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VERIFICATION OF THE BASIC VALUES OF RESPIRATORY INDICES DUE TO POLISH KAYAKERS

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Abstract. The aim of the present investigation was to examine the effect of training of kayakers on their pulmonary function based on the measurements of spirometric indices and to determine values thereof due to kayakers. Seventy-nine male kayakers from the national and Olympic teams going in for sprint and slalom kayaking participated in the study. Physical characteristics of the subjects were as follows: age 16-24 (mean 18.8±2.2) years, body mass 58-95 (mean 77.7±8.2) kg, height 169-197 (mean 181.2±6.7) cm, training history 2-15 (mean 7.2±2.6) years. Functional respiratory tests were performed using a computerized spirometer. Statistical analysis of the results obtained during the long-term, repeatedly performed studies revealed that values of FEV1, MEF25, MEF50, MEF75, PEF, VC, ERV, and MVV equaled to 112%, 118%, 117%, 110%, 122%, 118%, 138%, and 119%, respectively, of the corresponding predicted values for members of the average Caucasian population whose pulmonary function most strongly depends on the body height and age. In the kayakers the values of the tested indices changed in a straight linear manner and increased with age. In these subjects the regression plotted for the predicted and measured values relative to age ran at a significantly higher level that that obtained for non-training individuals (predicted values). In case of MVV and ERV, variation in changes of these indices with age was noted ($F=9.81$, $p<0.01$ and $F=7.39$, $p<0.01$, respectively). The values of FEV1 and VC most strongly correlated with the body mass and height ($r=0.60$, $p<0.001$ and $r=0.68$, $p<0.001$, respectively) and the values of MEF75, PEF, and MVV with the body mass ($r=0.45$, $p<0.001$, $r=0.45$, $p<0.001$ and $r=0.58$, $p<0.001$, respectively). The values of these indices derived from the elaborated nomograms were by 11%, 12%, 22%, 18% and 18% for FEV1, MEF75, PEF, VC and MVV, respectively, higher than the corresponding values predicted for the average Caucasian population and considerably closer to the values actually measured in the tested kayakers. Presumably, the verified reference values of the basic spirometric indices estimated in the kayakers will answer the needs of this type of sport. ***(Biol.Sport 24:31-46, 2007)***

Key words: Kayaking – Men – Spirometry - Norms

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Introduction

In kayaking the intensity and duration of the competition efforts on various distances imply that the athletes' exercise fitness depends on both the anaerobic as well as aerobic capacities. In turn, high exercise performance of kayakers hinges on the efficiency of cardio-pulmonary system. Specific training of kayakers leads to development in the athletes of muscular (including respiratory muscles) strength which obviously affects functioning of the lungs. Hence, a standardized and reproducible method of estimation of the respiratory mechanics and pulmonary ventilation such as spirometry serves as a crucial assessment test of the respiratory function.

With respect to kayakers, few reports have been published on the lungs' function of the athletes at rest. It has been shown that both dynamic and static indices of this function, such as FEV1, MEF25, MEF50, MEF75, PEF, and VC, increase as a result of a systematical, prolonged (i.e. at least several months-long) training [1,11].

Values of spirometric indices determined in athletes are usually referred to norms (i.e., predicted values) for the average population of healthy subjects developed by various authors or recommended by such international organizations as European Respiration Society (ERS), European Commonwealth of Coal and Steel (ECCS) or American Thoracic Society (ATS) [4,8,9,12,14,18].

In this paper we present results of the four-year spirometric investigations performed in one group of kayakers of variable training status. The aim of this study was to estimate the effect of training on the respiratory function based on measurements of spirometric indices as well as to determine the values of these indices predicted for kayakers.

Materials and Methods

Seventy nine male kayakers from the national and Olympic teams going in for sprint and slalom kayaking were recruited to participate in the study. Physical characteristics of the athletes were as follows: age from 16 to 24 (mean 18.8 ± 2.2) years, body mass from 58 to 95 (mean 77.7±8.2) kg, height from 169 to 197 (mean 181.2±6.7) cm, training history from 2 to 15 (mean 7.2±2.6) years.

