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Physiological load and posture control thresholds

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ABSTRACT

The aim of the study was to evaluate the influence of the physiological load on postural control. Special attention was directed toward the identifying the intensity level in which the major deterioration in balance abilities occurs. Thirty subjects randomly divided into two groups performed multistage all-out exertion protocol on cycle-ergometer with measurements of ventilatory–metabolic and subjective parameters of exertion. Each stage lasted three minutes and was followed with three minute breaks during which the subjects underwent the static (keeping the cursor in the center of the screen) and the dynamic balance testing (following the cursor clockwise or counter clock wise by body movements) on balance platform. In a control group, the protocol encompassed only balance testing procedures followed by 3 min rest. After the completion of the testing procedures, the five intensity zones were determined according to the ventilatory–metabolic parameters. The significant differences in both static and dynamic balance tests were found between the test stages in exercising group. The post hoc analyses revealed the significant negative effect of exercise on the static balance with three visible "balance thresholds". The first threshold was at the rest to work transition, the second at the anaerobic threshold and the third at the maximal exertion level. The dynamic balance was also negatively affected with exercise, however no "balance thresholds" were clearly identified. No significant changes in neither static nor dynamic balance abilities were observed in the control group so the changes in the experimental group could have been attributed to the exercise intensity.

1. Introduction

The postural control and bipodal balance or simply keeping balance while standing on two legs with the eyes wide open is an essential part of the habitual daily activities [1] and good balance abilities are necessary in rehabilitation [2,3] but also during simple tasks like taking a ride on a tram or mobile escalators or dancing [1,3]. The influence of muscle exertion on balance was studied in bipedal and monopedal stance as well as and in open and closed eyes situations [4–6] and the maintenance of postural equilibrium is essential in sports. Muscular fatigue negatively influences ones postural control abilities [7,8].

Previous experiments used different exercise to test influence of fatigue on postural control [9–13]. Such protocol design resulted in various levels of local or central fatigue after which postural control abilities were tested. Final part of ski race or final quarter of soccer match represent critical moments of sports competition when postural control is most challenged. It would be of interest to know if there is specific exercise intensity zone at which postural control deteriorates causing loss of balance. If such exercise intensity zone would be detected we could plan specific training more closely to real situation. To our knowledge no previous study has investigated influence of fatigue on postural control with precise determination of exercise intensity zones from rest until exhaustion. We hypothesized that postural control either linearly deteriorates with the exercise intensity zone or that there is a "balance threshold" after which postural control exponentially worsens.

2. Methods

2.1. Subjects

Thirty healthy male subjects (mean age 28.4 ± 4.2 years, height 183 ± 3.8 cm, weight 88 ± 6.6 kg) were randomly divided into experimental and control group. All participants had aerobic capacity above 35 ml kg min^{-1} and had no previous cardiovascular, neurological or vestibular impairment. Informed consent was obtained from

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all participants and study was approved by Ethics committee of the faculty of Kinesiology, University of Zagreb.

2.2. Protocol

2.2.1. Balance

The protocol was conducted in a laboratory with constant microclimate conditions (temperature between 19 and 21 C, air humidity 60%). Before the beginning of the exertion protocol subjects were familiarized with the balance assessment system, the SportKAT 2000 (Berg. Inc.San Marcos, CA, USA) platform [14–16]. SportKAT platform is composed of a movable platform which is on its central point supported by a small pivot (Fig. 1). According to the manufacturer the deviation of a platform from a reference point is registered by a tilt sensor which is connected to a computer and the distance between reference and deviation point is measured 18.2 times per second. The balance index scores are determined by the time and distance that the subject is away from the intended target. Zero is a perfect score and scores range from 0 to 500. The platform field is divided into quadrants and the scores are recorded for each quadrant. The Balance Index Score is the sum of all the 4 quadrant scores (front, back, left and right). Less deviation from the reference point (lower score) implies better balance.

2.2.2. Exertion and balance protocols

A multistage all-out exertion protocol of spiroergometric testing on cycle-ergometer until exhaustion with continuous measurement of ventilatory–metabolic and subjective parameters of exertion began with minute of rest and customization with local microclimate conditions. Three trial static followed by three dynamic balance tests were performed. Static balance test consists of a subject standing on a movable pressure pillow which was set on bar 6 with eyes open and hips and knees flexed for approximately 20°. During static test subject tries to keep a cursor in the center of the monitor screen. Computer calculates the balance indices from time and distance that cursor spent away from a monitor center so balance index = sum of two front fields + sum of two back fields. In a dynamic test during 10 s point performs a full circle in a clockwise pattern on a monitor screen. Subjects aim is to follow circulating point by a cursor.

"Breath-by-breath" telemetric metabolimeter (K4, Cosmed, Italy) for gas analyzes and the heart rate monitor (Polar Electro OY CE 0537, Finland) were mounted on testing subjects. Subjects were asked to pedal on cycle ergometer (Monark 818-E, Stockholm, Sweden) beginning at a power output of 75 W for 3 min at 50 rev/min. Subjective evaluation of physical exertion using Borg scale of perceived exertion (Borg 1-13, RPA-rate of perceived exertion) was performed after each testing step. The three minute break between pedaling steps was used to draw the blood sample for blood lactate level measurement followed by both static and dynamic balance tests. Each balance test lasted for 30 s. This multistage testing protocol was conducted until the full exhaustion.

Fig. 1. SportKAT 2000 balance platform.

2.3. Control group

In a control group subjects performed only 7 repetitive static and dynamic balance tests on SportKAT balance platform. Tests were performed in a same manner as described for experimental group. In contrast to experimental group, after performing the static and the dynamic balance test, the subjects rested (seated) for 3 min.

2.4. Statistical analysis

We used STATISTICA (data analysis software system, version 7.1. StatSoft Inc. Tulsa, USA) for statistic analysis. After determination of means and standard deviations we used Friedman ANOVA to test the differences among repetitive measurements in the same group. Mann–Whitney-*U* test was used to test the differences between the groups and the differences among subsequent pairs of measurements within the same group were analyzed with Wilcoxon matched pairs.

3. Results

Age, sex, height and weight of the subjects showed no statistically significant difference between the experimental and the control group.

After all-out multi stage test the mean ventilatory–metabolic parameters (heart rate, absolute and relative VO_2 uptake, blood lactate concentration, ventilatory equivalent) and Borg subjective exertion level were analyzed and five intensity zones were determined (aerobic extensive or Zone 1, below the aerobic threshold, aerobic intensive, between the aerobic and aerobic threshold-Zone 2, anaerobic threshold zone determined according to Wasserman et al. [17]- Zone 3, lactate tolerance zone or above lactate threshold but 3 min were completed-Zone 4 and all-exertion zone or maximal effort zone when the activity was ceased before 3 min elapsed-Zone 5). To identify the intensity zones firstly the aerobic and anaerobic thresholds were determined and according to the values of heart rate, lactate and VO_2 the trial was appointed to one of the zones [17,18]. Depending on the subjects it took them one to three trials to reach the next intensity