratory test. This suggested that metabolic parameter values differ despite similar VO_{2max} values (22). Moreover, new tests have been designed to evaluate TR athletes. Scheer et al. (21) proposed a trail test with a continuous increase of both speed (+0.5 km/h per minute) and inclination (1% per minute). The athletes reached higher VO_{2max} values during the trail test compared to the horizontal test, suggesting that the use of graded inclinations during testing should be employed to match to the specificity of TR. However, this test limits the ability to use the results to prescribe training. Doucende et al. (10) developed a specific incremental trail test with increment expressed in metres per hour. The test was performed on a 25% slope, and the speed increment was designed to increase ascending speed (AS) by 100 m/h every minute. In others tests, different constant slopes (from 10 to 30%) have been used, and allow the determination of sub-maximal and maximal aptitude in TR racers

(4,9,11). Whether ascending speed may be used by coaches to prescribe training has not yet been determined.

The aim of the present study was to compare incremental tests using an identical ascensional speed increment (100 m/h) at different slopes to determine whether AS or power better reflects the metabolic cost of running at different slope gradients. We hypothesised that the maximal AS would vary with the slope and would be a reference parameter to prescribe training intensity.

METHODS

Experimental Approach to the Problem

Subjects completed three laboratory tests in this randomised, cross-over study. All visits were separated by at least 48 hours, over a 10-day period. Subjects performed three maximal graded tests on a treadmill to determine VO_{2max}. Power and O_2 consumption were monitored to assess the relationship between AS and power, or O_2 consumption.

Subjects

For this study, 10 subjects were recruited (female n=2 and male n=8), who were trail runners, (mean ± SD: age 27.9 ± 8.74 years; height 175 ± 9.3 cm; body mass 65.3 ± 12.54 kg; and fat mass 10.9 ± 3.99%) and considered to be strong to advanced athletes by the ITRA performance index (index: 542-781; (26)). All subjects were healthy and free of any history of metabolic, cardiovascular, hormonal, and respiratory diseases, or musculoskeletal disorders. None of the subjects were taking any medications or supplements, and they were advised to maintain their normal dietary intake throughout the study. All subjects provided written informed consent after ethical approval was obtained for the Ethics Committee of the University of Lille (2019-381-S77).

Procedures

All subjects completed the three different exercise test protocols on three different occasions. All subjects were familiar with treadmill running, and performed the tests with their usual training shoes. Before all testing, subjects refrained from severe physical activity for at least 48 hours.

A standardised warm-up programme of 15 minutes preceded each test. The three tests were performed on a motorised treadmill (Intelligent Suspension 3, Cybex International Inc, MA, USA) as follows: (1) incremental test (IT01) starting at 8km/h with a progressive increase of 1km/h every minute and an inclination of 1%; (2) incremental test (IT10) starting at an AS of 500 m/h with a progressive increase of 100 m/h every minute with an inclination of 10%; and (3) incremental test (IT25) starting at an AS of 500 m/h with a progressive increase of 100 m/h every minute with an inclination of 25%.

During all tests, gas exchanges were collected breath by breath, together with heart rate, by a Metamax 3B-R2 system (Biophysik GmbH, Leipzig, Germany). VO_{2max} was defined as the highest 30-s average VO_2 value. The mean value over the last 20-s of each step was used to determine the relationship between AS and VO_2.

Power was monitored using a power meter (Stryd Powermeter; Stryd Inc., Boulder, CO, USA), which is a foot-mounted inertia sensor of 9.1 g reinforced with carbon fibre that estimates power in watts. Based on 6-axis inertial motion sensor with a 1 Hz sampling frequency, the device provides several metrics to characterize performance: pace, elevation, distance, cadence, ground contact time, vertical oscillation, leg stiffness, running power, form power. The device has been validated previously at different running velocities (13,16). The power meter was firmly attached to the shoe according to the manufacturer recommendations. Subjects provided their body mass prior to its use; this was a requisite for the power estimation. The data extracted from the Stryd power meter were timed averages of 10-s, and the mean value over the last 20-s of each step was used to determine the relationship between AS and power.

