AGE-RELATED CHANGES IN ANAEROBIC POWER IN THE FORMER HIGHLY TRAINED OARSMEN AND KAYAKERS

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Abstract. The purpose of this study was to evaluate the age-related changes in anaerobic power in the former highly trained oarsmen and kayakers, i.e. the representatives of sports requiring high endurance capacity and strength. Sixty-six former athletes, aged 30-67 years participated in this study. The subjects were assessed for peak anaerobic power in arms ($P_{an\ arms}$) and legs ($P_{an\ legs}$) during 10 s-maximal cycle ergometer exercise tests and for peak aerobic power (P_{VO2max}) during incremental exercise. Body mass, lean body mass and body fat content were measured as well. The peak anaerobic power decline in the former highly trained athletes examined in the present study equalled to 0.6-0.7% per year. The recreational physical activity, based primarily on the endurance exercises, did not affect the peak anaerobic power whereas the peak aerobic power and body fat content strongly depended on the age and physical activity. The peak anaerobic power in the upper and lower extremities exhibited similar reduction with age of the subjects. Furthermore, in the less active group the ratio of $P_{an\ legs}$ to P_{VO2max} did not change with age whereas in physically active subjects this index increased. It was concluded that in the sample of former highly trained oarsmen and kayakers the age-related decline in the peak anaerobic power approximated that reported by other authors for untrained or endurance trained subjects, the peak anaerobic power in the arms was almost the same as that in the legs and that in the less active group the ratio of the peak anaerobic power to the peak aerobic power was independent of age and strongly tended to increase in the physically active subjects.

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Key words: Ageing - Anaerobic power - Aerobic power - Elite oarsmen - Kayakers

Introduction

Studies of the age-related changes in physical fitness were initiated by Robinson already 70 years ago [32]. The topic has since been tackled by numerous

researchers. Thus far, however, the studies have been devoted primarily to the age-related changes of aerobic capacity [e.g. 4,14,34] and only few reports have described alterations of anaerobic power in untrained subjects [1,9,25,26,30] or in the endurance-trained young and master athletes [5,13]. Noteworthy, no reports have been published so far on the effects of the former competitive engagement in strength/endurance sports, such as rowing and kayaking, on the age-induced changes in anaerobic power. The athletes doing these sports demonstrate high aerobic capacity. Indeed, maximal oxygen uptake (VO_{2max}) in the elite oarsmen exceeds 6.0 $L \cdot min^{-1}$ [15,20]. In case of kayakers, high aerobic capacity is also required to achieve satisfactory results and VO_{2max} values obtained by the top athletes exceed 5.5 $L \cdot min^{-1}$ [22,35,39]. As in the case of athletes from other endurance sports the Type I (slow-twitch) muscle fibres predominate in the structure of skeletal muscles of oarsmen [17,23] and kayakers [12]. At the same time, in contrast to athletes doing most of the other endurance sports, both oarsmen [33,36] and kayakers [10,29,36] demonstrate high mass and strength of the muscles. The only report of the age-related changes in physical capacity of oarsmen was published by Hagerman *et al.* [8], who demonstrated mostly alterations in the aerobic capacity but, although only during the 6-minute rowing ergometry, analysed also the peak power output.

In this context, the aim of the present study was to evaluate the age-related changes in anaerobic power of former highly trained oarsmen and kayakers as well as to assess the impact of their current physical recreational activity on the examined changes.

Materials and Methods

Subjects: Sixty-six, healthy, former highly trained oarsmen and kayakers, aged 30-67 years participated in this study. Among them four Olympic Games' medallists and 15 world championships' medallists, including a triple winner of the gold medal of the world championships and a ten-fold winner of medals (including two gold) of the world championships and the Olympic Games were examined. The subjects were initially divided into a group of former kayakers and a group of former rowers. Analysis of variance demonstrated no effect of the type of sport on the values of the tested parameters. Hence, in further evaluations the results obtained from the rowers and kayakers were analysed collectively. All of the subjects undertook a complete physical examination. The athletes who showed any contraindications to maximal exercise were excluded. Each subject was informed of the aim and methodology of the study and the written consent to participate was

obtained. The Ethical Committee at the Institute of Sport approved the study design. The athletes were classified as physically active (A) or less active (L), depending on the level of their occupational and recreational activity. As physically active were defined those subjects who exercised vigorously at least 3 times a week, for 3 or more hour per week. According to the interviews, physically active subjects were recreationally going in for running, swimming, cycling, playing tennis and volleyball, i.e., engaged predominately in the endurance-type exercises.