General characteristics of kayakers and their training structure have already been described by other authors [7]. In the kayakers assayed in the present investigation spirometric tests were performed repeatedly during the four-year period at annual training cycles. From each athlete the result of a single spirometric test which showed the highest value of the assayed indices measured during the whole period of observation was collected and analyzed. For the tests, a computerized spirometer (abcMed, Poland) was used and the measurements were carried out in the morning (between 8 and 10 a.m.) in seated subjects at rest. The following indices were estimated: forced expiratory volume in one second (FEV1), maximal expiratory flow at 25%, 50%, and 75% of the forced vital capacity (MEF25, MEF50, MEF75), peak expiratory flow (PEF), vital capacity (VC), Tiffeneau index, i.e. the FEV1 to VC ratio expressed in percentages (FEV1%VC), expiratory reserve volume (ERV), and maximal voluntary ventilation within 12 seconds (MVV).

As shown by the results of medical examinations which preceded the above tests all the investigated kayakers were healthy and fit for training. The spirometric assays were performed in accordance with the standard procedures defining preconditioning of a spirometer, methodology of the tests as well as informing of the subjects of the aim and method of examination. The measurements were repeated several times until a reproducible and technically correct result was obtained.

The results of the tests were compared with values predicted for 16 to 24-year-old men from the average Caucasian population calculated with allowances for sex, age, body mass and height of the subjects [4,9,12]. The value predicted for a given kayaker obtained from the tables was automatically included in a set of the kayaker’s data registered on the computer. Analyzed were both the absolute numbers of the assayed indices and percentages of the due values. For the interpretation of the obtained data 80% of the predicted value was assumed as the threshold between the correct and incorrect result.

Statistical analysis: Mean values, standard deviation, and standard error were calculated for the obtained results. Differences between the tested parameters were estimated using the Student’s t test for independent trials with p value less than 0.05 regarded as significant. Relations between the parameters were tested using the Pearson’s correlation coefficient (r). Relations between the parameters and age of the subjects were estimated with use of the linear regression analysis. In order to compare the course of the regression line for the predicted and actually measured values of the tested spirometric indices differences in the slope and intercept were analyzed. Relation between the values of the pulmonary function indices and anthropometric indices was determined using the multiple regression analysis (stepwise backward regression). The calculations and statistical analyses were performed using the Statistica 6.0 and Statgraphics Plus V 3.0 (Statistica Graphics Co.) softwares.

Results

The tested kayakers presented with the following anthropometric features: age from 16 to 24 (mean 18.8±2.2) years (45 athletes aged between 16 and 18 years), body mass from 58 to 95 (mean 77.7±8.2) kg, height from 169 to 197 (mean 181.2±6.7) cm, body mass index from 18.90 to 27.47 (mean 23.6±1.8), slenderness index from 40.0 to 46.0 (mean 43.0±1.0), body surface from 1.71 to 2.25 (mean 1.98±0.13) m^2.

The calculated mean body mass and body height predicted for the tested kayakers equaled to 68.9±6.3 kg and 177.9±1.3 cm, respectively, and the detected differences between the measured and predicted values equaled to 8.8 kg ($p<0.001$) and 3.3 cm ($p<0.001$), respectively.

Table 1
Values of the measured spirometric indices in kayakers (mean±SD) and per cents of the predicted values

Index	Predicted value	Measured value	%of due value
FEV_1 (L/s)	4.40±0.37	4.89±0.61	112±11***
MEF_{25} (L/s)	3.36±0.30	3.92±1.03	118±30***
MEF_{50} (L/s)	5.70±0.50	6.76±1.16	117±19**
MEF_{75} (L/s)	8.35±0.70	9.32±1.62	110±18***
PEF (L/s)	9.18±0.70	11.2±1.85	122±18***
VC (L)	5.01±0.40	5.92±0.86	118±13***
FEV_1%VC (%)	85.8±2. 8	83.3±8.2	97±10**
ERV (L)	1.54±0.21	2.07±0.48	138±35***
MVV (L/min)	162.5±8.0	192.0±32.5	119±18***

**indicates significance of the difference between the measured and predicted values at $p<0.01$
***indicates significance of the difference between the measured and predicted values at $p<0.001$

Mean values of the measured spirometric indices made up to 112% (in case of FEV1), 118% (MEF25), 117% (MEF50), 110% (MEF75), 122% (PEF), 118% (VC), 97% (FEV1%VC), 138% (ERV), and 119% (MVV) of the respective values predicted for the average Caucasian population and the detected differences were statistically significant (Table 1). Changes of the selected indices in the tested kayakers took a straight linear course and the values of the measured indices, save for the MEF25 value, increased with age of the subjects (Fig. 1 through 5).

