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Original article

Non-exhaustive double effort test is reliable and estimates the first ventilatory threshold intensity in running exercise

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Abstract

Purpose: The present study aimed to investigate the reliability of the non-exhaustive double effort (NEDE) test in running exercise and its associations with the ventilatory thresholds (VT_1 and VT_2) and the maximal lactate steady state (MLSS).

Methods: Ten healthy male adults (age: 23 ± 4 years, height: 176.6 ± 6.4 cm, body mass: 76.6 ± 10.7 kg, mean ± SD) performed 4 procedures: (1) a ramp test for VT_1 and VT_2 determinations measured by the expired ventilation to O_2 uptake (VE:VO_2) and ratio of expired ventilation to CO_2 output (VE:VCO_2) equivalents, respectively; (2) the NEDE test measured by blood lactate concentration ($NEDE_{LAC}$) and heart rate responses ($NEDE_{HR}$); (3) a retest of NEDE for reliability analysis; and (4) continuous efforts to determine the MLSS intensity. The NEDE test consisted of 4 sessions at different running intensities. Each session was characterized by double efforts at the same running velocity (E1 and E2, 180 s), separated by a passive recovery period (90 s rest). LAC and HR values after E1 and E2 (in 4 sessions) were used to estimate the intensity equivalent to "null delta" by linear fit. This parameter represents, theoretically, the intensity equivalent to maximal aerobic capacity.

Results: The intraclass correlation coefficient indicated significant reliability for $NEDE_{LAC}$ (0.93) and $NEDE_{HR}$ (0.79) (all $p < 0.05$). There were significant correlations, no differences, and strong agreement with the intensities predicted by $NEDE_{LAC}$ (10.1 ± 1.9 km/h) and $NEDE_{HR}$ (9.8 ± 2.0 km/h) to VT_1 (10.2 ± 1.1 km/h). In addition, despite significantly lower MLSS intensity (12.2 ± 1.2 km/h), $NEDE_{LAC}$ and $NEDE_{HR}$ intensities were highly correlated with this parameter (0.90 and 0.88, respectively).

Conclusion: The NEDE test applied to running exercise is reliable and estimates the VT_1 intensity. Additionally, NEDE intensities were lower but still correlated with VT_2 and MLSS.

Keywords: Anaerobic threshold; Aerobic exercise; Maximal lactate steady state; Non-exhaustive protocol; Training prescription; Ventilatory threshold

1. Introduction

Aerobic exercise (long duration at low-to-moderate intensity) promotes several morphologic and physiological adaptations, such as improved oxidative metabolism, higher fat mobilization, weight loss, and optimization of cardiorespiratory capacities.[1] Individual detection of maximal aerobic intensity is the first step for an optimal training prescription and monitoring. In this regard, detection of maximal oxygen consumption (VO_{2max}) and aerobic and anaerobic thresholds are the main determinants of aerobic fitness in athletes,[2,3] subjects with impaired health,[4,5] and healthy individuals.[6,7]

Initially, the first studies that identified the metabolic thresholds used gas analyzers during incremental efforts to determine anaerobic threshold [first increase in ratio of expired ventilation to O_2 uptake (VE:VO_2) ratio] and the respiratory compensation point [first increase in ratio of expired ventilation to CO_2 output (VE:VCO_2 ratio)], currently also known as ventilatory threshold 1 and 2 (VT_1 and VT_2).[8] Later, another research group determined these phenomena by measuring blood lactate (LAC) concentration and conceptualizing them as aerobic (~2 mmol/L lactate) and anaerobic thresholds (~4 mmol/L lactate).[9] Despite being determined by different physiological measures, the metabolic thresholds represent similar intensities

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(VT_1 being similar to aerobic threshold by LAC determination and VT_2 being similar to anaerobic threshold by lactatemia). Because lactate production and gas exchange rates directly reflect metabolic aspects, methods like maximal lactate steady state (MLSS) and ventilatory thresholds are currently the most frequently used for aerobic and anaerobic threshold determination. The MLSS indicates the maximal capacity of lactate production without its progressive accumulation during continuous exercise (near to VT_2 intensity).[10,11]

Although VTs and MLSS are reliable methods for aerobic and anaerobic threshold determination in sports,[12,13] clinics,[1] and health promotion,[5] they are time-consuming, expensive, and exhaustive for participants, characteristics that limit their application for aerobic evaluation and training prescription for all populations. For this reason, several studies have tried to validate less expensive[4,12,14] and non-exhaustive methods[6,15] for anaerobic threshold determination and aerobic training prescription. Among these efforts is one proposed by Chassain,[16] which is based on non-exhaustive double efforts (NEDE). This procedure is characterized by low cost, short duration, and low-to-moderate intensity of effort.[15,16]

