ANTHROPOMETRIC AND PHYSIOLOGICAL PROFILES OF ROWERS OF VARYING AGES AND RANKS

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Abstract:

This study was aimed at assessing the anthropometric and physiological profiles of elite junior, sub-elite senior and elite senior rowers and at determining and explaining the differences between these groups. For that purpose, the anthropometric and physiological profiles of 53 Croatian rowing champions and members of Croatia's national team were assessed. A one-way ANOVA was used to determine the differences between the groups. The results demonstrated that, when assessed against their sub-elite counterparts, the elite seniors were found to be taller (194.0±2.7 cm vs 188.6±5.4 cm) and heavier (97.2±4.4 kg vs 92.9±5.4 kg), with larger length dimensions. The juniors, anthropometrically similar to the sub-elite seniors, were nonetheless lighter (86.1±4.4 kg), with smaller girth dimensions and lower body fat levels. Similarly, the elite juniors were shorter and lighter than the elite seniors, with not only less body fat, but also a smaller girth and length dimensions. Maximal oxygen uptake (5.67±0.27 $lmin^{-1}$), power output (350.6±12.4 W), and oxygen uptake at the anaerobic threshold intensity (4.94±0.27 $lmin^{-1}$) were higher in the elite seniors than in the sub-elite seniors (VO_{2max}: 5.13±0.40 $lmin^{-1}$; P_{AT}: 318.8±19.6 W; VO_{2AT}: 4.55±0.33 $lmin^{-1}$) and the juniors (VO_{2max}: 5.37±0.37 $lmin^{-1}$; P_{AT}: 296.9±28.8 W; VO_{2AT}: 4.58±0.23 $l{\cdot}min^{-1}$). Elite male junior and senior rower profiles may be used for talent identification and selection purposes.

Key words: *rowing, elite rowers, juniors, anthropometric measurements, physiological parameters*

Introduction

The ability to obtain and to use precise information regarding the anthropometric and physiological status of athletes is a fundamental issue in contemporary sport for at least two reasons: (*a*) a detailed insight into a particular athlete's status is needed to design an effective training programme and (*b*) to select athletes appropriately, because some characteristics (e.g., anthropometric length and breadth measurements) are almost exclusively genetically determined and can hardly be changed within the context of a training programme. Various anthropometric and physiological characteristics have been found to be closely related to successful performance in rowing, and they need to be assessed for the previously mentioned purposes.

Anthropometric data for adult male and female rowers emphasize the importance of body mass (Secher, 1983; Secher & Vaage 1983; Shephard, 1998) and body size (Hebbelinck, Ross, Carter, & Borms, 1980; Hebbelinck, Ross, & Carter, 1981; Rodriguez, 1986; De Rose, Crawford, Kerr, Ward, & Ross, 1989) in determining successful rowing performance at an international level. As a number of researchers (Secher 1983; Shephard, 1998; Russel, le Rossignol, & Sparrow, 1998) have observed, a typical heavyweight rower is a tall, heavy, and lean athlete with a high percentage of slow-twitch muscle fibers. Similarly, research targeting junior rowers has profiled these younger athletes as being taller and heavier and having greater length, breadth and girth dimensions than the general population within the same chronological age group (Bourgois et al., 2000). Because both strength and endurance are needed for high-level rowing performance, long hours of rowing-specific training programmes combined with weight training typically result in a large aerobic capacity and increased metabolic efficiency, a low percentage of body fat and increased muscle mass (Russel et al., 1998).

Physiological data of elite rowers indicate impressive aerobic capacity values; furthermore, the VO_{2max} of internationally successful rowers frequently surpasses 6.0 $lmin^{-1}$, and may reach and exceed 6.5 $lmin^{-1}$ with ventilation values higher than 240 $lmin^{-1}$ (Secher, 1993; Steinacker, 1993). Since it is estimated that the relative anaerobic contribution in a 5.5-7.0 min race ranges from 21 to 30% (Secher, 1993), a high level of anaerobic capacities is also crucial for successful international performance

(Hagerman, 1984; Koerner & Schwanitz, 1985; Maestu, Jürimäe, T., & Jürimäe, J., 2005).

