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FACTOR STRUCTURE OF MORPHOLOGICAL VARIABILITY IN MALE AND FEMALE ROWERS

Key words: rowers, typology, body build, body composition.

ABSTRACT

The paper discusses morphological features of rowers with the aim to establish a rower's body build model. Three factors were isolated in the factor analysis. Factor 1 related to body mass, body circumferences and adiposity was found to be the highest contributor to total variance in the group of male and female rowers under study. A secondary role was attributed to Factor 2 connected with body length and horizontal reach and – in female sweep rowers – to body circumferences and adiposity. It is supposed that ascribing the highest significance to the most eco-sensitive features results not only from the process of selection of prospective rowers, but is also an effect of strength and endurance training. A tertiary role was ascribed to Factor 3 related to body length parameters, which can be explained by the subjects' young age and their ongoing physical development.

INTRODUCTION

Rowing is a water sport practiced professionally by men and women. Competitive rowing is a sport in which athletes race against each other in boats propelled by oars placed in revolving oarlocks. Rowers sit in the boats facing backwards pushing the oar blades against the water. The coxswain sits in the stern or lies semi-supine in the bow facing the bow. Rowing involves cyclical movements of both upper and lower limbs in a synchronic manner. It engages over 70% of body muscle mass, numerous muscle groups of the lower limbs, abdomen, buttocks, shoulders and arms, and it increases metabolic changes in the rower's body [1, 2]. Rowers need a great deal of muscle strength to give speed to the boat at the start of the race, and high efficiency to maintain speed throughout the race. Rowing requires from athletes great endurance and strength as well as high efficiency parameters [2, 3, 4]. A significant role in rowing is ascribed to the mobility of joints used in the biomechanical rowing cycle and development of muscular strength [5]. Rowers must also possess appropriate morphological traits such as long upper and lower limbs and trunk, necessary to perform rowing movements in the most optimal angle range. Sports results in rowing depend on many factors: rowers' somatic build, fitness, high level of technical, tactical and psychical preparation [6, 7], nutrition, technological development of rowing shells and oars, weather conditions and optimization of the training process [5].

The somatic factor, which includes the sizes of different body parts, body proportions, tissue composition and body build type, is one of

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determinants of success in sport. Research shows that rowing is one of those sports, in which the athlete's morphological build is a necessary condition to achieve high sports results. At the same time, the somatic build of rowers varies depending on the type of rowing discipline (sculling, sweep rowing) and specific rowing events.

The rower's body build is strictly linked with the specificity of this particular sport. Mikołajczak [8] observes that a rower should have a slender body of large height and weight. The rower's trunk should be also characterised by large length and width parameters, e.g. broad shoulders and considerably wide pelvis, broad chest and the circumferences of the hips and abdomen proportionnally small in relation to the body length parameters. The rower's upper and lower limbs should have good musculature and high length parameters proportional to the whole body. Harmonious muscular development of the whole body, particularly, of the back and pectoral girdle, is very characteristic among rowers.

The studies of Garay et al. [9], Piotrowski et al. [10] and Skład et al. [11] show that rowers differ from non-training individuals not only in their greater body height and weight, but also in their length of upper limbs, lower limbs (shanks, in particular), width of shoulders, width of distal epiphyses of upper and lower limbs and muscular girths of limbs (forearms, in particular). Other rowers' characteristics noted by the aforementioned authors include proper correlations between tissue components – minimal adiposity and high level of lean body mass. Martirosow et al. [12], on the other hand, consider body height, body weight, horizontal arms reach, trunk length, lower limb length as well as muscular and fat mass as the most diagnostic features of the body build of male and female rowers.

The development of a model of body build of junior male and female rowers can be useful for gradual assessment of their adaptation to particular training loads, preparation and development. For junior rowers their age is merely one of stages on their way to championship [5].

The following study was aimed at the establishment of a body build type most appropriate for present-day rowing, through determination of morphological features of the greatest significance in this sport. The desired body build type in rowing is the effect of selection of prospective rowers and then of realization of specific training loads.