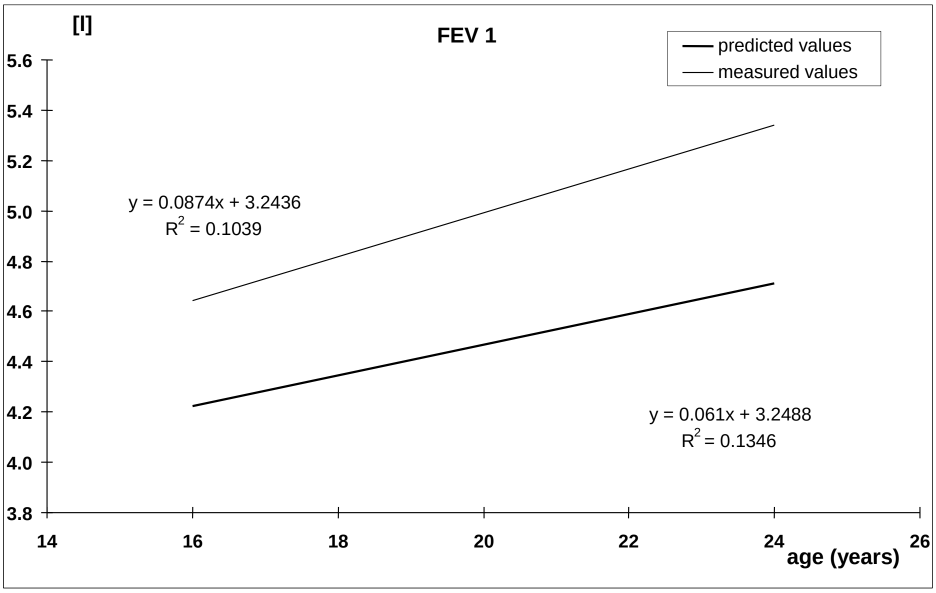

Fig. 1
Relationship between age of the subjects and the forced expiratory volume on one second (FEV1); Comparison of the predicted and measured values
Intercept F=41.4; p<0.001; Slope F=ns

Analysis of the relation of the predicted and measured values of the tested spirometric indices for the kayakers' age indicated that the regression lines plotted for the values measured in the athletes ran significantly higher than those plotted for the values predicted for non-training individuals (Fig. 1 through 3). In case of MVV and ERV significant (p<0.01) differences in the course of changes in the values of these parameters with age of the subjects (F=9.81 and F=7.39, respectively) were also detected (Figs. 4 and 5).

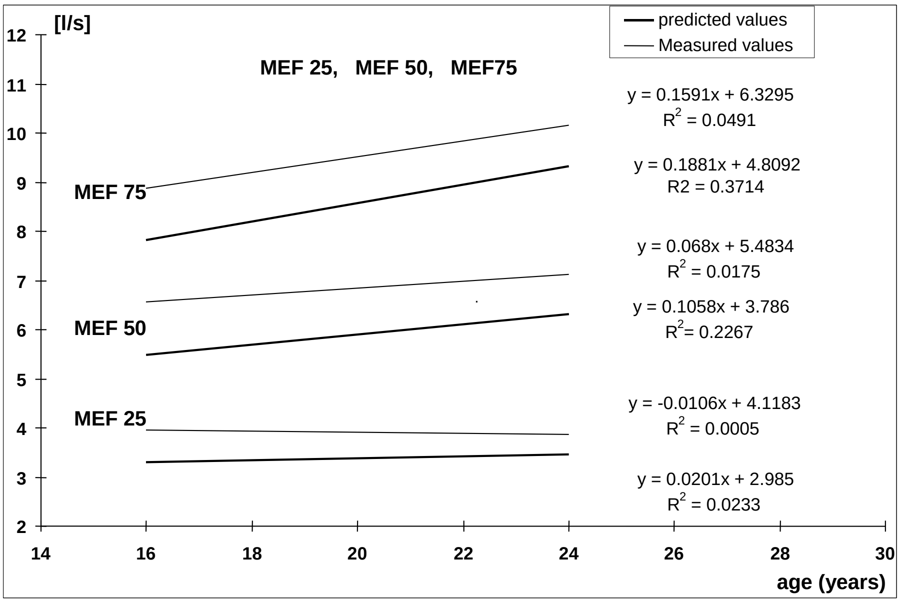

Fig. 2
Relationship between age of the subjects and the maximal expiratory flow at 25%, 50%,and 75% FVC (MEF25, MEF50, MEF75); Comparison of the predicted and measured values
MEF25: Intercept F=21.1; p<0.001; Slope F=ns
MEF50: Intercept F=50.1; p<0.001; Slope F=ns
MEF75: Intercept F=26.5; p<0.001; Slope F=ns