Previous studies have compared rowers of varying ages and rank; however, the comparison was established primarily through the use of reference data. The main findings were as follows (Steinacker, 1993; Bourgois et al., 2000): more successful rowers are typically heavier and taller than their less successful counterparts. The stature of junior rowers is similar to that of adult heavyweight rowers except that the junior rowers are lighter. With regard to physiological data, crews ranked higher in an international championship regatta have consistently exhibited a higher average VO_{2max}.

Over the past seven years (2000-2006) a comprehensive anthropometric and physiological investigation of the most talented Croatian rowers competing successfully at both the junior and senior international levels was carried out annually at the Human Performance Laboratory of the Faculty of Kinesiology, University of Zagreb. Assuming that distinctions can be made concerning the anthropometric and physiological characteristics of rowers of varying ages and ranks, the study sought to accomplish the following aims: (*a*) to assess the anthropometric and physiological profiles of elite junior Croatian rowers, sub-elite senior rowers, and elite senior rowers; (*b*) to determine and explain the differences between the observed groups; and (*c*) to compare the findings with the available reference data.

Methods

Sample

The sample consisted of 53 male rowers, all of whom were Croatian national champions and members of the Croatian national team between 2000 and 2006. Each rower was classified into one of three groups according to his age category and international competitive achievements: a group of elite juniors (N=18; age 17.6±0.4; rowing experience 5.6±1.5 years), a group of sub-elite seniors (N=21; age 22.16±2.8; rowing experience 8.4±3.3 years), and a group of elite seniors (N=14; age 28.1±3.0; rowing experience 14.1±3.1 years). The following criteria were applied for inclusion in the sample: elite juniors - junior rowers who competed in the FISA World Junior Rowing Championship "A" Finals; sub-elite seniors - senior rowers who were internationally competitive seniors yet had not reached the level needed to compete in the Olympics or the World Rowing Championship "A" Finals; and elite seniors - rowers who had competed in the FISA World Rowing Championship "A" Finals or in the Olympics (including six medalists at Sydney 2000 and Athens 2004). We assumed that the rowers selected for the juniors group and the second group of seniors possessed the characteristics of top-level male rowing competitors (for the junior and senior categories, respectively) and could thus be considered to be "elite". The testing was conducted at the Human Performance Laboratory of the Faculty of Kinesiology at the University Zagreb during the winter periods (December or January) of each rowing season between 2000 and 2006. This testing procedure was already part of an existing programme, being conducted in collaboration with the Croatian Olympic Committee and the Croatian Rowing Federation, designed to support top Croatian athletes as they strive to qualify for and compete in the Olympics.

Data collection and equipment

Since it was possible to test most of the rowers on a yearly basis between 2000 and 2006, the data for each rower refers to the data for the year (rowing season) in which he achieved his best result (i.e., progressed to the World Championship "A" finals or competed in the Olympics). If a rower qualified on more than one occasion, then the year in which he achieved his top classification was considered. At all times we instructed the coaches not to engage the subjects in any strenuous training the day before the testing took place, and the subjects were advised not to change their usual dietary habits. Each subject was always tested in the morning. According to the recommendations of the International Biological Programme (Weiner & Lourie, 1969), we took the following anthropometric measurements: body height (body h.), body mass (body m.), arm span (arm s.), leg length (leg l.), arm length (arm l.), biacromial diameter (biacromial d.), bicristal diameter (bicristal d.), humerus and femur widths (humerus w. and femur w.), upper arm, forearm, chest, thigh, and calf girths (upper arm g., forearm g., chest g., thigh g., and calf g.), biceps, triceps, subscapular and suprailiac skinfolds (biceps s., triceps s., subscapular s., and suprailiac s.). Skinfolds were obtained using the Harpenden calliper. The body fat percentage (fat p.) was estimated according to the Durnin and Womersley technique (1974). Fat mass (fat m.) was also calculated. Fat-free mass (fat-free m.) was calculated by subtracting the estimated body fat from the total body mass. A spirometry test was also performed and included forced vital capacity (FVK), forced expiratory volume (FEV1) and Tiffaneau's index. All values were obtained using the Quark b^2 system (*Cosmed*, Rome, Italy).