The research results constitute a theoretical model of body build of male and female rowers, whose main objective is to provide rowing coaches with some practical information, which might be used as a set of criteria in the process of selection of prospective rowers and programming of training loads.

METHODS

The study sample consisted of a group of rowers (28 men and 26 women, aged 16-18 years) with training experience between five months and five years, who were members of the Polish Junior National Team (Tab. 1-2). The analysis included anthropometric measurements performed during autumnal consultations in 2005 organized by the Polish Union of Rowing Associations. At the time of measurements the rowers were in their extensive preparation period before competition.

The analysis included direct and indirect measurements of the rowers' somatic features [9, 10, 11, 12]:

1) length features: body height, trunk length, upper limb length, arm length, forearm length, hand length, lower limb length, thigh length, shank length, foot length;
2) width features: shoulders width, chest width, chest depth, pelvis width, foot width, hand width;
3) body circumferences: chest (at rest), waist, abdomen, hips, arm (at rest, at half of its length), forearm (maximum), thigh (maximum), shank (maximum);
4) body mass;
5) skinfold thickness: under shoulder blade, on the arm (triceps), forearm, abdomen, thigh and shank;
6) horizontal reach of arms: at the widest obtuse angle of upper limbs (distance between anthropometric points da_{III} of the right and the left hand with both arms fully spread aside).

Table 1. Number of examined male and female rowers

Men			Women		
total	sculls	sweeps	total	sculls	sweeps
28	10	18	26	11	15

Table 2. Age and competitive experience length (in years) of examined male and female rowers

	Men							Women						
	min	max	M	m(M)	δ	m(δ)	V(δ)	min	max	M	m(M)	δ	m(δ)	V(δ)
age	15.97	17.77	17.08	0.10	0.51	0.07	2.99	15.53	17.83	16.98	0.14	0.70	0.10	4.13
comp. exp.	1.17	5.50	3.13	0.27	1.41	0.19	44.93	0.50	5.00	2.80	0.26	1.34	0.19	48.08

The measurements were taken in accordance with general anthropometrical standards, using conventional instruments. The body measurements were taken with an electronic scale (0.1 kg accurate); length measurements with an anthropometer (0.1 cm), width measurements with a small and large breadth caliper (0.1 cm); circumferences with an anthropometric tape (0.1 cm), skinfold thickness with skinfold calipers (0.2 mm), and the horizontal reach of arms with an anthropometric tape (0.1 cm).

The subjects' body tissue composition was also examined using bioelectrical impendance analysis, following the guidelines of Bergman and Janusz [13], with the amounts of body water, fat and LBM measured with the Spectrum Lightweight II analyzer.

Data on subjects' age and length of training experience were collected from survey questionnaires (Table 2).

The collected data was processed statistically with the use of the following tools: arithmetic mean (M), standard deviation (δ), mean errors ($m_{(M)}$, $m_{(\delta)}$) and coefficient of variation ($V_{(\delta)}$) of individual features for all subjects, with regard to the rowing discipline (sculls, sweeps). Minimum and maximum values were enumerated to obtain the total range of variability of the measured parameters. The significance of variance of mean values was estimated with the use of Student's t-test for independent variables [14].

To examine the subjects' body build traits crucial for rowing, factor analysis using the principal component method was applied. All calculations were made with the use of Statistica PL software package [15]. Factor analysis transforms a number of possibly correlated variables into a smaller number of uncorrelated variables [15, 16].

The arrangement of analysed features suggests that in such an area of variability a factor structure can appear, i.e. some features can constitute a factor, which due to their similarity, although arbitrarily, can be given particular significance. Factor analysis was used as a method of data reduction or disclosure of a structure in correlations between variables. It consists of linking correlated variables into a single factor. Each factor is defined in such a way as to maximize the variability which has not been encompassed by the preceding factor. In order to determine the number of factors in a particular area of variability, eigenvalues were marked on linear diagrams (variances isolated by factors). The analysis of eigenvalues in the groups of male and female scullers and sweep rowers led to selection of three factors from among the analyzed set of data.