At the end of each test, participants were asked to provide perceived exertion on the 6–20 point Borg scale (5).

Statistical Analyses

Descriptive statistics are represented as mean ± SD. Tests of normal distribution and homogeneity (Shapiro–Wilk and Levene's test, respectively) were performed on all data before analysis. Pairwise comparisons of mean (t-test) were conducted between the conditions at the different AS over the incremental test. A One-way ANOVA for repeated measure was performed to compare variables between the three conditions and a Tukey post-hoc test was used to identify significant difference between protocols. Relationships between variables were analysed using a Pearson's product–moment correlation. Correlation coefficients were evaluated using the following criteria: small = 0.10–0.29, moderate = 0.30–0.49, large = 0.50–0.69, very large = 0.70–0.89, nearly perfect = 0.90–0.99 (15). Data analysis was performed using Prism 9.1 (GraphPad Software, Inc., San Diego, CA). The magnitude of the differences between values was also interpreted using the Cohen's *d* effect size (ES)(7). Effect sizes of <0.20, 0.20–0.50, 0.50–0.80, and > 0.80 were considered as trivial, small, moderate, and large, respectively. The level of significance used was set a $p < 0.05$.

RESULTS

Table 1 summarises the mean maximal values of the three exercise test protocols. No difference was observed between the protocols for VO_{2max}, heart rate, power, and ratings of perceived exertion. A higher maximal velocity was observed in IT01 *vs*. IT10 and IT25 (ES = 3.96 and 8.76, respectively, p<0.001), and maximal velocity was higher in IT10 compared to IT25 (ES = 6.55, p<0.001). A greater AS was reached in the IT25 vs IT10 (ES = 2.79, p<0.001).

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A significant relationship between AS and VO_2 was observed in IT10 and IT25 (r^2=0.991, p<0.001, and r^2=0.997, p<0.001, respectively, Figure 1A), and a significant difference between the slopes of the linear regression was observed (P<0.001). Similarly, a significant relationship between AS and power was observed in IT10 and IT25 (r^2=0.992, p<0.001, and r^2=0.965, p<0.001, respectively,

Figure 1B), and a significant difference between the slopes of the linear regression was observed (*P*<0.001). A significant relationship between relative VO_2 and relative power was observed in IT10 and IT25 (r^2=0.895, *p*<0.001, and r^2=0.852, *p*<0.001, respectively, Figure 1C), and no difference was observed between the slopes (*P*=0.38).

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DISCUSSION

The goal of this study was to determine whether the slope gradient influenced the peak AS in order to determine the utility of peak AS to prescribe training programs. Our results demonstrate that the slope gradient influence the peak AS but not maximal cardiometabolic values. The relationships between AS and VO_2 and AS and power were different across the slopes. The power is related to VO_2 independently of the slope gradient.

The peak AS reached by athletes was different upon the slope gradient. However, they reached similar VO_{2max} in the three conditions. In the literature, the results of the influence of the slope on VO_{2max} are contradictory: some studies observed an influence of slope (21,25) while others did not (3,8,17). The level of the population may explain these discrepancies as differences in VO_{2max} became smaller when investigation trained subject (8,22). In our study, the subjects were considered to be trained, which may mitigate VO_{2max} differences across exercise protocols. Therefore, these results suggest that all the protocols are appropriate for VO_{2max} assessment for trained trail runners. The protocol of test that was used to determine VO_{2max} may explain the discrepancies across the studies (23). In our study, we used a constant increment (100m/h) while Scheer et al.'s study (21) used incremental increments (107 m/h to 217 m/h). Therefore, the difference of VO_{2max} might be explained by the different increments in workload over time. An underestimation of VO_{2max} would be expected due to steeper increases of metabolic requirement (4).