After the anthropometric measurements were taken, the rowers completed an incremental maximal test on the rowing ergometer (*Concept II model B*, Morrisville, VT, USA). The test started with a three-minute rowing session at 150 W and was then intensified by 25 W increments per minute. When a rower was no longer able to maintain the demanded mechanical power due to fatigue, he was asked to perform a 30-second "all out" effort to ensure that he achieved maximal levels of aerobic capacity. Expired air was collected and analysed using the *Quark b^2* system equipped with the *Quark b^2 6.0* PC software support. Heart rate was monitored using the short-range radio telemetry system *Polar Electro* (Oulu, Finland). Cardio-respiratory parameters were calculated automatically and printed every 30 seconds. The highest values were calculated as the arithmetic means of two consecutive highest 30-second values. To ensure that the rowers gave their best effort, we observed the following criteria (Åstrand & Rodahl, 1986; Basset & Howley, 2000): (a) a plateau in VO_2 against exercise intensity; (b) a respiratory exchange ratio exceeding 1.15; (c) achievement of an age-predicted maximal heart rate.

The following physiological variables have been observed: maximal oxygen uptake (VO_2max), maximal heart rate (HRmax), maximal oxygen pulse (PO_2max), maximal ventilation (VEmax), power at maximal oxygen uptake (mechanical power at VO_{2max}, Pmax), power at ventilatory anaerobic threshold (P_{AT}), heart rate at ventilatory anaerobic threshold (HR_{AT}), and oxygen uptake at ventilatory anaerobic threshold expressed as a percentage of VO_{2max} ($\%VO_{2AT}$) and as an absolute value (VO_{2AT}). The ventilatory anaerobic threshold was determined non-invasively using the "V-slope" method (Beaver, Wasserman, & Whipp, 1986).

Data analysis

The *SPSS 11.5 for Windows* statistical software package was used to compute and report the data. The data were computed for each group separately and reported as means and standard deviations (mean±SD). The normality of distribution for each variable was tested using the Shapiro-Wilks test. Differences between the groups with regard to the observed anthropometric and physiological variables were calculated using a one-way ANOVA after the assumption that the groups came from populations with equal variances was tested and confirmed using Levene's homogeneity-of-variance test. The use of $p<.05$ was considered to be statistically significant.

Limitations of the study

It can be argued that the time point used for the measurement of the rowers' physiological capacity was not ideal since it fell within the preparatory period, approximately 3-4 months before the start of the competitive season. However, this was taken into account when interpreting the results. The periodization of a yearly training cycle for the rowers on the northern hemisphere is standardized, and every year it follows the same pattern: preparatory period (October - March), competition period (April - early September), and transition period (late September). Therefore, it is reasonable to assume that the groups of rowers were training with similar training volume and intensity at the time of the measurement. In addition, they were all equally away from the major competitions in the competition period.

Results

The anthropometric characteristics that were recorded for the observed sample of rowers are presented in Table 1. The elite seniors were significantly ($p<.01$) taller than the sub-elite seniors and the elite juniors. No difference was observed between the sub-elite seniors and the elite juniors. The elite seniors were also significantly ($p<.05$) heavier than their sub-elite counterparts and heavier ($p<.01$) than the elite juniors. The sub-elite seniors were heavier ($p<.01$) than the elite juniors. No difference was observed between the elite and sub-elite seniors with regard to fat percentage, fat-mass and fat-free mass; however, the juniors, when compared with the elite seniors, had a lower fat percentage, lower fat-mass, and lower fat-free mass. The juniors had a lower fat percentage and fat-mass than the sub-elite seniors, although there was no difference in fat-free mass. Significant ($p<.05$) differences between the sub-elite and elite seniors were observed in two out of three length dimensions (arm span and leg length); similarly, there were also significant ($p<.01$) differences between the elite juniors and seniors. All values were higher for the elite seniors. In all four measured width dimensions, no differences between either pair of groups were observed, as was also the case for all three spirometry test measurements.