Protocol: After physical examination of the subjects the body mass and skinfold thickness over the biceps, the lower angle of the scapula, and the abdomen by the Harpenden calliper were measured in the morning before breakfast. Body fat was estimated according to Durnin and Domersley [8]. On the two other days the athletes were subjected to the following three exercise tests: the incremental exercise until volitional fatigue and two days later two 10 s anaerobic tests, one for legs and one for arms, performed at the maximal individual power, separated by a two- hour rest. Each test was preceded by the five-minute, 80 W-exercise followed by a two-minute rest.

Incremental exercise test: The incremental exercise test was performed on the Jeager ER 900 cycle ergometer. The initial workload and pedalling rhythm equalled to 50 W and 55 revolutions·min^{-1}, respectively; these parameters were increased gradually by 50 W and 5 revolutions·min^{-1}, respectively, during the consecutive four-minute exercise stages until exhaustion. At the fourth minute after completion of the test, blood samples were collected from the finger pulp and the serum lactate concentration was determined using an enzymatic method (Boehringer-Mannheim kit, Germany). Heart rate was measured continuously at rest and during the exercise using the Medea Stress Test (Gliwice) or the Marquette Hellige computers, the latter operating in the MemoPort 4000 system. The respiratory gas exchange parameters, such as pulmonary ventilation, oxygen uptake, and carbon dioxide production were estimated with the use of the MMC Beckman set (Beckman Instruments, Inc. USA). The printouts were obtained every 30 seconds. The power output at VO_{2max} was referred to as the peak aerobic power (P_{VO2max}). The criteria upon which the attainment of VO_{2max} was based included:

-plateau VO_2 despite the increase in the workload;

-the post-exercise lactate concentration in blood exceeding 8 mmol·L^{-1};

-respiratory quotient (RQ) in excess of 1.10;

-maximal heart rate adequate to age as calculated from the formula $HR_{max}=220-0.9$·years of age [21].

The oxygen uptake was considered maximal if at least two of the above criteria were fulfilled.

Anaerobic tests: The 10 s-tests were performed on the Monark 824 E cycle ergometer (Sweden) connected with the IBM PC Pentium equipped in the "MCE v. 4.0" software ("JBA" Z.Staniak, Poland). The resistance from the start of the exercise was set at 0.075 kg·kg^{-1} body mass for the legs and 0.065 kg·kg^{-1} body mass for the arms. The exercises were carried out at the individually maximal power. In the case of legs, the exercise was performed in the vertical position. When arms were tested, the subject was standing on his feet with his hips immobilised. The pedals of the elevated ergometer were replaced with handholds. The highest power output over one second was referred to as the peak anaerobic power (P_{an}).

Statistical analyses: After checking for the normality of the distribution with the Kolmogorov-Smirnov test the obtained results were analysed by the two-factorial analysis of variance (ANOVA) in terms of the effect of the age and physical activity. In case when the calculated value of F appeared to be significant ($P<0.05$), significance of the differences between the respective means were analysed using the Newman-Keuls test. The differences between means were regarded significant at $P<0.05$. The Pearson's simple correlation was calculated to check for the relation between the obtained indices. In order to compare the regression lines, the differences in the slopes and the intercepts were analysed. All the calculations and statistical analyses were carried out using the Statistica 5.1 and Statgraphics Plus V. 3.0 software.

The data in the text and the tables are presented as means ± SD.

Results

The selected anthropometric data which could affect the peak power output are shown in Table 1. Analysis of variance demonstrated no significant differences in the body masses related to physical activity and age of the subjects. Likewise, no significant differences could be detected in the exercise-related lean body masses (LBM) expressed in kilograms, although in group A this index demonstrated a marked tendency to attain higher values for age ranges of 35-44 years and 45-55 years. The results of ANOVA also showed that the percentage of the body fat (BF) significantly depended on the physical activity and age of the subjects. The average percentage of the BF in subjects aged 35-44 years was significantly lower in the A than in the L group. For the subjects aged 45-55 years and those over 55 years of age the tested parameter strongly tended to demonstrate lower values in group A. As shown on Table 2, no effect of physical activity was demonstrated on the peak anaerobic power in arms ($P_{an\ arms}$) or legs ($P_{an\ legs}$) expressed per kilogram of body

