EXHAUSTIVE EXERCISE AND SHORT TERM MEMORY

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ABSTRACT

Introduction*: The brain needs a continuous supply of O_2 and its deficiency may interfere with cognitive function. It has been observed that, during the performance of a maximal exercise, in the central nervous system (CNS) increases the use of lactate and glucose. Moreover, it has been described that during a maximal exercise the increase of blood lactate is associated with a worsening of attentive processes. The aim of this study was to investigate whether high levels of Lactate are capable of influencing other cognitive domains as Short-term memory.*

Materials and methods*: Fifteen male and healthy athletes participated in the research. Short-term memory span was carried through the Italian computerized version of Wechsler's Digit Span. The subjects were asked to perform an incremental cycling test on a mechanically braked cycloergometer. The measurement of values of blood lactate and the assessment of Short-term memory through the Italian computerized version of Wechsler's Digit Span were performed in three specific moments: 1) at rest (before); 2) immediately after performing an exhaustive exercise (end); 3) 10 minutes after the end of the exercise (10 min).*

Results*: Blood lactate levels increased from 1.5 mmol / l (± 0.21) at rest (pre), to 12.0 mmol / l (± 2.14) immediately after the exercise (end), and decreased to 1.6 mmol / l (± 0.21) 10 min after its conclusion (post). In parallel, we observed that the digit span shows a worsening of short term memory at the end of exercised and returned to the pre-exercise values within 10 min after the conclusion of exercise.*

Conclusion*: The present results show that high levels of blood lactate, as those induced with an exhaustive exercise, influence the cognitive domain of the memory in the same way observed for the cognitive domain of attention.*

Key words*: exhaustive exercise, brain, lactate, short term memory.*
DOI:10.19193/0393-6384_2016_1_03

Received *January 30, 2015;* ***Accepted*** *March 30, 2015*

Introduction

The brain needs a continuous supply of O_2 and its deficiency may interfere with cognitive function.

It has been observed, that during the performance of a maximal exercise, in the central nervous system (CNS) the consumption of lactate and glucose increases[1,2]. Moreover, it has been described that during a maximal exercise the increase of blood lactate is associated, in the frontal lobe, with an improvement of the excitability of primary motor cortex and with a worsening of attentive processes[3-10].

The aim of this study was to investigate whether high levels of blood lactate are capable of influencing besides the attentional processes other cognitive domains, as Short-term memory, evaluated by measuring the memory span. This term refers to the ability of an individual to reproduce instantly, after a single presentation, a series of stimuli in their original order. Any type of stimuli may be presented, such as digits, letters, words, and sounds, and almost any sense organ may be used to collect the stimuli[11-15].

Digit-span task is used to measure memory span, i.e. memory's number storage capacity[16-20].

Subjects are presented with a series of digits (e.g., 3 numbers) and must immediately repeat them forward and backward. If they do this successfully, they receive a longer list (i.e. 4 numbers). The length of the longest list a subjects is capable to remember is the digit span of that subject. Whereas the subject is asked to enter the numbers in the given order in the forward digit-span task, in the backward digit-span task the subject has to reverse the order of the digits[21-25].

Materials and methods

Subjects

Fifteen male and healthy athletes participated in the research. Table 1 shows some anthropometric characteristics of the subjects as the mean age of the sample, and their body mass index (BMI), as defined by Keys et al[26]; BMI is obtained by dividing the body weight by the square of the height (kg / m^2). As can be seen, subjects had a mean height of 1.8 m (± 0.01), a mean weight of 79.1 kg (± 12.66) and a mean BMI of 24.5 m (± 2.46).

Height (cm)	Weight (Kg)	BMI
1.73	71	23.72
1.68	66	23.38
1.75	70	22.86
1.69	64	22.41
1.78	81	25.56
1.95	94	24.72
1.8	90	27.78
1.82	95	28.68
1.7	65	22.49
1.98	93	23.72
1.7	62	21.45
1.81	95	29.00
1.75	70	22.86
1.8	87	26.85
1.92	83	22.52

Table 1: Anthropometric characteristics of the subjects participating the study. BMI: body mass index.

All participants, after being informed about the purpose of the work and the connected possible risks, have signed an informed consent written in accordance with the ethical standards laid down by the Declaration of Helsinki[27].

Protocol

The subjects were asked to perform an incremental cycling test on a mechanically braked cycloergometer (Monark, Vansbro, Sweden), at a constant pedaling rate of 60 rpm, while electrocardiogram was monitored[28].

The measurement of values of blood lactate and the assessment of digit span was performed in three specific moments: 1) at rest (before); 2) immediately after performing an exhaustive exercise (end); 3) 10 minutes after the end of the exercise (10 min).

Blood Lactate

The blood lactate levels were measured using a "Lactate Pro" portable lactate analyzer (FaCT Canada Consulting Ltd., Quesnel, Canada); this blood lactate test meter has been previously validated for its reliability by Mc Naughton et al.[29] and Buckley et al.[30].

