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BODY COMPOSITION AND PEAK EXERCISE HAEMATOLOGY IN ADULT MALES

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Abstract

The relative plasma volume decrease has mostly been studied in exercises of long duration and without respect to habitual physical activity. Anthropometric characteristics and peak-exercise plasma volume decrease were compared in adult male non-athletic subjects (n = 20), PE students (n = 25) and League I soccer players (n = 25). Height, body mass, CONRAD (1963) indices, muscle and fat mass were compared. The all-out exercise was performed on the treadmill. Haematology was studied by the QBC AUTOREADER technique at rest and immediately after exercise in 30 μl arterialized blood samples. The relative plasma volume decrease was estimated by the method of GREENLEAF and HINGHOFER-SZALKAY (1985) With the exception of the mononuclear percentage, the initial haematology was similar in all groups. The peak-exercise plasma volume decrease was significantly smaller and the mononuclear percentage was significantly larger in the physically active groups. The greater mononuclear percentage is likely to be one of the indicators of those regulatory processes that play an important part in the appearance of the smaller peak-exercise plasma volume decrease in the physically active groups.

Key words: plasma volume decrease, physical activity, body composition, all-out exercise

Introduction

Increased resting blood and/or plasma volumes induced by regular physical training have been reported by several authors in the past two decades (CONVERTINO et al., 1980; COLLINS et al., 1986; SCHMIDT et al., 1988). Since this increase in blood/plasma volume can develop even after only some weeks of regular endurance training, it may be considered an early sign of cardiorespiratory and metabolic adaptation to exercise. An experimentally increased resting plasma/blood volume (within the range 400-700 ml) has been found to be favourable by allowing a larger stroke volume and cardiac output (HOPPER et al. 1988).

FORTNEY et al. (1983) made the exercise-physiologically intriguing statement that the exercise decrease of the blood or plasma volume was directly proportional to the stroke volume, and in this way to the cardiac output measured during submaximum exercise. Thus, cardially very fit athletes having an exceptionally high aerobic power, i.e. maximum stroke volume and cardiac output, would be in a less advantageous position than non-athletes, since in this way the haemoconcentration would be more marked in them and therefore impair their physiological performance.

The purpose of the present study was to compare the peak-exercise plasma volume decreases in young adult males of different habitual physical activity.

Our research hypothesis was as follows. Cardially well-trained athletes have a larger stroke volume and cardiac output during exercise (BLOMQVIST and SALTIN, 1983). If the plasma volume decrease were directly related to the cardiac output or stroke volume, the plasma volume decrease during exercise should be smaller in non-athletic subjects.

Subjects and methods

The investigated subjects were volunteers:

1. Adult male League I soccer players (n = 25) participating in 11 intense training sessions and at least one competition per week.

2. Students at the Hungarian University of Physical Education (n = 25) taking part in 5 practical sessions (of 90 min. each) and 3-5 event training sessions of high intensity per week.

3. Non-athletes (n = 20) performing a maximum of 2 hours a week of non-regular fitness activity.

The members of Groups 1 and 2 held sport medical licences for competitions; the non-athletic subjects underwent detailed internal medical and cardiorespiratory screening before the data collection.

For the sake of comparability, the subjects' relative body linearity and skeleto-muscular robustness were described by CONRAD's (1963) metric and plastic indices. The metric index is the ratio of chest breadth to chest depth, corrected for height. The plastic index is the sum of shoulder width, lower arm girth and hand circumference.

Body mass-related muscle and fat masses were estimated by the DRINKWATER and ROSS (1980) body mass fractionation technique and expressed as percentages. In the measurement of the necessary body dimensions, the IBP suggestions (WEINER and LOURIE, 1969) were observed.

The all-out laboratory exercise was performed on the treadmill. The test exercise began at a 12 km/h belt speed and zero level of inclination after individual warming-up. (The soccer players and university students warmed up independently; for the non-athletes, the warming-up was directed by a PE teacher and consisted of callisthenics, skipping, jogging and stretching exercises). The belt inclination was increased by 3% every second minute until exhaustion. The belt was stopped by the subjects.

Peak exercise serum lactate levels were measured with an LP-20 miniphotometer (Dr. LANGE, Germany) in 10 μl capillary blood samples. Haematology (haematocrit, haemoglobin level, white blood cell count, granulocyte and lymphocyte + monocyte percentage) was determined by the QBC AUTOREADER (USA) technique, using 30 μl arterialized blood samples. Blood was sampled at rest (before the anthropometric data collection) and immediately after stopping the exercise, from the fingertip in the sitting position.