The applied factor analysis tends to classify features (variables) using the principal component method. The achieved results are clearly marked by high values for some variables and low values for others. Table 3 and Table 4 present factor values (coefficients of correlation between variables and factors), with the significant ones at $x>0.700$ set in bold. It should be noticed that apart from the values marked as significant, there are also factors whose numerical values are very close to the significant ones. Such a structure should be obtained for each factor which demonstrates the highest possible diversity. Interpretation of factors obtained with the use of principal component analysis is usually heterogonous and troublesome. It becomes easier following a varimax rotation. Factors before the rotation become normalized, and all variables are ascribed the same significance [15, 16].

RESULTS

The analysis of values of the isolated factors, with the significant ones at $x>0.700$, allowed to determine sets of characteristic features for each factor.

The factor analysis in the group of male rowers (Table 3) indicates their diverse contribution to total variance. Among the male rowers the most significant was Factor 1 (30.05%) encompassing features connected with body mass, body circumferences and trunk adiposity. Factor 2 (23.91%) grouping features connected with body length and horizontal reach was the second most significant contributor. Factor 3 encompassing body components accounted for 13.04% of the variability range. Altogether the three Factors accounted for 67% of total variance, indicated by the variability of given parameters in the whole group of male rowers.

Table 3. Values of factors isolated in the group of male rowers

Feature	Total			Sculls			Sweeps		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
body height	0.1912	**0.8144***	0.3250	0.2420	**0.8574***	0.3237	0.1444	**0.8837***	0.2168
body mass	**0.8455***	0.4317	0.2252	**0.8481***	0.4690	0.2073	**0.8420***	0.4186	0.1138
trunk length	0.3464	–0.1922	0.5312	0.5112	–0.2638	**0.7219***	0.1712	–0.0644	**0.8225***
upper limb length	0.0757	**0.8147***	0.4205	0.3495	**0.7306***	0.3927	0.0656	**0.9232***	0.0809
arm length	0.1504	**0.7041***	0.3337	0.6305	0.5991	–0.0167	–0.0898	**0.7152***	0.3488
forearm length	0.0514	0.1531	0.5461	–0.0821	0.0066	**0.8175***	0.2284	**0.7540***	0.0796
hand length	–0.0887	**0.7535***	–0.0702	–0.1935	0.5358	–0.5269	0.0514	0.6661	–0.2859
lower limb length	–0.0004	**0.9333***	0.1324	–0.0356	**0.9790***	0.0206	0.0573	**0.8877***	–0.2000
thigh length	–0.3576	**0.7147***	0.0345	–0.6166	0.6254	–0.1294	–0.2265	0.5674	–0.2283
shank length	0.3848	0.6824	0.2213	0.5443	**0.7058***	0.0968	0.3307	**0.7206***	–0.0374
foot length	0.2078	**0.8853***	0.0103	0.2035	**0.8892***	–0.1258	0.3437	0.6971	–0.3114
horizontal reach of arms	0.1105	**0.7962***	0.4731	0.4800	0.6370	0.5151	0.0043	**0.9621***	0.0725
