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Original research

Test–retest reliability of a 3-min isokinetic all-out test using two different cadences

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ABSTRACT

Objectives: To investigate the test–retest reliability of mechanical parameters derived from a 3-min isokinetic all-out test, performed at 60 and 100 rpm. Reliability and validity of the peak oxygen uptake derived from 3-min isokinetic all-out test were also tested.
Design: 14 healthy male subjects completed an incremental ramp testing and four randomized 3-min isokinetic all-out test (two at 60 rpm and two at 100 rpm).
Methods: The absolute and relative reliability of the following parameters were analyzed: peak power, mean power, end power, fatigue index, work performed above end power and peak oxygen uptake.
Results: No difference was found between each two sets of data, although there were between-cadence differences for peak power, mean power, end power, and fatigue index. Higher intra-class correlation (ICC) and lower coefficient of variation (CV) were found for end power (ICC = 0.91 and 0.95; CV = 5.6 and 5.7%) and mean power (ICC = 0.97 and 0.98; CV = 2.4 and 3.1%), than for peak power (ICC = 0.81 and 0.84; CV = 8.7 and 10%) and work performed above end power (ICC = 0.79 and 0.84; CV = 7.9 and 10.6%; values reported for 60 rpm and 100 rpm, respectively). High reliability scores were also observed for peak oxygen uptake at both cadences (60 rpm, CV = 3.2%; 100 rpm, CV = 2.3%,) with no difference with the incremental ramp testing peak oxygen uptake.
Conclusions: The power profile and peak oxygen uptake of a 3-min isokinetic all-out test are both highly reliable, whether the test is performed at 60 or 100 rpm. Besides, peak oxygen uptake and work performed above end power were not affected by the change in cadence while peak power, mean power, end power, and fatigue index were.

1. Introduction

The study of the power–time relationship has facilitated the understanding of the limits of human performance.[1] The asymptote of this relationship, termed Critical power, can be determined using a variety of methodologies with the traditional methods relying on the modeling of the power–time relationship plotted from the performance of several exhaustive constant-load tests.[2–4] A 2-parameter model is then usually computed to obtain an asymptote (CP) and a curvature (W').[1,2,4]

The determination of CP from the performance of a single 3-min all-out test (3MT) was recently proposed[5] and further investigated.[6–8] The original 3MT was performed on a Lode ergometer set up to work against a fixed resistance (i.e. flywheel resistance or linear factor)[5] and thereafter applied on different ergometers, such as wind load[3] and Computrainer™,[9] although the concurrent validity of the 3MT performed on those latter two ergometers was not tested. The mean power output of the last 30 s of the test, termed end-power (EP), and the amount of work done above EP (the WEP) have been considered as alternatives for CP and W' estimation, respectively.[10] The 3MT was also shown to give a valid measure of peak oxygen uptake ($\dot{V}O_2$ peak) as obtained from a traditional incremental test,[5,11] although a single study[12] has found a greater intra-individual variability for this physiological variable.

Although reliability and validity of the original 3MT support the use of this test to estimate the boundary between the heavy and severe intensity domains,[1,7,13] all-out tests are particularly affected by a manipulation of cadence.[8] Because of the

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power-velocity relationship of the musculature involved in cycling,[14] an optimal cadence can be chosen for a maximal power output to be obtained. But this optimal cadence for maximal power output may be suboptimal for other variables derived from the 3MT power output profile such as EP. Vanhantalo et al.[8] found that a change (by manipulating cadence in equation of linear factor) in the resistance of the Lode ergometer during a 3MT affected cadence throughout the test and altered PP, EP and WEP, when compared to the standard resistance. Similarly, the conventional critical power protocol tends to yield reduced estimates of CP at high cadences while W' remains unaffected.[13,15] Thus, EP and WEP are likely to be affected by a change in cadence and therefore by the choice of the flywheel resistance when conducting a traditional 3MT.

Reliability data will likewise give an indication of the biological and technical noise/error of the protocol[16,17] before any consideration could be given to the validity of the variables investigated. The 3MT has not yet been investigated in an isokinetic mode. No flywheel resistance needs to be chosen but a given pedaling frequency. Dekerle et al.[2] have suggested that the control of cadence during the 3MT ($3MT_{ISO}$) could improve an experimental design (i.e. control of the frequency of muscle contraction and maximization of the total work). To our knowledge, the reliability of a power output profile from an isokinetic cycling test has only been studied during a short all-out test (i.e. 90 s), in both adults[18] and children.[19] Mean power was reported to be the most reliable measure (i.e. greater intra class correlation, ICC of 0.99), followed by EP and fatigue index. The reliability of peak power was found to be fairly poor, as demonstrated by significant difference in the test-retest analysis. The cadence in this study was fixed cadence at 93 rpm.[18] The authors suggested that the reliability of EP, and therefore FI, was likely to be affected by the duration of the test. Furthermore, the cadence chosen for the test could also impact on the reliability of the parameters. Indeed, Hopkins et al.[16] suggested that isokinetic testing may be less reliable at higher speed of movement, leading to the hypothesis that the reliability of a $3MT_{ISO}$ would be better at lower cadences.

