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Original article

# Number of raised steps: A tool to assess brief and intense effort involving anaerobic metabolism

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ABSTRACT

*Background:* Although the initial anaerobic component of exercise adaptation is unavoidable, no specific functional test is available for use in routine non-sporting practice to evaluate it.
*Objective:* To assess the bioenergetic and biomechanical properties of the Short and Fast Step Test (SFST), which consists of walking up and down a step as many times as possible in 1 minute and to analyse its ability to explore the initial anaerobic component of effort in comparison to a reference self-paced step test.
*Methods:* Overall, 31 healthy subjects (19 women; mean [SD] age, 32.4 [10.2] years) completed a test–retest of a self-paced step test and the SFST, with pre- and post-test measurement of blood lactate concentration and continuous recording of $VO_2$ and modelling of excess post-exercise oxygen consumption (EPOC), near-infrared spectroscopy (NIRS) of the quadriceps and mechanical power (estimated by the number of steps climbed and 3-D motion analysis).
*Results:* Both step tests were well tolerated. The reliability of the bioenergetics parameters, number of raised steps, mechanical power and NIRS tissue saturation index was good. Indirect mechanical power (estimated from number of steps) was correlated with direct power (computed from the centre of mass). Lactate accumulation was significantly increased during exercise with only the SFST (mean [SD] increase, 3.86 [3.26] mmol $L^{-1}$ from resting values, $P < 0.05$). EPOC was higher with the SFST than the self-paced step test ($P < 0.05$). Only the SFST showed significant correlations between number of steps climbed and EPOC ($r = 0.84$; $P < 0.001$) and decreased tissue saturation index (NIRS) and EPOC area ($r = -0.39$; $P < 0.05$).
*Conclusions:* SFST is feasible, well tolerated, reliable and responsive to explore a brief exercise involving anaerobic metabolism at submaximal intensity. The number of steps taken in 1 minute seems a suitable parameter for practical application.





## 1. Introduction

Exercise programs are increasingly being proposed in clinical practice, the main objective being to increase aerobic capacities. A specific impact on anaerobic metabolism alone is never considered a goal for exercise programs or only partially for high-intensity training (e.g., interval training) to optimize physical performance when aerobic capacity is exceeded [1]. This situation appears paradoxical given the indispensable involvement of alactic and lactic anaerobic metabolism in the initial muscle metabolic pathways and its essential role in the activities of daily living, which are often too short to mobilize aerobic metabolism up to a stabilized stage. The context is different in athletes, for whom the improvement in anaerobic capacity is a priority in the practice of high-intensity sports, such as sprinting.

Two field tests have been developed to specifically assess the anaerobic component of effort and its evolution under the effect of sports training: the Margaria test [2] and the Wingate test [3]. Because of their constraints — important proprioceptive demand with maximum speed to climb stairs (taking steps 2 by 2 or 3 by 3) for the Margaria and extreme intensity on a cycle ergometer for the Wingate — these 2 tests are not suitable for people with chronic disabilities, who are often older and frequently

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have co-morbidities. Given the lack of specific field tests, the anaerobic component of exercise programs in individuals with chronic disability is neglected, even though it is probably of great importance for their autonomy.

Among potentially available tests to assess this dimension of adaptation to short-duration effort, standardized walk tests do not seem relevant, because they primarily quantify aerobic capacities [4]. Moreover, brisk walking and running are not usually possible for frail subjects [5]. Possibly, a single-step test would be more appropriate to assess populations with disabilities, because the metabolic stress is greater than with level walking [6], and such a test would be easier to implement, requiring no preliminary maximum stress test.

This study aimed to evaluate the metrological properties of a new functional test, the Short and Fast Step Test (SFST), in healthy individuals. Because of its short duration, 1 minute, and its high intensity, this test was initially designed to indirectly measure adaptation to effort mainly involving anaerobic metabolism, when aerobic metabolism has not yet reached its equilibrium state. This was a pilot study to explore the biomechanical and bioenergetic components of the SFST in comparison to a reference step test performed at a self-paced (comfortable) speed and to serve as a basis for a subsequent validation phase in people with chronic disabilities. We hypothesized that results from this new test would be submaximal in healthy people (as compared with the Margaria and Wingate tests), on the assumption that they would be maximal for disabled people, the aim being to look for correlations between biomechanical and bioenergetics parameters at different levels of intensity of the SFST.

