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Anthropometric and cardio-respiratory indices and aerobic capacity of male and female students

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Summary

Study aim: To assess the relations between anthropometric and cardio-respiratory indices, and aerobic capacity of students, differing in the level of physical activity, under resting and exercise conditions.
Material and methods: A group of 87 male and 75 female students volunteered to participate in the study. Their physical activity was evaluated by Seven-Day Physical Activity Recall questionnaire. Anthropometric (body height and mass, body fat content, BMI and WHR) and physiological indices (heart rate, blood pressure, $\dot{V}O_2$max, $\dot{V}CO_2$ and minute ventilation) were recorded. Body fat content was determined using a BIA device; respiratory data were recorded in a cycle ergometer test. The subjects were classified by their $\dot{V}O_2$max values into 'high' or 'low' categories, the cut-off values of lower and upper quartiles serving as criteria.
Results: Male and female students expended 10.2 ± 4.6 and 8.4 ± 5.3 kcal/kg/day, respectively, the $\dot{V}O_2$max amounting to 48.4 ± 6.4 and 41.1 ± 4.7 ml/kg/min, respectively. Subjects having high $\dot{V}O_2$max had significantly higher energy expenditure on physical activities, fat-free mass, body water content and maximal ventilation, and lower body mass, BMI, body fat content, resting heart rate and diastolic pressure.
Conclusions: When investigating into the relationships between physical activity and physiological features, the latter ought to be related to $\dot{V}O_2$max rather than to energy expenditure which may depend on other than physiological variables.

Key words: Aerobic capacity – Physical activity – Body composition – Cardio-respiratory indices

Introduction

Physical activity is a natural need, indispensable for maintaining health and normal physiological functions. Insufficient physical activity is an independent risk factor of many diseases, like obesity, type 2 diabetes, osteoporosis, hypertension, coronary heart disease, emotional disorders, etc.; it increases the global death rate, as well as that due to cardiovascular and malignant diseases [1,11,17]. Low physical activity is widely spread in highly developed countries [8,12]. As shown by studies conducted in 2002 – 2004 in Poland, physical activity of adult population increased as compared with the previous decade [5,6].

Physical activity has an impact on work capacity and body composition. Basal metabolic rate, $\dot{V}O_2$max and hemodynamic responses to exercise are known to be stronger related to fat-free mass than to body height or total body mass [15,19]. Physical education (PE) students, especially those engaged in sports, exhibit a higher physical activity than the adult population [16,23]. The aim of this study was to assess the relationships between the aerobic capacity of first-year PE students and their somatic and physiological indices, and physical activity.

Material and Methods

A group of 87 male and 75 female first-year physical education students volunteered to participate in the study. The subjects were instructed to check at the laboratory after a light breakfast without coffee, to abstain from smoking and/or alcoholic beverages and not to perform any strenuous exercise for not less than 24 h preceding the examination. Only non-menstruating female students were admitted. The study was approved by the local Committee of Ethics.

The amount of physical activity was expressed as the daily energy expenditure on leisure and sport activities

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resulting from the Seven-Day Physical Activity Recall (SDPAR) questionnaire [21,22]. A bioimpedance-based device (BC-418 MA, Tanita Europe, UK) was used to assess body composition. Resting heart rate (HRr), systolic pressure (SPr) and diastolic pressure (DPr) were determined by Korotkov's procedure; moreover, the so-called double product (HRr × SPr) was computed. Aerobic capacity was expressed as maximal oxygen uptake ($\dot{V}O_2$max) measured with the use of cycle ergometer (Ergomedic 874E, Monark, Sweden); expired air analyser Sensor Medics 2900/2900c (USA) was used; heart rate, minute ventilation ($\dot{V}E$) and oxygen uptake ($\dot{V}O_2$) were recorded throughout the test.

The subjects were arranged according to their relative $\dot{V}O_2$max and the results of those from the lower and upper quartiles were subjected to further analysis by two-way ANOVA followed by Student's *t*-test for independent data in cases of significant gender × aerobic capacity interaction. Pearson's coefficients of correlation between the relative $\dot{V}O_2$max and other variables were computed. The level of $p \leq 0.05$ was considered significant.

Results

Mean values (±SD) of basic anthropometric variables are shown in Table 1 and those of body composition and physiological ones in Table 2.

Table 1. Physical characteristics of subjects

Variable	Men (n = 87)	Women (n = 75)
Age (years)	20.2 ± 0.8	20.2 ± 1.1
Body height (cm)	180.6 ± 6.0	167.5 ± 5.4
Body mass (kg)	76.6 ± 8.7	60.1 ± 7.5
BMI	23.5 ± 2.5	21.4 ± 2.4
WHR	0.90 ± 0.06	0.85 ± 0.05

Legend: BMI – Body mass index; WHR – Waist-to-hip ratio

Female students did not differ from the male ones in maximal heart rate but their relative maximal oxygen uptake and lung ventilation were significantly lower than in males (41.1 ± 4.7 and 48.4 ± 6.4 ml/kg/min, and 81.5 ± 20.3 and 119.9 ± 26.2 l/min, respectively). Also, their daily energy expenditure on leisure and sport activities was significantly lower (8.4 5.3 and 10.2 4.6 kcal/kg/day, respectively).