The physiological profile of the observed sample of rowers is presented in Table 2. Significant differences ($p<.05$) in absolute VO_{2max} were observed between the elite seniors and juniors and between ($p<.01$) the elite and sub-elite seniors. It is perhaps noteworthy that, when observed in relation to body mass ($mlmin^{-1}kg^{-1}$), VO_{2max} was highest in the elite juniors, followed by the elite seniors and the sub-elite seniors. Mechanical power at VO_{2max} was higher ($p<.01$) in the sub-elite and elite seniors than in the juniors, with no difference observed between the sub-elite and elite seniors. Power at the ventilatory anaerobic threshold significantly ($p<.01$) differred between all observed groups of rowers, as did absolute oxygen uptake at the ventilatory anaerobic threshold, with the exception of the juniors and sub-elite seniors, where no difference was observed.

Table 1. Comparison of anthropometric data for Croatian elite junior rowers, sub-elite senior rowers, and elite senior rowers

Variable	Elite juniors (N=18)	Sub-elite seniors (N=21)	Elite seniors (N=12)	ANOVA (F-test): Elite juniors vs Sub-elite seniors	ANOVA (F-test): Elite juniors vs Elite seniors	ANOVA (F-test): Sub-elite seniors vs Elite seniors
Body h. (cm)	188.9±3.6	188.6±5.4	194.0±2.7	.023	13.737**	7.973**
Body m. (kg)	86.1±4.1	92.9±5.4	97.2±4.4	16.687**	39.225**	4.432*
Fat p. (%)	12.9±2.1	16.1±3.5	15.90±3.1	8.981**	7.076*	.024
Fat m. (kg)	11.1±2.2	15.0±3.6	16.1±3.6	14.122**	17.966**	.568
Fat-free m. (kg)	75.0±3.2	77.9±5.1	81.1±4.5	3.716	15.420**	2.711
Lengths (cm)						
Arm s.	192.6±4.3	194.4±7.5	200.6±5.1	.659	16.843**	5.107*
Arm l.	83.7±2.5	83.5±3.2	85.6±3.4	.047	2.670	2.781
Leg l.	107.2±3.6	108.2±6.1	113.1±2.7	.359	18.316**	5.197*
Widths (cm)						
Biacromial d.	43.2±1.5	43.6±1.9	43.5±0.9	.417	.188	.044
Bicristal d.	29.7±1.9	30.9±1.9	30.5±1.6	3.275	1.117	.231
Humerus w.	7.5±0.4	7.6±0.3	7.7±0.3	.268	1.225	.784
Femur w.	10.1±0.6	10.1±0.6	10.1±1.3	.008	.004	.000
Girths (cm)						
Upper arm g.	31.4±1.4	33.9±1.8	34.9±0.7	19.784**	50.554**	2.634
Forearm g.	29.2±1.9	31.0±2.2	32.2±2.8	6.430*	9.598**	1.558
Chest g.	102.1±3.2	106.8±3.6	107.1±3.0	15.850**	13.815**	.049
Thigh g.	60.2±2.2	63.1±2.7	63.2±2.2	11.719**	10.467**	.004
Calf g.	39.4±2.0	40.1±1.4	40.3±2.0	1.545	1.095	.068
Spirometry						
FVK (l)	7.1±0.8	7.2±0.7	7.3±0.7	.174	.368	.101
FEV1 (l·s)	5.7±0.4	5.6±0.6	5.7±0.6	.321	.000	.188
Tiffaneau's index	81.0±8.1	78.0±7.6	78.2±2.5	1.222	.958	.005

* p<.05
** p<.01

Table 2. Comparison of physiological data for Croatian elite junior rowers, sub-elite senior rowers, and elite senior rowers