shoulders width	0.2830	0.5384	–0.4085	0.4525	0.6574	–0.4700	0.1085	0.0629	**–0.7718***
chest width	0.3908	0.2313	0.1560	**0.7001***	–0.3708	–0.1428	0.3710	0.4471	0.2062
chest depth	0.6375	–0.1319	0.3810	**0.7339***	0.2213	0.5705	0.5732	–0.3216	0.0600
pelvis width	0.1986	0.6820	–0.2041	0.1464	**0.7870***	–0.3252	0.2534	0.4108	–0.5293
foot width	0.2462	0.6621	–0.4515	0.2709	0.2476	**–0.7848***	0.3298	0.4896	–0.5429
hand width	0.2595	**0.7310***	–0.2645	0.4800	0.5079	–0.4986	0.0450	0.6404	–0.1428
chest circumference	**0.8316***	0.1773	0.3277	**0.9263***	0.2297	0.2616	**0.8093***	0.2740	0.1704
waist circumference	0.6875	0.0831	0.3472	**0.7993***	0.1876	0.4030	0.6882	0.3264	0.0050
abdomen circumference	**0.8448***	0.1010	0.3459	**0.8885***	0.2480	0.3058	**0.8558***	0.0788	0.1379
hips circumference	**0.8172***	0.3436	0.1928	**0.7659***	0.5464	0.1093	**0.8228***	0.3140	0.1058
arm circumference	**0.8905***	–0.1746	0.0180	**0.8515***	0.2559	0.1413	**0.8167***	–0.2808	0.1073
forearm circumference	**0.7654***	0.3939	–0.1475	**0.7833***	0.5128	–0.0217	**0.7777***	0.0486	–0.3334
thigh circumference	**0.9068***	0.0595	0.2366	**0.8942***	0.3191	0.2326	**0.8537***	0.0125	0.2242
shank circumference	**0.7672***	0.2902	–0.1854	**0.7141***	0.4912	–0.2164	0.6608	0.1256	0.0791
shoulder blade skinfold	**0.8190***	0.0565	0.0614	**0.8594***	0.1131	0.0765	**0.8057***	0.0499	–0.1278
arm skinfold	0.6837	0.1518	0.0470	0.5877	0.4514	–0.0647	**0.7171***	–0.1092	0.1175
forearm skinfold	0.5610	0.2211	0.1135	**0.7707***	0.0445	–0.1015	0.4916	0.1329	0.4580
abdomen skinfold	**0.7782***	–0.2311	0.3792	**0.9276***	–0.0341	0.2740	0.6363	–0.1674	0.6613
thigh skinfold	0.6464	–0.1143	0.3983	**0.7567***	–0.0496	0.3356	0.5641	–0.0593	**0.7036***
shank skinfold	0.4781	0.2212	0.3681	**0.7170***	0.3529	0.1078	0.1656	0.2993	**0.7238***
% body fat	0.3858	0.1043	**0.7344***	0.3764	0.1147	**0.8555***	0.6857	0.1629	–0.0353
% non-fat body mass	–0.3858	–0.1043	**–0.7344***	–0.3764	–0.1147	**–0.8555***	–0.6857	–0.1629	0.0353
% body water	–0.3615	–0.1167	**–0.7462***	–0.3454	–0.1173	**–0.8757***	–0.6699	–0.1772	0.0584
% of total variance	30.05	23.91	13.04	39.03	23.75	18.63	29.38	23.21	12.36
accumulated variance		67.00			81.41			64.95	

***** x > 0.7000

In the group of male scullers the marked factors accounted for over 81% of total variance: Factor 1 (body mass, body circumferences, adiposity and chest measurements) – 39.03%; and Factor 2 (body lengths) – 23.75%. The third in terms of percentage contribution to total variance was Factor 3 (body components with significantly correlated trunk length, forearm length and foot width).

The factor analysis of male sweep rowers revealed the highest contribution of Factor 1 (body mass, body circumferences, skinfold thickness) – 29.38%; followed by Factor 2 (body length and horizontal reach) – 23.21%; and Factor 3 (lower limb adiposity, shoulder width, trunk length) – 12.36%. In this group the mentioned factors accounted for 65% of total variance.