The post-exercise relative plasma volume was calculated by the equation of GREENLEAF and HINGHOFER -SZALKAY (1985):

$$PV\% = 100 \times [HGB_b \times HGB_a^{-1} \times (1\text{-}HCT_a) \times (1\text{-}HCT_b^{-1})]$$

where PV% = relative plasma volume as a percentage of the initial volume, HGB = haemoglobin concentration ($g \times 100\ ml^{-1}$), HCT = haematocrit (%), b = before exercise, a = after exercise.

Means and standard deviations of the anthropometric and haematological parameters were tested by F-test at the 5% level of random error after one-way ANOVA. Differences between the resting and post-exercise variable means were analyzed by t-tests for dependent samples.

Results and discussion

The first part of this section contains the results of the studied anthropometric variables, while in the second part the haematological and plasma volume changes are reported.

Statistical means and standard deviations of the anthropometric variables are listed in Table 1. The mean calendar age of the non-athletes was significantly greater than that of the university students and soccer players, but in this young adult age range no particular importance was attributed to a difference of 2-4 years.

Table 1. Basic statistics of the compared anthropometric variables.

Variable	Non-athletes Mean	SD	University students Mean	SD	Soccer players Mean	SD	P
DA(yr.)	27.20	2.53	23.14	2.27	25.47	3.50	< 5%
BH (cm)	175.89	6.23	180.84	6.09	181.73	4.84	< 5%
BM (kg)	77.43	6.46	74.21	5.95	73.04	4.87	< 5%
M(%)	45.01	1.11	48.79	1.06	49.25	1.14	< 5%
F(%)	15.55	2.83	9.23	1.58	9.03	1.20	< 5%
MIX (cm)	−0.85	0.29	−1.14	0.28	−1.27	0.24	< 5%
PLX (cm)	86.08	3.12	88.96	3.26	91.41	2.25	< 5%

Abbreviations: DA = chronological age expressed in decimal years, BH = height, BM = body mass, M = body mass-related muscle mass, F = body mass-related fat mass, MIX = metric index, PLX = plastic index, < 5% = the difference between the compared means is statistically significant.

The non-athletes were significantly shorter and heavier than the university students and soccer players (termed active groups hereafter). Both active groups had significantly greater muscle and markedly lower fat percentage means. The growth type of the non-athletes was metromorphic and normoplastic according to the CONRAD (1963) categories. The active groups could be qualified as hyperplastic and slightly leptomorphic. The leptomorphy was rather "athletic" and not extremely linear, as one of the consequences of sports selection effects (MÉSZÁROS and MOHÁCSI, 1982a; 1982b; MOHÁCSI and MÉSZÁROS, 1982). The well-developed bone-muscle system was attributed to their regular physical activity. All the studied anthropometric characteristics of the PE students and soccer players were statistically the same.

The basic statistics of the physiological variables are summarized in Table 2. An evaluation of the statistically different running distances (all three means were different from each other) and the really high associated blood lactates (no essential differences were found between the means) clearly revealed that the investigated subjects performed at (or very near to) their momentary maximum. In absolute terms, the physical performances of groups were naturally different, but all three groups worked at their physiological maximum, so this is the basis of the present comparison.

No significant differences were found in the resting haematological group means. (The observed means were very near to the centre of the physiological ranges.) The only exception among the studied haematological parameters was the lower resting mononuclear percentage of the non-athletes. In other words, the two active groups had greater resting lymphocyte and monocyte counts at rest. This finding agrees with the observations of KEAST et al. (1988) and MACKINNON (1989): Regular physical activity has positive effects on the immune functions, represented by an increased lymphocyte count and also an increased activity of lymphocytes and other parts of the lymphatic immune system.

The initial haemoglobin and haematocrit levels and total white blood cell count increased significantly in all groups during the applied all-out exercise, a well-known consequence of long- or short-term (but intense) physical exercise (see SENAY and PIVARNIK, 1985; SCHMIDT et al.,1989; NG et al.,1996). Although there were no statistical differences between the exercise-induced haemoglobin and haematocrit increases, the differences between the calculated mean plasma volume decreases were significant. In the two active groups, the relative plasma volume decrease was of a similar extent and significantly smaller than in the non-athletes.