Variable	Elite juniors (N=18)	Sub-elite seniors (N=21)	Elite seniors (N=12)	ANOVA (F-test): Elite juniors vs Sub-elite seniors	ANOVA (F-test): Elite juniors vs Elite seniors	ANOVA (F-test): Sub-elite seniors vs Elite seniors
VO_2max ($lmin^{-1}$)	5.37±0.31	5.13±0.40	5.67±0.27	3.573	5.758*	13.389**
VO_2max ($mlmin^{-1}kg^{-1}$)	62.5±4.7	55.3±3.5	58.4±3.9	27.750**	4.614*	4.771**
P_{VO2max} (W)	391.3±26.1	423.5±25.1	441.6±18.7	13.990**	25.310**	3.736
HRmax (beats/min)	198.1±7.6	196.8±9.8	194.2±10.5	.190	1.125	.419
PO_2max (ml/min)	28.2±2.3	27.7±2.8	30.8±2.1	.248	7.834**	8.488**
VEmax ($lmin^{-1}$)	191.0±14.0	196.0±13.4	206.2±16.1	1.202	6.009*	3.271
P_{AT} (W)	296.9±28.8	318.8±19.6	350.6±12.4	7.351**	27.645**	19.874**
HR_{AT} (beats/min)	175.9±8.2	171.9±11.6	169.2±9.2	1.322	3.439	.376
VO_{2AT} (%VO_2max)	85.5±2.3	88.7±2.4	87.0±2.7	16.688**	2.144	3.009
VO_{2AT} ($lmin^{-1}$)	4.58±0.23	4.55±0.33	4.94±0.27	.082	11.387**	8.997**

* p<.05
** p<.01

Discussion and conclusions

Anthropometric profile

The anthropometric profiles of rowers of varying ages and ranks were assessed with regard to skeletal robustness (body height and mass, length and breadth variables), muscle development (arm, leg and chest girths), fat-mass and fat-free mass (skinfolds).

The elite senior rowers' height was greater than that of their sub-elite senior (+ 5.4 cm) and junior (+ 5.1 cm) counterparts. Arm span and leg length values also distinguished the elite seniors from their sub-elite counterparts and juniors. The results of the present study are in line with previous studies (Cosgrove, Wilson, Watt, & Grant, 1999; Yoshiga & Higuchi, 2003) that support the belief that a rower's height and length measurements are proportionately commensurate with his rowing performance levels. For example, when compared with the non-finalists, the 1997 World Junior Rowing Championship finalists were found to be significantly taller and had greater length dimensions (Bourgois et al., 2000). Tall rowers are able to make long rowing strokes (Secher & Vaage, 1983), and long stroke lengths are closely identified with high-level rowing performance (Ingham, Whyte, Jones, & Nevill, 2002). Moreover, long legs increase the drive phase of the rowing stroke, thus providing the rowers with long legs with a biomechanical advantage (Claessens et al., 2005). The values for Croatian elite juniors are in line with the values that were generally observed for the World Junior Rowing Championship finalists (data according to Bourgois et al., 2000).

Body mass values were also higher in the elite seniors than in their less successful counterparts (+ 4.3 kg) and in the juniors (+ 11.1 kg). The sub-elite seniors were also heavier (+ 6.8 kg) than the elite juniors. These findings are supported by a study conducted by Secher (1975), who reported that the body mass of internationally competitive rowers was greater than that of club rowers. In addition, Bourgois et al. (2000) observed that junior finalists were generally heavier than non-finalists. In rowing, body mass is typically supported by a sliding seat in the boat or on a rowing ergometer, and large individuals possess an advantage (Secher, 1983; Secher & Vaage 1983; Secher, 2000). Because of this support, body fat in rowers does not put rowers at the same disadvantage that it would put athletes who carry their own body weight (i.e. running, jumping, etc.), although a high body fat content has been found to affect adversely the 2000 m rowing ergometer performance (Secher, 1983; Ingham et al., 2002). Compared with elite rowers from various countries who have won international tournaments and world championships (Secher, 1983), the elite seniors in the present study have been found to have similar height and weight values, although comparable values were somewhat lower for the group of sub-elite seniors.