Table 4. Values of factors isolated in the group of female rowers

Feature	Total			Sculls			Sweeps		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
body height	–0.1788	0.5451	0.6945	0.0314	**0.8359***	0.5219	0.2486	–0.5115	0.4876
body mass	**0.7799***	0.1840	0.5576	**0.8755***	0.4406	–0.0791	**0.8181***	0.4768	0.0352
trunk length	–0.1158	–0.1770	**0.7526***	0.0840	**0.7164***	0.2017	0.2415	–0.4943	–0.6627
upper limb length	0.1320	**0.7851***	0.2119	–0.0846	0.4944	0.6623	0.4196	0.2433	**0.7448***
arm length	–0.0575	0.6782	0.0406	–0.0022	0.2828	**0.8139***	–0.1369	0.0222	**0.7854***
forearm length	0.0643	**0.7242***	0.0433	–0.1619	0.5078	0.6333	0.3875	0.2520	0.5860
hand length	0.3001	–0.1041	0.3358	–0.0501	0.2312	–0.4024	0.5719	0.1672	–0.2761
lower limb length	–0.1442	0.8846	0.0759	–0.1807	0.3386	**0.7127***	–0.0025	–0.0959	**0.9443***
thigh length	–0.0202	0.6191	–0.4022	–0.2385	–0.3168	0.2416	–0.1269	0.2096	**0.8149***
shank length	–0.1889	**0.8351***	0.3000	–0.1217	0.6195	0.6562	0.2180	–0.2753	**0.8428***
foot length	0.0815	0.2228	0.5382	–0.1373	**0.8538***	–0.0327	0.0115	0.3834	0.0737
horizontal reach of arms	–0.1728	–0.1325	**0.8906***	0.0237	**0.9478***	–0.0319	0.2888	–0.6446	–0.4813
shoulders width	0.3062	0.2842	0.5068	0.0211	0.3564	0.0972	0.5656	0.1856	0.0494
chest width	0.4220	0.3680	0.3376	0.4187	0.6823	0.3215	0.3697	0.4656	0.3186
chest depth	0.6986	0.1608	0.0015	**0.8331***	–0.1310	0.2938	0.3095	0.5865	0.0868
pelvis width	0.4223	–0.0182	0.1939	0.6937	0.3981	0.0129	–0.1190	0.5032	0.0740
foot width	0.0930	0.3569	0.3886	–0.1850	0.1569	0.0215	0.5342	–0.0500	0.1698
hand width	–0.0613	0.3102	0.5991	–0.2925	0.6652	0.1159	**0.7298***	–0.1179	0.0084
chest circumference	**0.8194***	0.0626	0.0878	**0.8393***	0.1946	0.1054	0.2713	**0.8445***	–0.0106
waist circumference	**0.8657***	0.0763	0.1681	**0.9254***	0.1615	0.0200	0.2309	**0.8935***	–0.0310
abdomen circumference	**0.9083***	–0.1023	0.0731	**0.9726***	–0.0825	–0.0273	0.2460	**0.8736***	–0.2357
hips circumference	**0.7536***	0.1285	0.4954	**0.8563***	0.3247	–0.0561	**0.7225***	0.4706	0.0291
arm circumference	**0.7570***	0.2605	0.1896	**0.7660***	–0.0559	–0.3866	**0.7469***	0.4096	0.1448
forearm circumference	0.4543	0.1854	0.5904	0.2543	**0.7416***	–0.3580	**0.8029***	0.1574	0.0079
thigh circumference	**0.7680***	0.0588	0.4884	**0.8557***	0.2134	–0.2665	**0.8759***	0.3016	–0.1039
shank circumference	0.4754	–0.1080	0.5127	0.6566	0.2035	–0.4989	0.5442	–0.0451	–0.2384
shoulder blade skinfold	**0.8527***	–0.0767	–0.2735	**0.8247***	–0.4078	–0.1807	0.1876	**0.8624***	0.0440
arm skinfold	0.5630	0.4709	–0.0458	0.6420	–0.3324	0.3780	0.5642	0.2433	0.3465
forearm skinfold	0.2744	0.5980	0.2083	0.4594	0.2176	0.6454	0.6152	–0.1135	0.4337
abdomen skinfold	**0.9293***	–0.0037	–0.1610	**0.9003***	–0.3886	–0.0130	0.3911	**0.8057***	–0.0264
thigh skinfold	0.6817	0.1767	–0.0893	0.6005	–0.3414	–0.4382	0.4123	0.4978	0.4059
shank skinfold	0.3182	0.4831	0.2170	0.4010	–0.0529	0.1234	0.6118	–0.1352	0.4980
% body fat	0.6738	0.0581	–0.1032	**0.7689***	–0.4520	0.3285	0.4132	0.4661	–0.0750
% non-fat body mass	–0.4277	–0.5640	0.1378	–0.0798	0.0971	**–0.8043***	–0.5513	–0.4583	–0.2614
% body water	–0.3838	–0.6023	0.1221	–0.0507	0.0298	**–0.8185***	–0.5358	–0.4239	–0.3132
% of total variance	27.30	17.31	14.85	30.56	20.37	17.24	23.31	21.60	17.03
accumulated variance		59.46			68.17			61.94	

