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Full Length Research Paper

Plasma volume decreases in obese adolescents: An important performance limiting factor during supramaximal exercise

Jabbour G* and Iancu HD

School of Kinesiology and Leisure, Faculty of Health Sciences and Community Services, Université de Moncton, New Brunswick, E1A 3E9, Canada.

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This work examines the relationship between plasma volume variation and performance measured during supramaximal exercise among adolescents with different body weight statuses. Sixteen adolescents (normal-weight, over weight and obese) performed an exercise sprint on an ergometer cycle. Following exercise, plasma volume decreased significantly in the obese group and was associated with decreases in performance ($r = -0.85$, $p<0.05$) compared to the overweight and normal-weight groups ($p<0.01$). Our results suggest that the decrease in plasma volume that occurs after an exercise sprint test may limit performance during repeated sprint exercise in obese and overweight adolescent boys.

Keywords: Obese, performance, supramaximal exercise, plasma decreases, adolescents, boys.

INTRODUCTION

Obese adolescents and adults can exhibit a considerable degree of functional limitation in motor activity due to a reduction in aerobic (Hulens, 2001) and anaerobic (Sartorio, 2006) capacities. The reduction in these fitness indices was usually interpreted as a consequence of the presence of excess fat (Lazzer, 2005; Blimkie, 1990). For aerobic aptitude, an excess of fat mass limits the muscular capacity to use oxygen (Lazzer, 2005). In terms of anaerobic capacity, an excess of fat mass reduces muscle efficiency (Blimkie, 1990). In normal-weight individuals, several studies observed a significant decrease of plasma volume values during short intermittent supramaximal exercise (Green, 1984), resulting in decreased exercise performance. A recent study by Jabbour et al. (2014) observed higher decreases in plasma volume in response to repeated supramaximal exercise in obese individuals compared to normal-weight individuals. Considering that plasma volume is a component responsible for the delivery of several nutrients and fuel to working muscles (Willmore, 1999), we speculated that the higher decreases in plasma volume observed in this model of exercise could affect the performance of obese individuals. Consequently, this work aims to study the links between plasma volume changes and performance during a supramaximal exercise period in adolescent boys with different body weight statuses.

EXPERIMENTAL PROCEDURES

The survey was approved by the Ethical Committee on Human Research (ECHR) of the University of Balamand (Lebanon), and parental informed consent was obtained. Before entering our protocol, the adolescents were

*Corresponding Author E-mail: georgesjabbour1980@hotmail.com; Phone number: (506) 858-4165; Fax number: (506) 858-4308

thoroughly familiarised with all of the testing equipment and procedures. Each subject cycled for many minutes against three different loads on the same cycle ergometer used for the entire experiment. Moreover, they were asked to determine the position at which they did not have any limitation to their pedalling movement. The exercise testing was conducted on 3 different days (D1, D2 and D3). On D1, the anthropometric measurements (body mass, height) were taken. The body mass index (BMI) was calculated as the ratio of mass (kg) to height2 (m2). The percentage of body fat was estimated from 3 skinfold thickness assessments (biceps, triceps and sub-scapular) according to the method of Slaughter et al. (1988). The fat-free mass was calculated by subtracting the fat mass from the body mass. Then, subjects performed a maximal exercise test on an upright cycle ergometer (Monarkergomedic 839E electronic test cycle, USA) to determine their peak oxygen consumption (VO_{2peak}). On D2, after 10 min of warming up, subjects performed a Force-Velocity test. The Force-Velocity test was performed on a cycle ergometer using a technique adapted from the study by Vandewalle et al. (1985). Power output was calculated by multiplying the load and speed, and a power curve was then compiled for each bout. The optimal load corresponding to the maximal power (POmax) was used for the supramaximal exercise test performed on D3. On D3, the testing started for all subjects at approximately 9 am, 3 hours after a standardised breakfast (10 kcal/kg, 55% carbohydrates, 33% lipids and 12% proteins). Initial venous blood samples from an antecubital vein were drawn after 5 min of rest at an upright position on the cycle ergometer, and the adolescents then warmed up for 10 min at a submaximal power between 55 and 65 Watts (corresponding to 55% of VO_{2peak}). Subsequently, each subject performed a repeated sprint cycling test (6 repetitions of 6-second maximal sprints with 2 min of passive rest between each repetition). The velocity was again recorded throughout the test and served to determine the mean power output (PO_{mean}: the mean of all powers developed during the supramaximal exercise test (SME). Performance reduction was determined as the percentage of the power variation from the first to the sixth repetition (ΔPm %).

Blood analyses

Haematocrit (Ht) was measured at rest, after the warm-up and at the end of SME for each blood sample by micro-centrifugation (JOUAN-HEMAC). Plasma volume variations (ΔVP), expressed as percentages of the rest values, were calculated from Ht variations according to Van Beaumont et al. (1972): %ΔPV = 100 [(Ht1-Htx) / Htx × (100-Ht1)], where Ht1 is the resting value and Htx is the value at the time of exercise or after the warm-up period.