No study has yet investigated the reliability of mechanical and metabolic parameters obtained from the performance of a $3MT_{ISO}$. Two cadences – a low (60 rpm) and high (100 rpm) – were studied in the present investigation. The aim of this study was therefore twofold: (1) to assess the reliability of the power output profile of a $3MT_{ISO}$ (dependent variables: peak power, mean power, end power, fatigue index and work above EP) with a further insight into the effect of cadence on these variables; and (2) to verify the test-retest reliability of $\dot{V}O_2$ peak and the agreement between $\dot{V}O_2$ peak obtained during the $3MT_{ISO}$ and the incremental exercise test.

2. Methods

Fourteen healthy, physically active men (27.1 ± 4.5 years; 174.8 ± 5.5 cm and 77.7 ± 9.6 kg) took part in this study after giving their written consent. The study was respecting the Declaration of Helsinki and the protocol was approved by the University's Ethics Committee. Subjects were not engaged in any form of aerobic training.

The subjects visited the laboratory on five separate occasions. Each subject performed the following testing: (1) An incremental ramp test to estimate peak oxygen uptake ($\dot{V}O_2$ peak) and the workload associated with $\dot{V}O_2$ peak; (2) four $3MT_{ISO}$ tests, two at 60 and two at 100 rpm. The $3MT_{ISO}$ tests were performed in randomized order. Participants performed only one test on any given day with all the testing completed within a period of 2–3 weeks. All exercise testing was conducted using an electrically braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands). The ergometer seat and handlebars positions were adjusted individually for comfort, and settings were recorded and replicated for subsequent tests. Blood samples were collected from the ear lobe into microcentrifuge tubes containing 50 μL NaF (1%) for the determination of [La] (YSI 2700 STAT, Yellow Springs, OH, EUA). Pulmonary gas exchange was measured continuously using a breath-by-breath analyzer (Cosmed, Quark PFTergo, Rome, Italy). Before each test, the O_2 and CO_2 analysis systems were calibrated using ambient air and a gas of known O_2 and CO_2 concentration according to the manufacturer's instructions, while the gas analyzer turbine flowmeter was calibrated using a 3-L syringe. Heart rate (HR) was also monitored throughout the tests (Polar, Kempele, Finland).

The subjects were instructed to arrive at the laboratory in a rested and fully hydrated state. They consumed a light carbohydrate meal 2–3 h before all tests. They were also asked not to do any strenuous activity during the day prior each test. All tests were performed in a climate-controlled (21–22 °C) laboratory at the same time of day (±2 h) to minimize the effects of diurnal biological variation on the results.[20]

The incremental ramp test consisted of 4 min of baseline pedaling at 20 W, followed by a ramp increase in workload rate of 20 W min^{-1} until volitional exhaustion or until the pedal cadence declined more than 5 rpm for 10 s, despite verbal encouragement. The subjects were allowed to choose the preferred cadence during this test. Peak heart rate was identified as the highest 5 s average value during the test. The gas exchange threshold (GET) was detected by V-slope method, as described by Beaver et al.[21]

Each participant completed two familiarization trials to the isokinetic mode, 15 min after the incremental ramp testing (GXT) test. The trials consisted of two randomized 20 s sprints at both 60 rpm and 100 rpm.

Before each $3MT_{ISO}$, subjects were given a 5 min warm-up at GET performed at a freely chosen cadence followed by 5 min of complete rest seated on bicycle. Each test started with 3 min of unloaded cycling at the specific cadence (60 or 100 rpm), followed by an all-out 3 min effort. Each subject was instructed to reach his peak power as quickly as possible, and to maintain an all-out effort for the entire duration of the test, thus avoiding pacing. The subjects received strong and consistent verbal encouragement. They were not informed of the elapsed time or power output in order to prevent pacing. Pulmonary gas exchange was recorded throughout the test. The $\dot{V}O_2$ peak was taken as the highest $\dot{V}O_2$ peak measured for 30 s during the test.[5]

The mechanical parameters derived from $3MT_{ISO}$ were peak-power (PP) defined as the highest 1 s power output recorded; mean-power (MP) calculated from the entire 180 s exercise; and end power (EP) or mean power over the last 30 s of the exercise. Fatigue index (FI) was also determined as the percentage decrease rate between PP and EP (i.e. $FI = [(PP - EP)/PP] \times 100$). The work done above EP (WEP) was calculated as the power-time integral above EP, using Graph Pad Prism software (version 4.0, San Diego, CA, USA).

Data are reported as mean ± standard deviation (SD). The normal distribution (Shapiro–Wilk test) and homogeneity of variance were checked for each set of data. A two-way ANOVA with repeated measures (trials × cadences) was used to detect differences in PP, MP, EP, FI and WEP. Significant F – ratios were followed by post hoc comparison using Bonferroni procedure, if necessary. Further, a one-way ANOVA with repeated measures was used to detect differences in $\dot{V}O_2$ peak measured during GXT and $3MT_{ISO}$ for each cadence. Heteroscedasticity was examined by plotting the absolute differences against the individual means and calculating the correlation coefficient, in order to assess the significance of the relationship.[22] Intraclass correlation coefficients (ICC), typical error of measurement (TE) and coefficient of variation (CV) were calculated according to Hopkins[17] to determine the test–retest reliability. The ICCs were interpreted as follows: 0.90–0.99, high