***** x >0.7000

The factor analysis in the group of all female rowers (Table 4) indicated the highest contribution of Factor 1 (27.30%), followed by Factor 2 (17.31%) and Factor 3 (14.85%), accounting altogether for about 60% of total variance.

Among the female scullers (Table 4) the three factors constituted 68% of total variance with the highest contribution of Factor 1 (30.56%). Factor 2 (body length, horizontal reach) amounted to 20.37% of total variance, and Factor 3 (body components, arm and leg lengths) to 17.24%.

In the case of female sweep rowers (Table 4) the most significant was Factor 1 (23.31%) connected with the body mass and body circumferences; followed by Factor 2 (circumferences and adiposity of trunk skinfolds) – 21.60%; and Factor 3 (length of upper and lower limbs) – 17.03%. All the three marked factors accounted for 62% of total variance in this group.

DISCUSSION

Within the last few years professional sport has undergone numerous transformations. Sports results have greatly improved, the scope of different disciplines has been extended, and the number of events within individual sports has also increased. Systemic solutions of problems connected with programming of the training process; specialist, technical, tactical, psychical and other special requirements as well as their scientific foundations have become hugely significant in modern professional sports. The best results cannot be attained anymore by using solutions used in preparation of top athletes even a few years age. Long-term observations of Olympic champions reveal that sports results in rowing are to a great extent determined by the somatic build and age of both male and female rowers.

The present study concentrated on the somatic build of rowers, members of the Polish Junior National Team, who have been successful in different international contests in their age category as well as constituted prospective members of future senior rowing crews.

The model of rowers' crucial somatic features of rowers is a result of specific selection for rowing, and it reflects the phenomenon of body adaptation to external factors. One of the most important environmental factors is physical exercise, especially sports training [17].

Using cross-sectional research it is very difficult to establish which elements of morphological build are results of training, and which were subject to the process of selection. A trait which should be definitely regarded as a selection feature is body height indicated by bone sizes [17, 18]. The growth of the skeleton is genetically conditioned and affected by the endocrine system, but it is also shaped in reaction to environmental factors. Most sport disciplines prefer athletes who possess higher values of this trait, even exceeding the standards for general population. The most extreme cases include basketball, volleyball and rowing. The subjects in the present study, who belonged to the national junior team, confirm the mentioned selection tendency, but are still behind the world top rowers in terms of their body height [19, 20]. Nevertheless, considering the juniors' young age the growth of their skeletons is still far from completion.

The length parameters of the body: body height, trunk length, length of upper and lower limbs – are immensely significant in many technical sports, including rowing, as they function as an effective leverage system, and their proper size enables the working of the body in the optimal angle ranges. The working of the body depends also on the mobility of joints involved in the biomechanical system of a rowing cycle, especially hip, shoulder and ankle joints [5]. The rowers' somatic traits, rowing boat type and crew arrangement, oar characteristics and factors determining individual rowing technique and rowing boat speed are all highly correlated. Long arms play a decisive role in this sport because they enable rowing in the optimal angle range, as well as rowers' lower limbs whose muscles are one of main driving forces during rowing [5]. A great significance for the movement of the centre of body weight is attributed to the positioning of the trunk during the leg drive, draw and catch stages.