mass. Analysis of variance demonstrated the effect of physical activity solely on $P_{an\ arms}$ and $P_{an\ legs}$ per kilogram of LBM with higher values recorded in group L. As expected, both ANOVA and the significant correlation coefficients (Table 3) demonstrated that the values of $P_{an\ arms}$ and $P_{an\ legs}$ declined with age. Noteworthy, significantly higher ($P<0.05$) differences in the values of the examined indices were detected between the age ranges of 45-55 years and >55 years than between those of 35-44 years and 45-55 years in which case the differences were statistically insignificant. No effect of age and physical activity was found on the ratio of $P_{an\ arms}$ to $P_{an\ legs}$ whereas the peak aerobic power (P_{VO2max}) strongly depended on the two parameters, as revealed by the ANOVA analysis. The 35-44 years old, physically active subjects demonstrated significantly higher values of P_{VO2max} than those less active. In the remaining age ranges, P_{VO2max} also tended to be higher in group A.

Table 1

Age, body mass, lean body mass (LBM) and body fat of the subjects (means±SD)

Variables	Age groups						ANOVA	
	35-44 years		45-55 years		>55 years		P	
Group	Active (n=6)	Less active (n=18)	Active (n=9)	Less active (n=14)	Active (n=13)	Less active (n=6)	Age	Activity
Age (years)	38.7± 3.8	39.3± 3.0	48.6± 2.2	48.3± 2.0	59.2± 2.4	59.9± 3.9	-	NS
Body mass (kg)	86.2± 7.1	89.7± 10.9	88.2± 6.7	88.3± 12.2	82.1± 8.1	88.2± 6.4	NS	NS
LBM (kg)	76.7± 4.9	72.7± 7.5	74.7± 5.1	71.4± 8.7	67.2± 5.0[b]	67.3± 3.0	0.0048	NS
Body fat (% of BM)	10.9± 2.7	18.7± 4.6[a]	15.1± 5.0	18.7± 6.2	17.8± 5.4[b]	23.4± 5.6	0.0080	0.0002

[a] and [b] indicate significant difference ($P<0.05$) from the respective value obtained for the Active group and for the age group 35-44 years, respectively

Table 2

Peak anaerobic power for arms ($P_{an\ arms}$) and legs ($P_{an\ legs}$), the relationship between $P_{an\ arms}$ and $P_{an\ legs}$, power at VO_{2max} (P_{VO2max}) and the relationship between P_{VO2max} and $P_{an\ legs}$ (means±SD)

Variables	Age groups						ANOVA	
	35-44		45-55		>55		(P)	
Group	Active	Less active	Active	Less active	Active	Less active	Age	Activity
$P_{an\ arms}$ ($W \cdot kg^{-1}$)	8.3± 0.3	8.2± 0.8	8.4± 0.6	8.0± 0.9	7.2± 0.8[b,c]	7.1± 0.7[b,c]	0.0001	NS
$P_{an\ arms}$ ($W \cdot kgLBM^{-1}$)	9.4± 0.4	10.0± 0.7	9.8± 0.7	9.8± 0.7	8.7± 0.7[c]	9.4± 1.4	0.0260	0.0360
$P_{an\ legs}$ ($W \cdot kg^{-1}$)	10.4± 0.4	10.4± 1.1	10.1± 0.8	10.1± 0.9	9.2± 0.8[b,c]	8.9± 0.4[b,c]	0.0001	NS
$P_{an\ legs}$ ($W \cdot kgLBM^{-1}$)	11.7± 0.6	12.8± 1.1	12.0± 1.1	12.3± 0.9	11.2± 1.0	11.8± 1.3	NS	0.0173
$\dfrac{P_{an\ arms}}{P_{an\ legs}}$	0.8± 0.1	0.8± 0.1	0.8± 0.1	0.8± 0.1	0.8± 0.1	0.8± 0.1	NS	NS
P_{VO2max} ($W \cdot kg^{-1}$)	4.2± 0.7	3.1± 0.4[a]	3.4± 0.4[b]	2.9± 0.7	3.1± 0.4[b]	2.6± 0.3	0.0008	0.0001
$\dfrac{P_{an\ legs}}{P_{VO2max}}$	2.6± 0.4	3.4± 0.5	2.9± 0.3	3.4± 0.7	3.0± 0.4	3.5± 0.6	NS	0.0026

[a,b] and [c] indicate significant difference (P<0.05) from the respective value obtained for the Active group, for the age group 35-44 years and for the age group 45-55 years, respectively

    In group L the ratio of $P_{an\ legs}$ to P_{VO2max} did not change with age whereas in group A this index tended to rise. In the A and L groups the $P_{an\ legs}$ /P_{VO2max} age-related correlation coefficients equaled to 0.40 (P<0.05) and 0.00, respectively. The age-related regression line of the examined index was at the markedly higher level in group L than in group A, the effect being caused by the higher value of P_{VO2max} in the latter group.