We observed a linear relationship between VO_2 and AS, and between power and AS, and greater metabolic and power values were observed on a 25% slope vs a 10% slope at a same absolute AS. These results are interesting for training purposes while considering AS as an intensity index during training sessions. In line, previous studies reported a linear increase in energy cost with each increment (3,19,24). The greater energy cost at a same absolute AS may result from the higher muscular mass involved while increasing the sloped gradient (22, 50, 52). The uphill running locomotion is associated with stronger muscular contraction and mechanical work (52). Moreover, for a same AS, the horizontal speed will be higher when the slope increment is lower suggesting that horizontal speed may be a potent explanation for the greater metabolic cost observed at low gradient slope. All together these data indicate that for a same absolute AS the increase of the slope gradient modifies running speed and running patterns which alter running economy and induce an increase of net energy generation.

The linear relationship between oxygen uptake and work rate has been widely described (12,20). Previous studies assessed the relationship between power and oxygen uptake, and all found a linear and positive relationship between the two parameters (1,2,16,18). Our results are in line with the literature where there is a strong and positive relationship between power and oxygen uptake. As previously suggested, we pay attention to the methodology employed to analyse VO_2 and Stryd power data (16). We used the last 20 seconds of the step to avoid the time delay for VO_2 to increase while power increases instantaneously. Our results also suggest that the power assessed using the Stryd was unaffected by the gradient of the slope, and should be an interesting tool to monitor exercise intensity during trail running.

PRACTICAL APPLICATIONS

The present study demonstrated that the use of peak AS should not be used by coaches to prescribe or individualise training programmes as the cardiometabolic responses were slope-dependent. However, AS would be a relevant parameter when coaches want to individualise uphill training sessions as long as the slope gradient remained similar. In that situation and considering that the slope gradient influences the cardiometabolic responses, the coaches should choose the AS according to the cardiometabolic target of the training session.

The use of a power meter could be an interesting tool to prescribe and individualise training intensity. In fact, the relationship between O_2 consumption and power were correlated and similar between the two-slope gradient explored in this study. These results suggest that power could be valid for different terrains as it was the case during trail running. Despite the growing offer of power meters, specific attention should be paid to the validity of the devices used.

ACKNOWLEDGEMENTS

The authors thank all the trail runners for their enthusiastic participation in the study. The authors have no conflict of interest to declare. The study was financed by the authors' own institutional resources. The results of the present study do not constitute endorsements of the products by the authors or the NSCA.

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TABLE

Table 1: The mean maximal values of the three exercise test protocols

Parameters	IT01	IT10	IT25
VO_{2max} ($mL \cdot min^{-1} \cdot kg^{-1}$)	68.7 ± 6.2 [64.3–73.1]	70.1 ± 7.3 [64.9–75.3]	67.6 ± 7.0 [62.6–72.6]
Maximal velocity ($km \cdot h^{-1}$)	19.2 ± 1.8 [18.0–20.5]	13.3 ± 1.1 [12.5–14.1][a]	7.0 ± 0.8 [6.5–7.6][a,b]
Ascensional speed ($m \cdot h^{-1}$)		1330 ± 106 [1254–1406]	1760 ± 190 [1624–1896][b]
Heart rate (bpm)	185 ± 11 [177–193]	182 ± 11 [174–190]	183 ± 14 [173–193]
Power ($W \cdot kg^{-1}$)	4.9 ± 1.1 [4.1–5.7]	5.4 ± 0.7 [4.9–6.0]	4.9 ± 1.4 [3.9–6.0]
Ratings of perceived exertion	16.7 ± 1.1 [15.9–17.5]	16.8 ± 1.7 [15.6–18.0]	17.3 ± 1.2 [16.5–18.1]

Mean values ± SD [95% CI], [a]$p<0.001$ *vs.* IT01, [b]$p<0.001$ *vs.* IT10

FIGURE

Figure 1: Relationships between A. oxygen consumption and ascensional velocity, B. power and ascensional velocity, and C. oxygen consumption and power. Oxygen consumption was expressed in mL·min^{-1}·kg^{-1}, and power was expressed in W·kg^{-1}. This represents pooled data from 10 subjects.