With respect to relation between the tested spirometric indices and age, body mass, and height of the subjects the strongest correlations were noted between FEV1 and the body mass and height (r=0.60, p<0.001), between VC and the body mass and height (r=0.68, p<0.001) and between MVV and the body mass (r=0.58, p<0.001). The MEF75 and PEF values most strongly correlated (in both cases r=0.45, p<0.001) with the body mass (Table 2). The highly positive correlation of the age and the training history of the subjects (r=0.75, p<0.001) resulted in the pronounced convergence of the β coefficients adopted for the training history and spirometric indices as well as for the age and spirometric indices. In the kayakers under study the values of the above indices most strongly depended on the body mass and height. In contrast, the calculated values of these parameters as predicted for members of the average Caucasian population most strongly correlated with the height and age of the subjects.

Table 2
Results of the multiple regression analysis of the spirometric indices vs. anthropometric features

Index	Body mass (kg)	Body height (cm)]	Age (years)]	Correlation coefficient (r)
FEV_1	+	+	-	0.60
MEF_{25}	-	+	-	0.33
MEF_{50}	-	+	-	0.24
MEF_{75}	+	-	-	0.45
PEF	+	-	-	0.45
VC	+	+	-	0.68
ERV	-	+	-	0.32
MVV	+	-	-	0.58

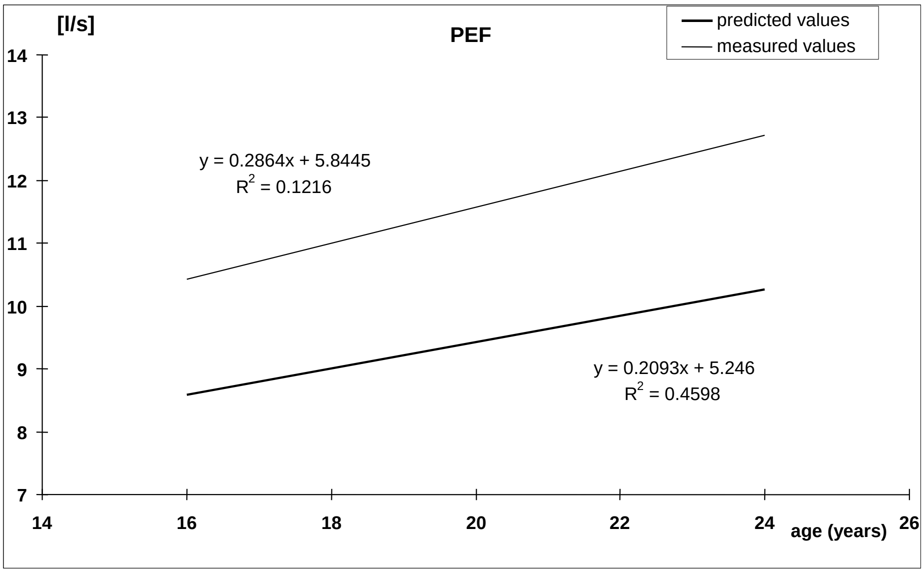

Fig. 3
Relationship between age of the subjects and the peak expiratory flow (PEF); Comparison of the predicted and measured values
Intercept F=100.1;
p<0.001; Slope F=ns

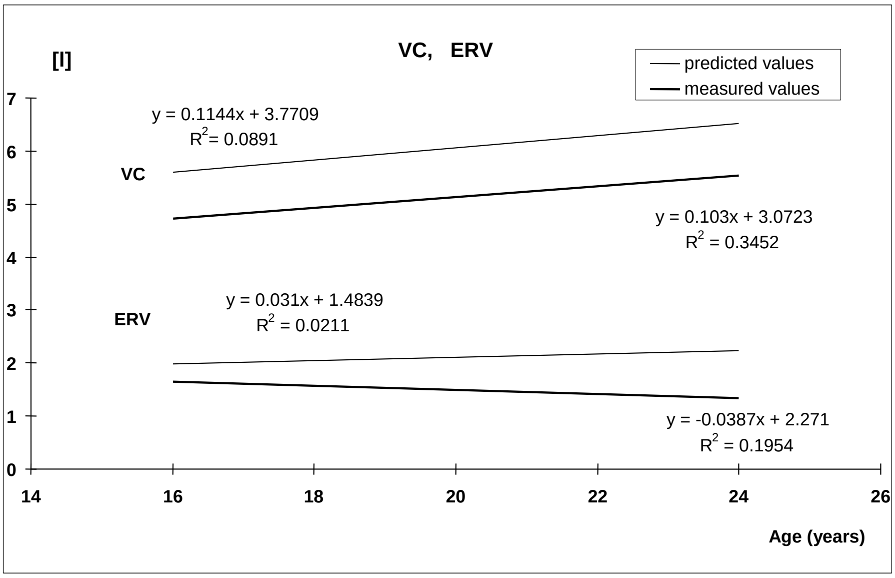

Fig. 4
Relationship between age of the subjects and the expiratory vital capacity (VC and the expiratory reserve volume (ERV)); Comparison of the predicted and measured values
VC: Intercept F=82.2; p<0.001; Slope F=ns
ERV: Intercept F=83.2; p<0.001; Slope F=7.39; p<0.01