Table 3
Regression equations and correlation coefficients (r) between the variables recorded in the subjects and their age (years) and the yearly decrease of the recorded variables in the percent of the values predicted for the age of 35 years

Variables	Group	Regression equation	r	P<	% decrease
$P_{an\ arms}$	A	y=-0.062 years+11.01	-0.64	0.001	0.7
$(W \cdot kg^{-1})$	L	y=-0.050 years +10.37	-0.49	0.01	0.6
$P_{an\ arms}$	A	y=-0.047 years+11.58	-0.50	0.01	0.5
$(W \cdot kgLBM^{-1})$	L	y=-0.037 years+11.56*	-0.37	0.05	0.4
$P_{an\ legs}$	A	y=-0.069 years+13.29	-0.65	0.001	0.6
$(W \cdot kg^{-1})$	L	y=-0.074 years+13.49	-0.56	0.001	0.7
$P_{an\ legs}$	A	y=-0.041 years+13.65	-0.35	0.05	0.3
$(W \cdot kgLBM^{-1})$	L	y=-0.052 years+14.96*	-0.36	0.05	0.3
P_{VO2max}	A	y=-0.050 years+5.993	-0.67	0.01	1.2
$(W \cdot kg^{-1})$	L	y=-0.023 years+4.011*	-0.36	0.05	0.7
$\underline{P_{an\ arms}}$	A	y=-0.000 years+0.810	0.00	NS	0.0
$P_{an\ legs}$					
	L	y=-0.000 years+0.800	0.00	NS	0.0
$\underline{P_{an}}$	A	y=0.020 years+1.84	0.40	0.05	Increase 0.8
P_{VO2max}	L	y=-0.000 years+3.40	0.00	NS	0.0

*indicates significant difference (P<0.05) from the respective value obtained for the Active group

Discussion

The main findings of the present study were that in the sample of former highly trained oarsmen and kayakers the age-related decline in the peak anaerobic power approximated that reported by other authors for untrained or endurance trained subjects, the peak anaerobic power in the arms was almost the same as that in the legs and that in the less active group the ratio of the peak anaerobic power to the peak aerobic power was independent of age and strongly tended to increase in the physically active subjects.

The rate of age-related decline of P_{an} relatively to the body mass in our study (0.6%-0.7% per year for arms and legs) was similar to that reported by Bonnefoy *et al.* [1] for quadriceps muscle (8.3% per decade in untrained subjects), Makrides

et al. (25) for legs (6% per decade in untrained subjects) and Marsh *et al.* [26] for legs (27% per 38 years in physically active subjects), however greater than that reported by Marsh *et al.* [26] for arms (16% per 38 years). Slightly larger reduction of P_{an} for legs have been found by Chamari *et al.* [5] in the force-velocity test performed on a cycle ergometer (about 42.7% per 40.3 years in endurance trained young and master athletes) and as measured by vertical jumping by Grassi *et al.* [13] (about 1% per year in power or endurance trained master athletes). The markedly lower differences recorded in the present study in the values of P_{an} between the age ranges of 35-44 years and 45-55 years then between those of 45-55 years and >55 years may be explained by the rapid decrease of the skeletal muscles' mass as well as the number of motor units after the age of 50 [24].

Interestingly, the present study demonstrated that P_{an} in the upper and lower extremities exhibited similar reduction with age of the subjects. In contrast, Marsh *et al.* [26] showed that the extent of the loss of anaerobic power in older subjects was more pronounced in the legs than in the arms. The slower age-related deterioration in muscle function in the upper limbs as compared to the lower limbs was demonstrated also by McDonagh *et al.* [27]. The most likely explanation for this discrepancy may be a relatively high anaerobic power in the upper as compared to the lower limbs of the examined individuals which averaged 0.8. In the study of Marsh *et al.* [26] approximate values of the same index (as could be calculated from the mean anaerobic power of the upper and lower limbs showed by cited authors) were markedly lower than those in our subjects and equaled to 0.61 and 0.70 in the groups of active young and older men, respectively. In other studies the estimated value of this index (as could be calculated from the mean values) also approximated 0.7 [16,31] and only in wrestlers reached 0.8 [2,18]. The relatively high value of the examined index in the subjects studied by us may result from their innate predispositions to go in for rowing and kayaking, the sports requiring both high aerobic capacity and great strength of the upper part of the body as well as from intensive training during the many years in the past. In turn, this relatively high value probably favored a larger decrease of this index with age as the intensity of training declined.