Body fat expressed as both fat mass and fat percentage was lower in the juniors than in the elite and sub-elite seniors, whereas no difference was observed between the two groups of seniors. It could be argued that junior rowers were leaner than senior rowers due to the fact that the best rowers tend to be heavy and there is a positive correlation between rowing strength and body weight. Furthermore, it is difficult to combine muscularity with leanness (Shephard, 1998), although the percentage of body fat seems to have been decreasing in recent years in elite rowers. Body fat content varies, depending on the period of the season, for lightweight rowers (Morris & Payne, 1996); however, to the author's knowledge, no equivalent studies have specifically targeted heavyweight rowers or juniors. Fat-free mass is greater in the elite seniors than in the juniors (+ 6.1 kg), with no difference observed between the elite and sub-elite seniors or between the juniors and sub-elite seniors. Rowing performance has been found to correspond closely to the fat-free mass values (Cosgrove et al., 1999; Yoshiga, Kawakami, Fukunaga, Okamura, & Higuchi, 2000). According to Yoshiga and Higuchi (2003), this may be the case because an association between the fat-free mass and blood volume and stroke volume of the heart has been established (i.e., greater fat free mass is associated with higher aerobic capacity, which is crucial for successful rowing performance). In studies designed to determine the best performance predictive parameters (Ingham et al., 2002; Riechman, Zoeller, Balasekaran, Goss, & Robertson, 2002), fat-free mass emerged as one of the strongest correlates with performance when the anthropometric characteristics are observed.

Physiological profile

Measured by VO_{2max}, the aerobic capacity observed in the group of elite Croatian seniors was found to be higher (+ 0.54 $lmin^{-1}$) than that of their sub-elite counterparts, and higher (+ 0.30 $lmin^{-1}$) than that of the elite juniors. Long hours of rowing specific training result in a large aerobic capacity of rowers, with the seniors having a higher VO_{2max} in $lmin^{-1}$ than juniors due to their larger body mass values. In general, elite heavyweight rowers belong to the group of athletes with the highest aerobic capacity values (Hagerman, 1984; Secher, 1983; Steinacker, 1993). It is perhaps noteworthy that we were not able to find many recent studies dealing with the physiological characteristics of elite international junior and senior rowers. This scarcity may be due to the limited access to such subjects, as it is seldom practical or possible to collect extensive data on well-trained subjects, regardless of the sport. Some studies can be criticized for failing to provide information on the period of the rowing season in which the physiological measurements were taken. VO_{2max}, for example, has been found to vary by as much as 20 %, depending on the period (preparatory, competition, transition) of the season (Hagerman & Staron, 1983). Thus, it can perhaps be assumed that if measurements were taken during the competition period, the VO_{2max} levels in the observed sample of rowers would show higher numbers.

A rowing crew's average VO_2max and its ranking in international competitions were found to be directly related (Secher, Vaage, & Jackson, 1982; Secher, 1983; Secher, 2000). Furthermore, a high correlation between the 2000 m ergometer rowing results and VO_{2max} values has also previously been reported (Cosgrove et al., 1999; Yoshiga et al., 2000; Ingham et al., 2002). However, it has previously been suggested that VO_{2max} may not correlate well with performance among a relatively homogeneous population of endurance athletes. When observed in relation to body mass, VO_2max values in rowers are not impressive due to the athletes' large body dimensions. Values in the 60-70 $mlmin^{-1} \cdot kg^{1}$ range are often observed for elite rowers (Secher, 1993). In the present study, lower values recorded in both groups of Croatian senior rowers might be partly attributed to the early preparatory period in which the testing took place. The juniors were dominant when VO_{2max} is observed in relation to body mass, which can be explained by their smaller body mass and lower fat mass percentage. Mechanical power at VO_{2max} was higher in the elite and sub-elite seniors than in the juniors, whereas no distinction is made between the elite and sub-elite seniors. The higher VO_{2max} together with lower P_{max} in junior rowers compared to sub-elite senior rowers might be explained by the expected differences in technique efficiency and/or possible differences in the anaerobic metabolism activation. Namely, senior rowers, due to their accumulated rowing experience, are expected to be technically more proficient as compared to junior rowers.