Based on the determined most pronounced correlations between MEF75, PEF, and MVV and body mass and between FEV1 and VC and body mass and height normograms were drafted for the tested kayakers using the following regression equations: FEV1=0.0227* Mc+0.0314* h–2.57, MEF75=0.089* Mc+2.41, PEF=0.101* Mc+3.376, VC=0.0385* Mc+0.0478* h–5.735, MVV=2.29* Mc+14.137 (Figs. 6 through 10). In the figures the respective regression equation and correlation coefficient for the given index vs body mass as well as standard error of the estimation are shown.

The predicted values of the above parameters calculated and derived from the nomograms exceeded on average the respective values predicted for the Caucasian population by 11% for FEV1, 12% for MEF75, 22% for PEF, 18% for VC, and 18% for MVV, the differences being statistically significant (p<0.001).

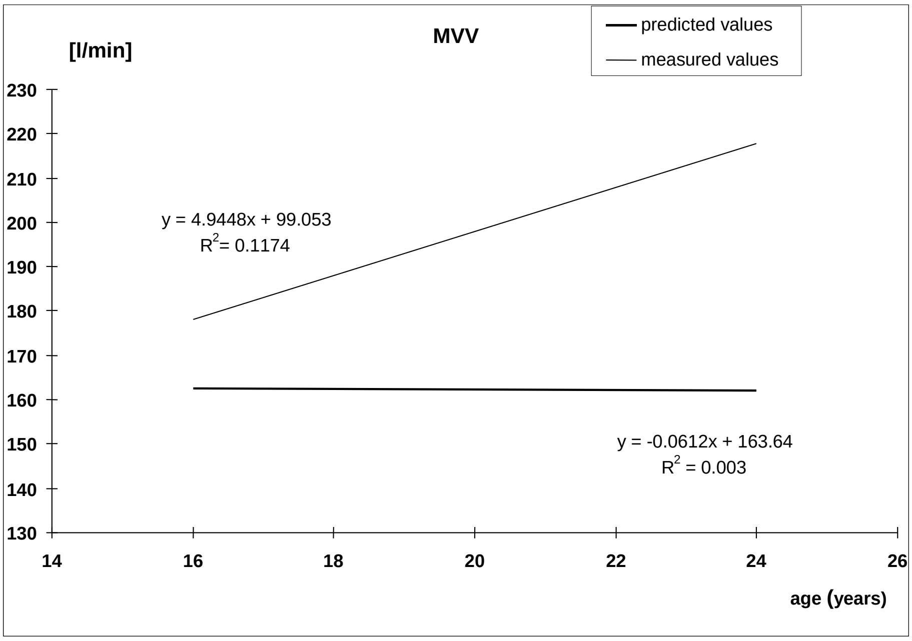

Fig. 5
Relationship between age of the subjects and the maximal voluntary ventilation (MVV); Comparison of the predicted and measured values
Intercept F=68.3; $p<0.001$; Slope F=9.8; $p<0.002$

Comparison of the predicted (P), measured (M) and verified (nom) values, as presented in Fig. 11, indicates that the values derived from the plotted nomograms much closer approximated the actual values of the given parameters measured in the tested kayakers than those predicted for members of the average Caucasian population.