## 2. Methods

### 2.1. Participants

Participants were prospectively recruited from the members (professionals and students) of a university hospital rehabilitation unit (inclusion from January to April 2016). The inclusion criteria were healthy persons without distinction of sex, between 18 and 65 years old, and moderate amount of physical activity. Exclusion criteria were hip, knee, ankle or foot disorders; chronic back pain; all neurological diseases; non-stabilized diabetes mellitus; cardiac, respiratory or renal failure; use of pharmacotherapy affecting adaptation to effort; and inability to understand the procedures. The participants' height and weight were measured, and the body mass index (BMI) was calculated. All participants gave their consent after being clearly informed about the protocol, which was approved by the institutional ethics committee (Patient Protection Committee, Dijon Est I, December 17, 2015).

### 2.2. Protocol design

Participants underwent the same protocol twice at an interval of 2 weeks to assess the reproducibility of the 2 different step tests. The same 2 investigators calibrated the apparatus, set up the equipment and gave instructions to participants. A 17.5-cm step height was used (depth 29 cm, width 60 cm) to match the dimensions of conventional stairs. However, this height was lower than that usually used in other studies [7] because the aim was to make the SFST suitable for older and deconditioned people who can have very diverse morphologic features.

The 2 step tests were conducted as follows:

Initial step test, at a comfortable speed (self-paced): after 10 minute of rest sitting down, the participant was instructed to "go up and down the step for 1 minute, at a comfortable pace to avoid fatigue and shortness of breath". In the current absence of reference standards on such a step test, the aim was to situate the relative intensity of the SFST in comparison with a moderate effort, as an extrapolation of the data established for walking, in which the self-selected (or comfortable) velocity corresponds to the most efficient energy use (i.e., the lowest adenosine triphosphate [ATP] expenditure per meter) [8]. After this 1-minute test, participants rested in a sitting position for 30 minute or longer if $VO_2$ had not returned to the same level ($\pm$1 ml/kg/minute) as the initial resting phase.

Second step test, at a brisk pace (SFST): the participant was instructed to "go up and down the step as many times as possible for 1 minute, without running". The aim was to analyse the participant's capacities in relation to a more intense demand on anaerobic metabolism, despite the probable submaximal intensity of this test in healthy participants. This effort was followed by a new 30-minute resting phase.

For each step test (self-paced and SFST), the participant was asked to always put the same foot first on the step at the beginning of each cycle of stepping up and down.

### 2.3. Outcome measures

Blood lactate levels were measured by enzymatic-amperometric detection (Lactate Scout, EKF Diagnostics) of the lactate concentration (pricking of a finger), just before and at the end of the test. This assessment was chosen to detect the first increase above the baseline level, as an indicator of the implementation of the glycolytic anaerobic system [9].

At the end of each test, participants had to rate their perceived exertion on the Borg scale, scores ranging from 6 to 20, with 6 rated as "very, very light" and 20 as "extremely hard") [10].

The main aim was to estimate the "oxygen debt" by assessing excess post-exercise oxygen consumption (EPOC). Continuous assessment of breath-by-breath gas exchange involved using a portable device (K4b2, Cosmed, Rome, Italy), with continuous heart rate monitoring (T31 coded TM-Polar). $VO_2$ uptake, $VCO_2$, and heart rate were directly computed and extracted from the device by using the incorporated software (K4b2 v10, Cosmed, Rome, Italy). Baseline values and variance of the $VO_2$ ($\delta^2_{VO_2}$) at rest were computed for each participant before beginning the modelling procedure.

The recovery period was fitted by using an exponential model:

$$VO_{2recov}(t) = \delta \times e^{\beta t}$$

with $\delta$ and $\beta$ constants derived from modelling (Matlab, the Mathworks, Tulsa, OK, USA).

EPOC was computed as follows:

$$EPOC = \int_{t=0}^{\partial} VO_{2recov}(t) \cdot dt$$

where $\partial$ is the time to reach a threshold calculated from $\delta^2_{VO_2}$:

$$threshold = 1.96 \times \sqrt{\delta^2_{VO_2}}.$$

Near-infrared spectroscopy (NIRS) involved use of a Portamon spectrometer (Artinis, The Netherlands) at 10 Hz frequency (for details see http://www.artinis.com/product/portamon). The skin was rubbed and cleaned with an alcohol swab and the NIRS detector was attached on the quadriceps muscle (lateral part at the mid position) of the dominant lower limb by means of an elastic bandage and tissue to reduce interference from outside light. The spectroscopy method was described previously [11]. NIRS data