Table 2. Means and standard deviations of the physiological parameters

Variable	Non-athletes		University students		Soccer players		P_F
	Mean	SD	Mean	SD	Mean	SD	
HCTb	46.00	0.89	46.16	1.00	46.24	0.81	NS
HCTa	49.68	1.58	48.79	1.79	49.01	1.52	NS
P_t	< 5%		< 5%		< 5%		
HGBb	15.05	0.59	15.21	0.61	15.11	0.52	NS
HGBa	16.68	0.61	16.38	0.76	16.15	078	NS
P_t	< 5%		< 5%		< 5%		
WBCb	5.10	0.58	5.39	0.60	5.05	0.45	NS
WBCa	8.58	1.39	8.85	1.35	9.21	1.19	NS
P_t	< 5%		< 5%		< 5%		
L+M%b	41.30	5.35	39.16	5.07	35.71	4.97	< 5%
L+M%a	45.30	6.60	53.40	6.39	54.45	6.31	< 5%
P_t	< 5%		< 5%		< 5%		
LA	15.06	2.94	15.60	2.86	14.82	2.17	NS
RD	1665.55	328.99	2362.76	281.55	2881.12	214.23	< 5%
PV%a	84.08	2.55	88.32	2.19	88.57	2.03	< 5%

Abbreviations: HCT = haematocrit (%), HGB = haemoglobin ($g \times 100\ ml^{-1}$), WBC = white blood cell count ($1000 \times \mu L$), L+M% = ratio of lymphocytes + monocytes in the measured WBC (%), LA = blood lactate concentration ($mmol \times L^{-1}$), RD = running distance (m), PV% = peak exercise plasma volume as a percentage of the initial value, $P_F < 5\%$ = the difference between the group means is significant at the 5% level of random error, $P_t < 5\%$ = significant difference before and after the exercise, NS = non-significant.

The post-exercise mononuclear percentages in the increased white blood cell count were also different between the active and non-active groups. This exercise-induced response was significantly greater in the university students and soccer players.

The international literature and the present results indicate that the plasma volume decrease during any physical activity is one of the consequences of exercise itself. The mechanisms of the decrease have not yet been clarified in detail.

SENAY and PIVARNIK (1985), and NIEMAN (1995) have described that, during graded exercise, 10 to 20% of the plasma volume leaves the blood and enters the active muscle tissue. This plasma volume shift, combined with the fluid loss from sweating, would lead to an increase in the thickness of the blood, called haemoconcentration.

WILMORE and COSTILL (1994) explained the plasma volume decrease as arising from an increased blood pressure and the changed metabolism of the working muscle. In contrast, NG et al., (1996) and MÉSZÁROS et al., (1996) found that, under laboratory conditions, the peak-exercise plasma volume decrease failed to correlate with the extent of fluid loss (either during exercise or sitting in a sauna), with the increased systolic blood pressure or with the increase in running distance. Instead, they reported a slight but significant relationship between the peak-exercise plasma volume decrease and the anthropometrically estimated muscle mass expressed as a percentage.

In the interpretation of WILMORE and COSTILL (1994), the fluid shift from the circulation to the working muscle is favourable in respect of its metabolism. However, the plasma volume decrease is unfavourable for the cardiac functions during high-intensity exercise (HOPPER et al., 1988).

Theoretically, the circulating plasma volume at or around peak-intensity exercise is the joint effect of the circulatory redistribution (BLOMQVIST and SALTIN, 1983; GISOLFI, 1983), the fluid shift towards the working muscle (STEPHENSON and KOLKA, 1988; SCHMIDT et al., 1989; NG et al., 1996) and the resting blood/plasma volume, which is increased in well-trained subjects (CONVERTINO et al., 1980; COLLINS et al., 1986; SCHMIDT et al., 1988).

Though the effects of the intracirculatory redistribution are measurable and cannot be neglected, they seem to be less important in respect of this specific kind of plasma volume decrease. Redistribution *per se* cannot completely compensate for the fluid loss, because some exercise-induced plasma volume decrease occurs consistently in everybody. In respect of the mentioned cardiac functions (stroke volume and cardiac output) and blood viscosity, within the physiological range a larger initial blood or plasma volume and a smaller plasma volume decrease would be favourable for any physical effort.

The present results have shown that the plasma volume decrease is significantly smaller in physically active students and endurance-trained soccer players. Taking all the studied effects in combination, it is the healthy but untrained organism that appears in a worse condition, because its initial blood volume is smaller and its plasma volume decrease during exercise is greater than in physically more active subjects.

The greater mononuclear percentage is likely to be one of the indicators of those regulatory processes that play an important part in the appearance of a smaller peak-exercise plasma volume decrease in physically active groups.

In conclusion, our working hypothesis had to be discarded, because the relative plasma volume decrease was significantly greater in non-athletic subjects than in the two investigated active groups. In respect of physical performance, the latter represent the more preferable state.

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