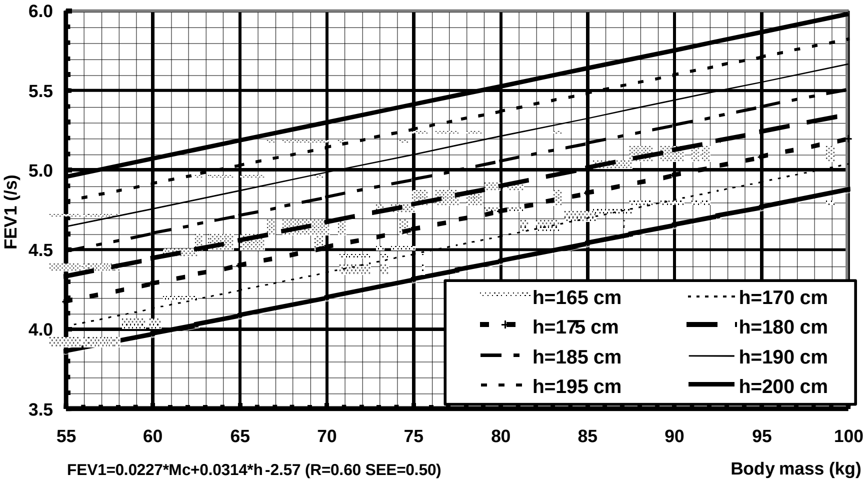

Fig. 6
Nomogram of the forced expiratory volume in one second (FEV1)

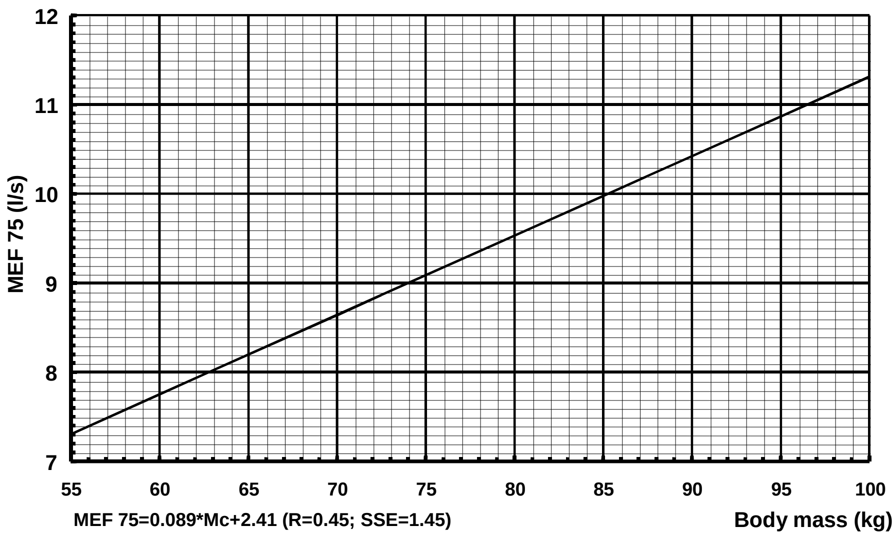

Fig. 7
Nomogram of the maximal expiratory flow at 75% FVC(MEF75)

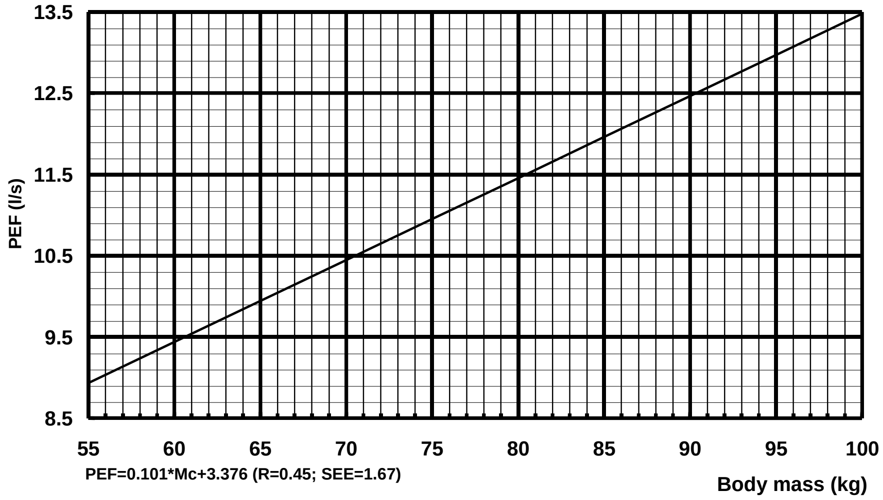

Fig. 8
Nomogram of the peak expiratory flow (PEF)