Noteworthy, in the present study the rates of decreases of $P_{an\ legs}$ and P_{VO2max} in the L group were exactly the same. Both the slope value of the regression lines of P_{an}/P_{VO2max}. ratio vs. age and the correlation coefficient between those indices were equal to 0.00. Moreover, in the A group the age related increase in the $P_{an\ legs}/P_{VO2max}$ value (by 0.8% per year) was seen, which was accompanied by low but significant correlation between P_{an}/P_{VO2max} ratio and age (r=0.4; P<0.05). This result is consistent with finding of Donato *et al.* [7], who demonstrated that the age-

related rates of decline in swimming performance, in swimmers who participated in the US Masters Swimming Championships were greater in a long-duration than in a short-duration event, suggesting a relatively smaller loss of anaerobic capacity with age compared with cardiovascular endurance. In contrast to these findings, Chamari *et al.* [5], who examined young- and master endurance-trained athletes, found that P_{an} was by 42.7% and P_{VO2max} by 35% lower in the 65- than in the 25-year-old subjects. Thus, the P_{an}/P_{VO2max} ratio was by 12.1% lower in the older subjects (i.e. decreased approximately by 3% per decade). Neder *et al.* [30] on the basis of indices derived from the critical power test in sedentary men also suggested that endurance-related parameters are less diminished with ageing than the maximal capacity. Galloway *et al.* [11] demonstrated as well that strength (power lifting) decreases more rapidly than endurance capacity (stationary rowing). One of the factors responsible for the age related decrease in P_{an}/P_{VO2max} ratio is probably reported by numerous authors [6,19,24] more rapid decline with increasing age in Type II (FT) than in Type I (ST) muscle fibre. However, contrary to these findings, results published by Tarpenning *et al.* [38] suggest that in male endurance-trained older athletes Type I and Type II fiber area and distribution did not differ between age groups through the eighth decade.

As described above, the rate of the P_{an} decline in the former athletes examined in the present study approximated that reported by other authors. Presumably, the lack of the age-related decrease in the P_{an}/P_{VO2max} ratio or even elevation of this value in group A may be primarily associated with the relatively fast reduction of P_{VO2max} in the examined athletes. This reduction equaled to 1.2% and 0.7% per year in the A and L group, respectively, and was higher than the mean decline (0.44%) calculated by Shvartz and Reibold [34] based on numerous reports by other authors. Hagerman *et al.* [14] reported that the decrease of VO_{2max} in rowers – the former silver medallists of the Olympic Games - was even larger than that demonstrated in the present study and equaled to 20% during the first 10 years of observation and to 10% during the next decade. These results, similar to the reports of other authors [4] suggest that VO_{2max} in subjects with high initial aerobic capacity markedly decreases during a period of the reduced physical activity.

The obtained results indicate that the recreational physical activity, based primarily on the endurance exercises, does not affect P_{an} of both the lower and upper extremities. Slightly higher values of P_{an} per LBM in the L group result from the higher content (in percentages) of lipids in the subjects' bodies and consequently the lower content (in percentages) of LBM. The age-related decrease of P_{an} was almost identical in the L and A groups. These findings are consistent with the results of Bonnefoy *et al.* [1] who have reported that in healthy elderly

men habitual physical activity did not attenuate the decline with age in maximal anaerobic power of the quadriceps muscle. Makrides *et al.* [25] showed as well no association between occupational and recreational physical activity in healthy subjects aged 15-70 years and their maximal short term exercise capacity. In fact, moderate intensity aerobic training that improved the maximal aerobic power does not change anaerobic capacity [3,28,37].

Conclusions

The obtained results indicate that the rate of the peak anaerobic power decline in the former highly trained oarsmen and kayakers athletes examined in the present study approximated that reported by other authors for untrained person and master athletes. The recreational physical activity, based primarily on the endurance exercises, did not affect the P_{an} of both the lower and upper extremities whereas the peak aerobic power (P_{VO2max}) and body fat content strongly depended on the age and physical activity. An interesting observation in the present study was that P_{an} in the upper and lower extremities exhibited similar reduction with age of the subjects. Furthermore, in the less active group the ratio of $P_{an\ legs}$ to P_{VO2max} did not change with age whereas in physically active subjects this index increased.

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