Mean values of somatic and physiological variables recorded in subjects from the upper and lower quartiles of $\dot{V}O_2$max values are presented in Table 3. Subjects with high $\dot{V}O_2$max had significantly lower body fat content, BMI, and Double Product than those with low aerobic capacity, and significantly higher body water content, $\dot{V}E$max, diastolic pressure and relative daily energy expenditure.

Table 2. Mean values (±SD) of body composition, circulatory and ventilatory indices and daily energy expenditures on leisure and sport activities

Variable	Men (n = 87)	Women (n = 75)
Body fat content (%)	12.6 ± 4.5	23.1 ± 4.9***
FM/FFM	0.15 ± 0.06	0.31 ± 0.09***
Body water content (%)	64.0 ± 3.2	56.3 ± 3.6***
HRr (bpm)	71.4 ± 10.0	76.4 ± 10.4**
SPr (mm Hg)	124.6 ± 7.2	119.5 ± 7.2***
DPr (mm Hg)	81.9 ± 5.9	78.3 ± 5.3***
SPr × HRr	8888 ± 1401	9132 ± 1330
HRmax (bpm)	179.9 ± 10.3	181.5 ± 9.3
$\dot{V}E$max (l/min)	119.9 ± 26.2	81.5 ± 20.3***
$\dot{V}O_2$max (ml/kg/min)	48.4 ± 6.4	41.1 ± 4.7***
$\dot{V}O_2$max(ml/FFM/min)	55.3 ± 6.4	53.4 ± 5.6*
PA-DEE (kcal/kg/day)	10.2 ± 4.6	8.4 ± 5.3***

Legend: FM/FFM – Fat mass to Fat-free mass ratio; HRr – Resting heart rate; SPr – Resting systolic blood pressure; DPr – Resting diastolic blood pressure; PA-DEE – Daily energy expenditure on physical activities.

Significantly different from the respective value in men: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

As follows from Table 4, daily energy expenditure was moderately correlated with $\dot{V}O_2$max in men and not significantly weaker in women, and the same was true for the double product. Interestingly, resting HR was significantly, negatively correlated with $\dot{V}O_2$max and with PA-DEE, in men and women alike.

Discussion

The curricula of physical education students contain more subjects based on physical activities than those of other students; moreover, PE students spend much of their leisure time on motor activities and/or sport training [16,23]. Aerobic capacity of subjects in this study was fairly differentiated, the $\dot{V}O_2$max ranging from 35.6 to 64.0 and from 31.2 to 53.2 ml/kg/min in men and women, respectively. Thus, aerobic capacity of male students from the lower quartile could be classified as low and of those from the upper quartile as moderate while female students were classified as having moderate and high capacity, respectively (cf. Table 3). It ought to be remembered that low aerobic capacity is regarded as a risk factor of cardiovascular diseases and correlates with mortality rates, both cardiovascular and general [4,12,24].

Table 3. Mean values (±SD) of anthropometric, circulatory and ventilatory indices and daily energy expenditure in men and women of low or high relative $\dot{V}O_2max$

Variable	ML (n = 22)	MU (n = 22)	FL (n = 19)	FU (n = 19)	Sex	L/U
Body mass (kg)	83.0 ± 10.3	76.2 ± 7.8	60.8 ± 9.1	59.3 ± 5.8	***	*
BMI	25.6 ± 2.7	23.4 ± 1.9	21.7 ± 2.6	21.2 ± 1.8	***	**
WHR	0.936 ± 0.050	0.895 ± 0.055	0.852 ± 0.058	0.857 ± 0.049	**	
Body fat content (%)	15.7 ± 5.5	12.3 ± 3.3	25.9 ± 5.8	21.9 ± 3.2	***	***
FM/FFM	0.191 ± 0.078	0.143 ± 0.041	0.358 ± 0.105	0.283 ± 0.053	***	***
Body water content (%)	61.6 ± 3.9	64.2 ± 2.4	54.2 ± 4.2	57.2 ± 2.3	**	**
HRr (bpm)	74.4 ± 7.4	71.3 ± 8.4	81.1 ± 9.0$^{\times}$	72.7 ± 8.0 ^{oo}	Int. **	
SPr (mm Hg)	124.7 ± 6.6	124.7 ± 8.9	120.3 ± 5.9	123.1 ± 5.2		
DPr (mm Hg)	81.6 ± 4.1	81.9 ± 6.6	78.4 ± 4.4	81.1 ± 3.6	*	**
Double Product (SPr×HRr)	9281 ± 1019	8888 ± 1147	9767 ± 1154	8945 ± 1081	*	***
HRmax (bpm)	177.5 ± 10.2	180.1 ± 7.9	181.4 ± 8.1	181.0 ± 10.1		
$\dot{V}E$max (l/kg/min)	1.254 ± 0.230	1.593 ± 0.319	1.161 ± 0.219	1.568 ± 0.312	**	***
$\dot{V}O_2max$ (ml/kg/min)	40.3 ± 2.5	48.9 ± 3.0	35.5 ± 1.8	47.6 ± 2.1	***	n.a.
$\dot{V}O_2max$ (ml/FFM/min)	47.8 ± 2.8	55.7 ± 3.9	48.1 ± 2.9	60.8 ± 2.6		n.a.
PA-DEE (kcal/kg/day)	8.40 ± 3.98	10.97 ± 5.17	8.31 ± 6.03	10.06 ± 6.35		**