Statistical analysis

The data were summarised as the mean and standard error of the mean (χ ±SEM) and analysed using Statistica 21 software. After testing for normal distribution (Kolmogorov–Smirnov test), differences within and between the groups were analysed using a two-way analysis of variance for repeated measurements. After confirming significant group differences over time, the Newman-Keuls post-hoc test was performed. Pearson correlations were used to assess the association between the plasma volume decrease at the end of SME and performance reduction for all of the experimental groups. A value of $p<0.05$ was set as the level of statistical significance.

Table 1. Anthropometric and performances characteristics of adolescents

	NW ***n=20***	**OW** ***n=20***	**OB** ***n=20***
Anthropometricmeasurements			
Age *(years)*	13.5 (0.2)	13.5 (0.4)	13.4 (0.7)
Weight*(kg)*	50.2 (5.4)	66.3 (11.1) [a]	90.8 (14.0) [a b]
FM *(%)*	16.3 (3.2)	22.3(4.1) [a]	29.8 (4.2) [a b]
BMI *(kg/m²)*	18.9 (1.2)	24.6(1.5) [a]	30.9 (2.4) [a b]
Maximal Exercise test			
VO_{2peak}*(ml.min⁻¹.kgFFM⁻¹)*	52.1 (4.1)	48.7 (5.7)	48.1 (4.4)
HRpeak*(beats.min)*	202.9 (4.1)	201.2 (3.7)	201.3 (4.1)
RER	1.22 (0.05)	1.18 (0.03)	1.20 (0.04)
Fore Velocity Test			
POmax*(W.Kg⁻¹.KgFFM⁻¹)*	7.7 ± 1.4	7.7 ± 1.2	7.6 ± 0.9
Supramaximal exercise test (SME)			
ΔPV (%) after warm-up	-2.51 (3.2)	-5.62 (2.4) [a]	-11.52 (2.6) [a]
ΔPV (%) end of SME	-5.41 (6.4)	-14.71 (1.4) [a]	-19.01 (5.3) [a b]
SME performances			
P1 (W.Kg-1)	9.8 (1.2)	9.6 (1.2)	9.7 (0.9)
P2 (W.Kg-1)	9.6 (0.5)	7.8 (1.6) [a c]	7.3 (0.1) [a c]
P3 (W.Kg-1)	9.8 (0.8)	7.8 (0.7) [a c]	7.1 (0.8) [a b c]
P4 (W.Kg-1)	9.5 (1.8)	7.7 (0.6) [a c]	7.1 (0.9) [a b c]
P5 (W.Kg-1)	9.7 (0.8)	7.4 (1.2) [a c]	7.1 (1.8) [a b c]
P6 (W.Kg-1)	9.7 (0.8)	7.5 (1.2) [a c]	6.2 (0.9) [a b c]
Pm (W.Kg-1)	9.7 (1.6)	7.7 (1.1) [a c]	7.3 (0.8) [a b c]
Δ Pm (%)	- 3 (1)	- 14 (9) [a]	- 20 (8) [a b]

Values are given as the mean (standard deviation). ***NW:*** normal-weight, ***OW:*** overweight, ***OB:*** obese, ***n:*** number of subjects, ***FM:***fat mass, ***BMI:***body mass index,***VO_2peak:*** peak oxygen consumption,***HRpeak:*** peak heart rate, ***RER:*** respiratory exchange ratio,***POmax:*** maximal power during the Force Velocity test, ***ΔPV***: Plasma volume change, ***P:*** power developed at each repetition, ***1, 2, 3, 4, 5, 6:*** number of repetition, Pm: mean of all powers developed during the CST, ***ΔPm (%)***: performance reduction determined as the percentage of the power variation from the first to the

sixth repetitions. Significant difference with NW: (a: $p<0.01$). Significant difference with OW (b: $p<0.01$). Significant difference with power developed at the first repetition (P1) (^{c} $p<0.01$).

RESULTS AND DISCUSSION

This study examined the relationship between plasma volume decrease in response to supramaximal exercise and the performance of adolescent boys with different body weight statuses. In this study, the mean power output during the SME was significantly lower in obese compared to overweight and normal-weight adolescent boys ($p<0.01$respectively) (Table 1). Similar results have been reported previously (Duché, 2002; Sartorio, 2006). In these previous studies, the supramaximal performances of obese subjects, assessed by a stair climbing test (Sartorio, 2006) or using the Force-Velocity test (Duché, 2002), was significantly lower compared to non-obese subjects. The difference in performance was thought to be related to the excess fat mass in obese individuals. Our results suggested that performance decreased with decreasing plasma volume and differed among the body weight status groups. In normal-weight individuals, limited data are available regarding the effects of plasma volume variation on exercise performance and, specifically, reduction in exercise performance in parallel with decreased plasma volume (Walsh, 1994). Indeed, a decrease in plasma volume may affect the delivery of several nutrients and fuel to working muscles and lead to impairment of exercise performance. In obese adolescents, our results demonstrated a significant relationship between decreased plasma volume and reduced supramaximal performance($r= 0.81$, $p<0.05$), which leads us to propose that this parameter is an important performance-limiting factor in obese adolescents. To date, we do not understand the mechanisms that contribute to the differences in plasma volume changes according to body weight statuses. However, our results add novel insight into the role of plasma volume as a factor affecting exercise performance in obese individuals. This finding may also provide a scientific rationale for trainers and conditioning professionals to rehydrate, for example, obese individuals appropriately following high intensity exercise bouts or moreover, to avoid training in high heat condition.

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