Physical activity has been known to affect bone mineralization by increasing bone thickness and massiveness [18]. Moreover, the action of muscles increases the thickness of places of muscle attachment. Therefore, in individual sports, the dominance of width features of these parts of the skeleton most engaged in the training process is greatly emphasized. It is justified by fact that the width features are slightly less genetically determined.

Undoubtedly, intense and systematic physical exercises, and sports training in particular, affect adaptive changes in the muscle system [21].

The body circumferences are eco-sensitive traits. The increase of muscle mass is mainly caused by the growth of the already existing muscle fibres, and the growing thickness of muscle fibres increases strength. The metabolism of highly energetic compounds and improvement of blood circulation in muscles are also greatly improved. According to Secher [22] and Steinacker [2] the muscles mostly engaged during competition contain from 70% to 85% of slow twitch fibres in elite rowers, which is a predestinating factor in taking up endurance sports. Strength training clearly affects the hypertrophy of those muscle groups which play the most important role in rowing; while endurance training leads to the development of more slender muscles with smaller circumferences.

The most eco-sensitive features also include body mass and skinfold thickness greatly affected by physical exercise as well as social and economic conditions. Apart from a high endurance level every rower should be able to develop high muscle strength, as the necessity of performing a number of repetitive movements requires much effort in every pull of the oars (the bigger effort the higher boat speed). The best way to improve the strength of working muscles would be to increase their mass and in consequence also the whole body mass [11, 19, 20].

The present study used an analysis of somatic features of scull and sweep rowers. The rowing technique in sweep rowing is generally very similar to sculling. The main difference is the use of a single oar and asymmetrical work of the whole body in sweeps [5]. According to Hennig [5] beginner rowers should start their training with short oars for health and prophylactic reasons (symmetrical body work is more advisable for proper physical development of a young body), safety reasons (it is easier to learn to maintain the balance in a rowing boat) and training advantages (having mastered rowing with short oars, it is easier to master sweep rowing).

The analysis of the obtained results showed that both male and female sweep rowers displayed higher levels of all the studied length parameters, with the exception of forearm length and thigh length (women only). Higher average values of width parameters were also observed among the sweep rowers. The male sweep rowers had larger circumferences of the chest, abdomen, hips, forearm and shank; whereas the female rowers achieved higher average values of all studied circumferences. The scullers featured only longer circumferences of the waist, arm and thigh. The analysis also revealed greater body mass, skinfold thickness and horizontal reach of the arms in sweep rowers.

Body build models of rowers in literature [8, 19, 23, 24] with regard to the type of rowing events, are confirmed in the present study. However, there are hardly any studies concerning the body build of rowers with regard to the type of rowing shells (sculls, sweeps). Junior rowers, due to their young age, cannot be classified for one event only, but their type of rowing boat remains unchanged. Therefore, verification of the obtained research results can be rather difficult. The discussed variability of rowers' morphological features was confirmed by Krupecki [20], who indicated significant differences between scullers and sweep rowers taking part in the Olympic Games in Barcelona and Atlanta. He showed that the former featured a lower body height (by 2.6 cm) and less body mass (by 2.8 kg) than the latter. Body build is just one of the indicators used in the process of selection of rowing crews in sculls and sweeps. Other factors also include athletes' ability to differentiate movements ("feeling the boat", "feeling the oar"), predilections and psychical predispositions (preferences of individual or team competitions, teamwork skills). The number of rowers in a rowing club is also important. Clubs with a small number of rowers more often prefer sculls because of the relatively easy selection of sculling crews, which require fewer rowers and offer the possibility of practicing single scull rowing (data gathered from an interview with the coach of Junior National Rowing Team).

The body components of male and female rowers are highly eco-sensitive features, which change their proportions in reaction to different exogenous factors, including physical activity. Elite rowers feature low body fat and highly developed active tissue [11, 18]. In the studied groups of male and female rowers, a higher percentage of body water and dry matter was noted in the group of scullers, and a higher content of body fat was observed among the sweep rowers. It shows that the higher level of body mass in sweep rowers is conditioned by somatic type predispositions to this category of rowing boats.