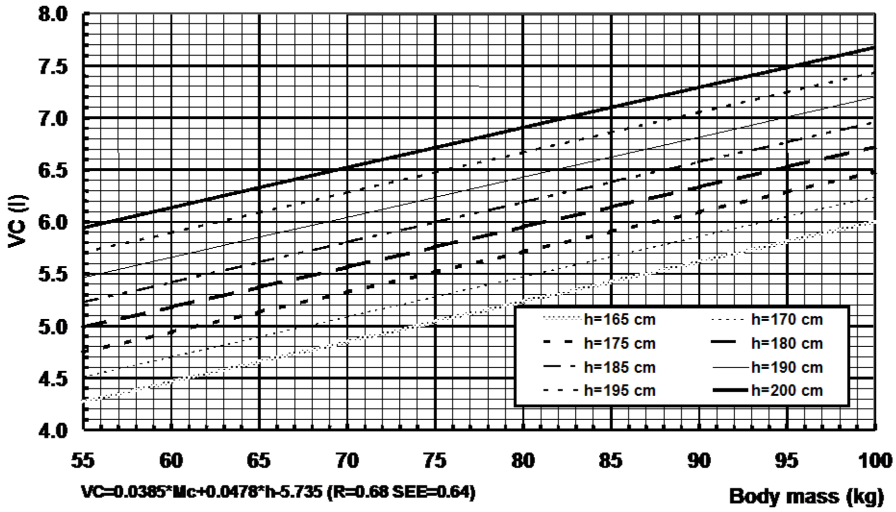

Fig. 9
Nomogram of the expiratory vital capacity (VC)

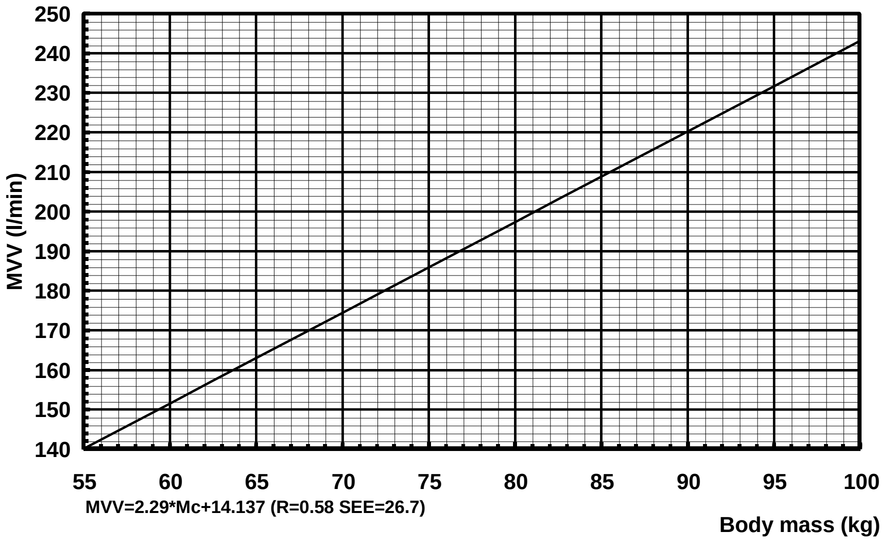

Fig. 10
Nomogram of the maximal voluntary ventilation (MVV)

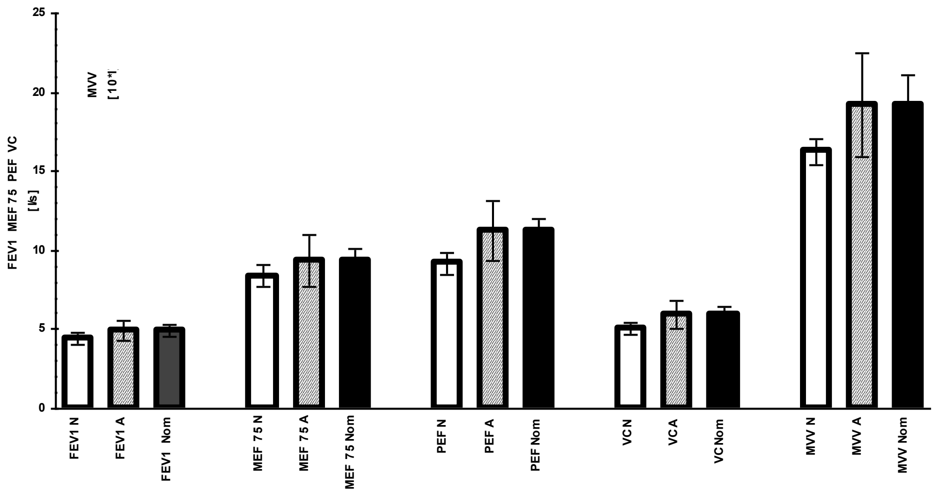

Fig. 11

Comparison of the values of the forced expiratory volume in one second (FEV1), of the maximal expiratory flow at 75% of the force vital capacity (MEF75), of the peak expiratory flow (PEF), of the expiratory vital capacity (VC), and of the maximal voluntary ventilation (MVV)
Mean ±SE; P – predicted values; M – Measured valuesnom – verified values

Discussion

The kayakers investigated in the present study constituted a group of young, healthy athletes aged 16 to 24 years. The subjects were of medium to strong body build, proper body mass-to-body height ratio, and their body masses and heights were markedly higher than those of their counterparts from the general Polish population [10,19]. The kayakers fulfilled the criteria of the selection of candidates to this sport with respect to both anthropometric features and age at the beginning of training; many of them also had a long training history [6,11,16].