The NEDE test uses non-exhaustive loads to determine the highest intensity at which the physiological variables [LAC and heart rate (HR)] do not increase beyond the initial transient level after 2 rounds of exercise.[15,16] In summary, the NEDE test consists of 4 sessions at different intensities. Each session is characterized by double efforts at the same intensity (E1 and E2, 180 s), separated by a passive recovery period (90 s rest). Physiological variables are measured at the end of E1 and E2 (in each of 4 sessions), and the physiological deltas at each different intensity are used to estimate the "null delta intensity" by linear fit. This parameter represents, theoretically, the intensity equivalent to maximal aerobic capacity (i.e., the highest intensity in which change of LAC and HR is equal to 0).[15,16]

In the original study, Chassain[16] did not compare the NEDE test with other methods used to determine the aerobic and anaerobic thresholds. Despite making some assumptions regarding the relation of the NEDE test and a protocol similar to MLSS, it was not tested with the same subjects. Other studies have investigated the relationship between the "null delta intensity" based on the original NEDE test and other aerobic parameters (i.e., critical velocity, lactate threshold,[17] and MLSS[18]). However, despite the use of the double effort test, the protocols had longer time durations than were used the original study (14 min and 20 min) and only tested the correlation between protocols, not their similarity in mean values.[17] In an experimental study using swimming and running rats, the "null delta intensity" obtained using the NEDE test showed an association with MLSS.[19,20] However, in a study involving menopausal women, these results were not confirmed.[15] Recently, our research group conducted an investigation with elite swimmers and confirmed that the NEDE test is reliable and can estimate MLSS, at least in a swimming exercise.[15,16]

Considering that the intensity predicted by the NEDE test indicates a work rate of physiological equilibrium, we hypothesize that this intensity is related to other aerobic physiological parameters, such as the VTs and the MLSS, in running exercise. Thus, the present study aimed to investigate the reliability of the NEDE test for LAC responses ($NEDE_{LAC}$) and HR measures ($NEDE_{HR}$) in running exercise. Also, we investigated the association of the null delta intensity obtained in the NEDE test with the ventilatory thresholds (VT_1 and VT_2) and MLSS in order to determine whether the NEDE test can be an effective alternative method for aerobic evaluation in running exercise.

2. Methods

2.1. Volunteers

Ten healthy young male adults (age: 23 ± 4 years, height: 176.6 ± 6.4 cm, and body mass: 76.6 ± 10.7 kg, mean ± SD) who were moderately active participated in the present study. All volunteers filled out the International Physical Activity Questionnaire and met one of the following 3 scores for the "moderately active" classification: (1) three or more days of vigorous-intensity activity lasting at least 20 min per day, (2) five or more days of moderate-intensity activity or walking lasting at least 30 min per day, or (3) five or more days of any combination of activities (including walking) at moderate or vigorous intensity to achieve a minimum total physical activity level of at least 600 MET-min per week (where MET is metabolic equivalent value).[21] All participants were informed of the risks and benefits of participating in the research and, in accordance with the Declaration of Helsinki and approved by the Institutional Research Ethics Committee of Human Research of University of Campinas (protocol number: 12-03-184), signed an informed consent form prior to the tests.

2.2. Experimental design

During the study, volunteers were instructed to maintain the same nutritional habits, avoid high-intensity exercise, and avoid caffeine or alcohol ingestion for 24 h before each test. All procedures were performed on a motorized treadmill (Super ATL, Inbrasport, Porto Alegre, Brazil) at a laboratory in a controlled environment (22°C ± 1°C temperature and 50% ± 2% relative humidity). After anthropometric measurements, the volunteers performed an individualized ramp protocol to determine VT_1, VT_2, and maximal oxygen uptake (VO_{2max}). Thereafter the MLSS and NEDE test and retest (NEDE-1 and NEDE-2) were carried out in random order separated by a minimal period of 24 h between each test. All volunteers completed all procedures within 2 weeks.

2.3. Ramp protocol and respiratory parameters

Immediately after a 5 min warm-up at 7 km/h, the individualized ramp protocol was carried out on a treadmill without inclination, at 8.0 km/h initial velocity and then constantly increased at a rate of 0.7 to 1.0 km/h/min (depending on the predicted VO_{2max} by individuals' age) as previously suggested.[22] During the whole test, the HR, ventilation, and expired gas responses were continuously measured by an integrated, computerized, breath-by-breath gas analyzer system ($K4b^2$, Cosmed, Rome, Italy) that was calibrated before each test according to manufacturer's instructions. The end of the test

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