The male and female rowers, members of the Polish Junior National Team belong only to the open weight category because of their young age. Competing in the lightweight category is most often connected with the necessity of decreasing body mass to the limits provided in regulations, and not only the body fat amount but also but also lean body mass or body water, which leads to a decrease in strength and physical endurance [25].

The observed differences in the level of development of somatic and body components in the groups of male and female rowers with regard to the type of rowing discipline suggest the appearance of a factor structure in the analysed area of variability. Among the male and female rowers a factor with the highest percentage contribution to total variance, was Factor 1 related to body mass, body circumferences and adiposity expressed by skinfold thickness. The second greatest contributor to total variance was Factor 2 connected with body length and horizontal reach. Only in the female sweep rowers was Factor 2 linked to body circumferences and trunk adiposity. Factor 3 showed discrepancies depending on subjects' sex: in the male rowers it was connected with body components, in the female rowers with trunk length and horizontal reach. However, among both female scullers and sweep rowers, this factor was associated with limbs length and, in female scullers, with body composition. In the group of male scullers the most significant were body components, and in the group of sweep rowers – trunk length, shoulder width and lower limb adiposity. The described model of rowers' massive body build was confirmed by Pietraszewska [26], who noted that the most characteristic features of rowers included strong development of the shoulder girdle and chest, upper limb muscularity (forearm in particular) as well as high body length parameters and wide hips helpful in maintaining balance in the boat.

Factor models of rowers' body build in literature from the 1970s, 1980s and 1990s describe in different ways the rowers' morphological build, stressing first of all the length factor and then the factors of muscularity, thickness and width of the skeleton [8, 19]. However, Martirosow et al. [12] did not mark such features as body length, horizontal reach, lower limb length, trunk length, body mass and tissue elements – i.e. features indicated in the somatic model of Polish junior rowers – as significant in rowing. The rower's body build model described by Ważny et al. [6] included body height and body mass, arms stretch (horizontal reach), trunk length and body composition as significant traits.

Large body mass, strong development of musculature and adiposity constituting Factor 1, i.e. the highest contributor to total variance, can be related to the studied rowers' young age and shorter competitive experience than in the case of the most experienced elite rowers. The noted large body mass and strong musculature, particularly of the trunk and limbs (mostly forearm) can be recognised not only as a result of selection but also training. Strength and endurance rowing training affects the development of muscle mass and body circumferences. Factor 2 connected with body length parameters, slightly less significant in the rower's body build, can be associated with the subjects' ongoing physical development, and it should be expected that the body height and development of other length features will significantly increase in the future, which should greatly influence the rowers' biomechanical systems.

On the other hand, ascribing a secondary role to the body length parameters can signal the necessity to select prospective rowers with lower values of these traits, to enable the proper balance of the boat and reduce resistance during boat movement [19]. Among the female rowers also Factor 3 was associated with the length parameters: trunk length and horizontal reach; whereas in male rowers a significant role was played by body components. Maintaining proper relations between body fat mass and lean body mass is one of the main indicators in the body build of male rowers, especially in sculls, therefore in the case of scull rowers Factor 3 is related to body components. Sweep rowers feature a more massive body build, that is why there are discrepancies between total groups of studied rowers and groups of scullers: Factor 3 (trunk length, width of shoulders, lower limb adiposity) in male rowers; and Factor 2 (trunk adiposity and circumferences) and Factor 3 (limb length) in female rowers.

In conclusion, in the studied group of male and female rowers the factor with the highest contribution to total variance was related to body mass, body circumferences and adiposity marked by skinfold thickness. A secondary role was ascribed to the factor connected with body length and horizontal reach and – in the case of female sweep rowers – with body circumferences and adiposity. Factor 3 showed discrepancies depending on rowers' gender and rowing discipline. It is supposed that attributing the most significant role to more eco-sensitive features is an effect of not only the selection process in rowing but also of strength and endurance training. The secondary significance of length features should be associated with the young age of junior rowers under study and their ongoing physical development.

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