Anaerobic threshold detection, which is now a necessary routine laboratory procedure used to plan out an athlete's training programme, is also a valuable parameter used to evaluate his/her preparedness. Steinacker (1993) reported that power at the anaerobic threshold intensity is the most predictive parameter of competition performance in trained rowers. This observation supports the findings of this study, which confirm the P_{AT} parameter's power to distinguish between the successful and less successful rowers (elite and sub-elite seniors). The elite seniors were able to maintain higher (+ 31.8 W) power per stroke values at the anaerobic threshold intensity. To a large extent, this advantage appears to explain the differences in rowing performance levels. It has been established (Maestu et al., 2005) that overall power in rowers depends on their aerobic and anaerobic energy supplies balanced by the efficiency of their technique. Another factor that distinguishes the successful seniors from the less successful seniors is oxygen uptake at the ventilatory anaerobic threshold level (VO_{2AT}). The value is higher (+ 0.39 $lmin^{-1}$) in the elite seniors than in their less successful counterparts and higher (+ 0.36 $lmin^{-1}$) than in the juniors.

To sum up, the elite seniors distinguished themselves from their less successful counterparts (the sub-elite seniors) anthropometrically by their taller body height and larger body mass, as well as their larger arm span and leg length. Moreover, the elite seniors stood out physiologically with their higher VO_{2max} (both in $lmin^{-1}$ and $mlmin^{-1}kg^{-1}$) and their higher power and oxygen uptake at the ventilatory anaerobic threshold intensity. The elite juniors were lighter and shorter than their elite senior counterparts, with somewhat smaller length and, especially, girth dimensions. No difference was observed with regard to widths and diameters or to spirometry test values across the observed groups. In order to reach higher levels in the future, less successful Croatian seniors should focus on specific training loads designed to increase maximal oxygen uptake, power output and oxygen uptake at the anaerobic threshold intensity.

The profiles of elite male junior and senior rowers may be used for talent identification and selection purposes. Much of what we consider to be "talent" is actually the degree to which each young rower possesses certain physical, physiological, or mental attributes that may contribute to performance. As specific data are obtained on elite junior and senior rowers regarding the characteristics that have been found to be important rowing performance predictors, we are able to form a "model," consisting of quantified characteristics (important performance predictors), of an elite rower. Those characteristics may be used in order to identify talent, assuming that we are able to predict an athlete's physical growth and development. According to the results of the present study, in order to reach top competition level a senior rower would need to exceed 190 cm and 95 kg with lean body mass exceeding 80 kg in the preparatory period. In the physiological sector, the desired level of VO_{2max} during the preparatory period approximates 5.7 $lmin^{-1}$, with power output at the ventilatory threshold of approximately 350 Watts. For junior level rowers, body mass should equal approximately 85 kg, with lean body mass of 75 kg. VO_{2max} values should reach 5.4 $lmin^{-1}$ with power output at the ventilatory threshold of approximately 300 Watts.

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ANTROPOMETRIJSKI I FIZIOLOŠKI PROFIL VESLAČA RAZLIČITE DOBI I KVALITATIVNE RAZINE