Legend: M – Men; F – Women; L – Lower quartile of $\dot{V}O_2max$; U – Upper quartile of $\dot{V}O_2max$; WHR – Waist-to-hip ratio; FM – Fat mass; FFM – Fat-free mass; HR – Heart rate; SP – Systolic pressure; DP – Diastolic pressure; r – Resting value; PA-DEE – Daily energy expenditure on physical activities; L/U – Lower/upper quartiles of $\dot{V}O_2max$; Int. – Gender × aerobic capacity interaction; n.a. – Not applicable, since relative $\dot{V}O_2max$ was the classification criterion.

Significance of ANOVA factors: * p<0.05; ** p<0.01; *** p<0.001; $^{\times}$ Significantly (p<0.05) different from the respective value in men; ^{oo} Significantly (p<0.01) different from the respective value in the 'Low $\dot{V}O_2max$' subgroup (FL).

Table 4. Pearson's coefficients of correlation between relative $\dot{V}O_2max$ or daily energy expenditure and selected somatic and physiological variables

Correlated variable	$\dot{V}O_2max$		PA-DEE	
	Men n = 87	Women n = 75	Men n = 87	Women n = 75
Fat-free mass (%)	0.491***	0.408***	0.216*	0.030
Body water content (%)	0.503***	0.413***	0.213	0.032
FM/FFM	-0.502***	-0.432***	-0.215	-0.042
HRr (bpm)	-0.398***	-0.310**	-0.416***	-0.308**
SPr × HRr	-0.335***	-0.156	-0.397***	-0.227
$\dot{V}E$max (l/kg/min)	0.579***	0.357**	0.225*	-0.095
PA-DEE (kcal/kg/day)	0.417***	0.271*	–	–

* p<0.05; ** p<0.01; *** p<0.001; for explanation of symbols see Table 2

Aerobic capacity significantly correlated (r = 0.417; p<0.001 in men and 0.271; p<0.05 in women) with daily energy expenditure on leisure and sport activities (PA-DEE), the latter being significantly (p<0.01) higher in subjects of high capacity than in those of low capacity. Interestingly, no significant gender-related differences were noted. On the other hand, low work capacity of youths tends to remain low at later age. Many authors reported positive relation between aerobic capacity and the amount of physical activity, and a negative one with body fat content [9,13]. Our results are concordant with other reports on significant relationships between aerobic capacity and BMI or body composition [3,10,20]. Some authors [3,7] reported no significant differences between groups of subjects, differing in the level of physical activity, in $\dot{V}O_2max$ values related to e.g. muscle mass.

When cardiorespiratory variables were analysed by ANOVA in relation to aerobic capacity expressed by $\dot{V}O_2$max, only in case of resting HR a significant gender × aerobic capacity interaction was found. In all other cases except HRmax and resting systolic pressure both factors proved independent from one another. As to the resting HR, mean values in male subgroups with high or low $\dot{V}O_2$max did not differ significantly although the respective coefficient of correlation was significant (-0.398; $p<0.001$). Mean HR values in the female subgroups differed significantly (cf. Table 3).

Heart rate and arterial pressure are controlled by the autonomous system; resting HR in young, physically active subjects depends predominantly on the parasympathetic tonus and is related to the level of physical activity. Oxygen consumption by the heart muscle depends chiefly on 3 factors: myocardial tonus, heart muscle contractility and heart rate. The so-called double product, i.e. heart rate times systolic pressure (at rest), closely correlates in healthy subjects with heart oxygen consumption and with the coronary flow and is used in the assessment of the relative workload of the heart muscle [18,25]. Endurance training brings about decreases in resting HR and arterial pressure; when such training is prolonged, maximal values of the diastolic pressure markedly increase which is associated with increased work capacity [18].

Significant relationships between relative $\dot{V}O_2$max and body composition or cardiorespiratory indices were found in this study; the correlation coefficients were negative in case of resting HR, double product and the fat-to-fat free mass ratio, and positive with minute ventilation, body water content and energy expenditure. Nearly the same values of correlation coefficients were found for relations between energy expenditure (PA-DEE) and resting HR or double product. Other correlations of PA-DEE were significantly ($p<0.05 – 0.001$) lower than the respective ones of $\dot{V}O_2$max. In conclusion, when investigating into the relationships between physical activity and physiological features, the latter ought to be related to $\dot{V}O_2$max rather than to energy expenditure which may depend on other than physiological variables.

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