During interpretation of the results of the spirometric tests performed in the investigated kayakers other data obtained at the medical examinations of the subjects were also taken into account. All the kayakers presented with correct spirometric indices. In accord with the recommendations of ATS and ERS [8,13,18] any existence of the restrictive alterations and obturational disorders associated with pathological air flow through large and small bronchi was ruled out.

In the course of the repeated over many years measurements of the pulmonary ventilation indices performed in the same athletes it was found that the obtained values were not only relatively high but they were also subject to change. For example, in kayakers the highest values of these indices were detected during winter and spring, i.e., when the training load for these athletes is particularly great and intense [3]. Generally, it is believed that spirometric values increase until the age of 20 and gradually decline afterwards, that they are smaller in women and vary with race [5]. The herein demonstrated statistically significant differences between the measured versus the due values of the spirometric indices, elevation of these values with age, straight linear type of the changes and age-dependent differences in case of MVV and ERV collectively point to the effect of training on the pulmonary ventilation capacity in kayakers. Noticeably, the strong correlation of the age of the subjects with their history of training ($r=0.75$, $p<0.001$) underlies the pronounced convergence of the β coefficients calculated for the training history and spirometric indices as well as for the age and spirometric indices. It has been reported that in rowers, kayakers and cyclists even a few months of specific training lead to changes in the spirometric indices, and that the detectable differences in changes of the dynamic and static indices relate to the type of the sport; in fact, the most pronounced increases in PEF, FEV1, and MEF75 were demonstrated in kayakers [1]. In studies of the cardio-pulmonary function in Croatian kayakers the measured VC and FEV1 values equaled to 106% and 117%, respectively, of the corresponding values due to members of the average population [11].

In studies of the function of lungs in exercising or resting athletes only classical spirometric indices are usually measured. Generally, athletes selected from the average population are young and healthy individuals who more often than not present with high body mass and height, the features playing a significant role in many sports. As demonstrated by the results of studies from the last 20-30 years Polish children and youth demonstrate a marked increase in their body mass and height, i.e., parameters bearing on the basic spirometric values [10]. As shown by the centile graphs of physical fitness of the Polish youth, the kayakers investigated in the present study exhibited the significantly higher body mass and height compared to their peers from the general Polish population [17,19].

As demonstrated by Polish authors, members of a huge group of the selected, physically fit, young (age range 18-22 years), male Polish candidates for military pilots presented with high values of the basic spirometric indices which equaled to 118%, 108.98%, 120.9% and 141% for FEV1, VC, PEF and MVV, respectively, of the due values according to ECCS [7]. Moreover, it was shown that the FEV1 and VC values recently measured in a large group of men aged 15 to 40 years were significantly increased compared to the respective values predicted to the male Polish population 25 years ago [15].

In kayakers investigated in the present study the basic spiromteric indices correlated most strongly with, in order of the correlation strength, the body mass and body height (Table 2). The verified predicted values for FEV1, MEF75, PEF, VC, and MVV were significantly higher than the corresponding values predicted for the average population and closer to the measured values (Fig. 11). In summary, the present results indicate that: 1) values of the spirometric indices measured in the top class kayakers are significantly higher than those described by the binding standards; 2) in case of the kayakers the regression line for the predicted and measured values relative to age runs at the significantly higher level that obtained for non-training individuals. Of note is also variation in changes of the MVV and ERV values with age; 3) compared to members of the average population whose spirometric values most heavily depend on the body height and age, these values in the tested kayakers most strongly correlated with the body mass and height; 4) in the kayakers under study the values of FEV1, MEF75, PEF, VC, and MVV derived from the prepared nomograms are significantly higher than the corresponding values predicted for the average population and markedly closer to the values actually measured in the kayakers.

It is important to note that most of the kayakers investigated in the present study are top representatives of this sport and medal winners at world championships and/or Olympic games. We believe that the present verification of the values of basic spirometric indices predicted to kayakers will meet the needs and requirements of this kind of sport.

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