Digit Span

Short-term memory span was carried through the Italian computerized version of Wechsler's Digit Span made by Di Nuovo[31].

While the subject was sitting in front of a computer screen, it was being shown a series of numbers of increasing length and he had to reproduce them either forward and backward. The session always begins with a list of two numbers that gradually increase whether the subject correctly identifies the figures previously proposed. The highest number of correctly remembered figures represents the subject's digit span. The average digit span for normal adults without error is seven plus or minus two[32].

Statistical analysis

Data was collected and averaged, and then compared by using one-way repeated measures analysis of variance (ANOVA; Friedman test), followed by post-hoc Dunn's Multiple Comparison Test. The relationship between variables was analyzed with linear regression. Significance was set at $p < 0.05$ and all data are reported as mean ± standard deviation (SD). All analyses were performed by means of using GraphPad Prism version 6.03 for Windows (GraphPad Software, San Diego, CA, USA).

Results

As shown in Figure 1A, values blood lactate increased from 1.5 mmol / l (± 0.21) at rest (pre), to 12.0 mmol / l (± 2.14) immediately after the exercise (end), and decreased to 1.6 mmol / l (± 0.21) 10 minutes after its conclusion (post).

In figures 1B and 1C it can be observed that the digit span shows statistically significant differences for both forward and backward recall between the values obtained before the exercise (pre) and end, with a worsening of short term memory at its end and a return to the values obtained before the exercise within 10 min after the conclusion of exercise (post).

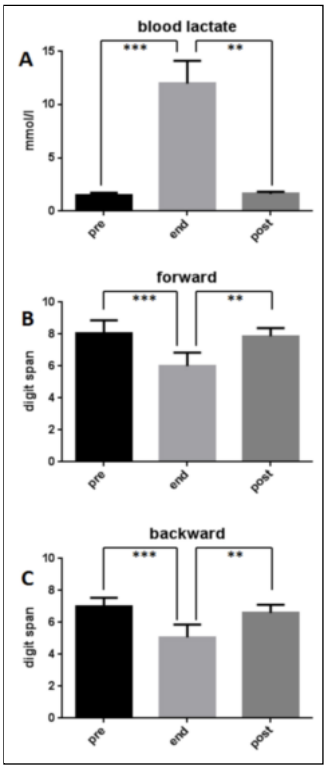

Figure 1: Mean values of blood lactate, digit span forward and digit span backward measured at rest (pre), at the conclusion of the exhaustive exercise (end) and 10 min after its conclusion (post). It can be seen that the increase of blood lactate, observed at the end of exercise, is associated with a worsening of both forward and backward digit span.

Table 2 shows a statistically significant difference between the values obtained before and at the end of exercise and between the end and 10 minutes after the conclusion of exercise. It can be seen that the increase of blood lactate, observed at the end of exercise, is associated with a worsening of both forward and backward digit span.

Dunn's Multiple Comparison Test	pre vs end	pre vs post		end vs post
Blood Lactate	P < 0.001 ***	P > 0.05	ns	P < 0.01**
Digit Span forward	P < 0.001 ***	P > 0.05	ns	P < 0.01**
Digit Span backward	P < 0.001 ***	P > 0.05	ns	P < 0.01**

Table 2: One-way repeated measures analysis of variance (ANOVA; Friedman test), followed by Dunn's Multiple Comparison Test, of data illustrated in figure 1.

Discussion

The Wechsler's Digit Span assesses the verbal Short-term memory, i.e. the efficiency of the cognitive system used for the temporary storage of information. According to Baddeley & Hitch theory[33], this system has specific modules, one of which, the 'Phonological loop', underlies verbal memory abilities[33]. The phonological loop involves a verbal storage system and a rehearsal system. It allows to record visual inputs so that they can enter Short-term memory verbal store, and it also restores decaying representations (i.e., any item that is about to be forgotten)[34-38].

The verbal Short-term memory is considered one of the components of intelligence; thus, the digit span task is present in many IQ (intelligence quotient) tests, as the Wechsler Adult Intelligence Scale (WAIS)[39].

The results obtained from this study show that high levels of blood lactate, as those induced with an exhaustive exercise, influence the cognitive domain of the memory in the same way as Coco et al.[4] observed for the cognitive domain of attention.

Alagona et al.[3] noted that using the repetitive TMS, in experimental conditions, in which the excluded muscle involvement that the lactate production is associated with an increase in blood lactate, which probably exceeds the blood brain barrier by modifying the excitability.

This paper observes that the memory span becomes less efficient after the execution of an anaerobic exercise. Therefore, it can be hypothesized that a massive lactate production can exert a negative action on the prefrontal cortex, worsening some cognitive functions such as attentional processes or short term memory.

The present results support the idea that blood lactate is able to exert on the CNS a double effect[40-47]: on one hand exerts a protective action against fatigue on the primary areas, such as the primary motor cortex, the primary visual cortex and the post-central gyrus, while the other it causes a deterioration of the non-primary areas, as the prefrontal cortex and the accessory visual and somatosensory areas.

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