Sažetak

Uvod

Nizom istraživanja utvrđeno je da su vrhunski veslači visoki, teški i muskulozni sportaši s visokim udjelom sporih mišićnih vlakana u strukturi mišićnog tkiva. Pobjednici međunarodnih regata tjelesnom visinom prelaze 190 cm, a tjelesnom težinom 90 kg. Fiziološki pokazatelji ukazuju na impresivne vrijednosti aerobnoga kapaciteta u međunarodno uspješnih veslača: maksimalni primitak kisika često prelazi vrijednost od 6,0 L/min, a može dosegnuti i prelaziti 6,5 L/min s maksimalnim vrijednostima ventilacije od 240 L/min. Dosadašnje studije uspoređivale su veslače različite dobne kategorije kao i različite kvalitativne razine, međutim, usporedbe su se uglavnom provodile korištenjem literaturnih podataka.. Pod pretpostavkom da se veslači različitih dobnih kategorija i različitih kvalitativnih razina razlikuju po razinama antropometrijskih i fizioloških karakteristika, ovoj je studij bio cilj: (a) odrediti antropometrijske i fiziološke karakteristike elitnih juniora, seniora međunarodnog ranga te elitnih seniora; (b) utvrditi i objasniti razlike između promatranih grupa veslača i (c) usporediti rezultate s dostupnim podacima iz literature.

Metode rada

Uzorak ispitanika sastojao se od 53 veslača, državna prvaka i člana hrvatske veslačke reprezentacije u periodu između 2000. i 2006. godine. Svaki veslač svrstan je u jednu od tri skupine s obzirom na dob, odnosno postignute međunarodne uspjehe: grupa elitnih juniora (N=18; dob 17,6±0,4; staž 5,6±1,5 godina), grupa seniora međunarodnog ranga (N=21; dob 22,16±2,8; staž 8,4±3,3 godina) i grupa elitnih seniora (N=14; dob 28,1±3,0; staž 14,±3,1 godina). Prema uputama Međunarodnog biološkog programa (Weiner & Lourie, 1969) izmjereno je 19 antropometrijskih varijabla te tri spirometrijske varijable. Pri progresivnom maksimalnom testu opterećenja na veslačkom ergometru izmjereno je 10 fizioloških varijabla. Razlike između grupa ispitanika u pojedinim varijablama utvrđivale su se univarijatnom analizom varijance. Značajnima se smatrala razlika na razini od $p<0.05$.

Rezultati i rasprava

Rezultati su pokazali da kada se promatraju u odnosu na kvalitetno slabije seniore (seniore međunarodnog ranga), elitni seniori su viši (+ 5,.4 cm) i teži (+ 4,.3 kg), s većim vrijednostima longitudinalnih dimenzija skeleta. Juniori, antropometrijski slični seniorima međunarodnog ranga, su pored toga lakši i s manjim vrijednostima opsega i nižom razinom tjelesne masti. Slično, elitni juniori su niži i lakši od elitnih seniora, sa ne samo manje tjelesne masti nego i s manjim vrijednostima opsega i longitudinalnih dimenzija skeleta. Ova saznanja su u skladu s podacima drugih istraživača koja upućuju da veslači više kvalitetne razine imaju i veće vrijednosti longitudinalnih dimenzija skeleta. S druge strane, u transverzalnim dimenzijama skeleta, kao i u spirometrijskim pokazateljima nisu zabilježene razlike između tri promatrane grupe. Količina bezmasne tjelesne mase najveća je kod elitnih seniora. U prilog objašnjenja te činjenice idu i studije kojima je cilj bio odrediti najbolje prediktore rezultata veslačkih natjecanja (Ingham i sur., 2002; Riechman i sur., 2002), a u kojima je upravo količina bezmasne tjelesne mase postigla najveću korelaciju s natjecateljskim rezultatom kao kriterijem kada se promatraju antropometrijske varijable.

Kod elitnih seniora u usporedbi sa seniorima niže kvalitetne razine veći su: maksimalni primitak kisika (VO_2max; + 0,54 L/min), snaga zaveslaja pri anaerobnom pragu (P_{AT}; + 31,8 W) i primitak kisika pri anaerobnom pragu (VO_{2AT}; + 0,39 L/min). I u usporedbi sa juniorima, elitni seniori dominiraju u VO_2max (+ 0,30 L/min), P_{AT} (+ 53,7 W) i VO_{2AT} (+ 0,36 L/min). Prosječna razina VO_2max pojedine posade i njezin plasman na međunarodnim natjecanjima pokazali su direktnu povezanost (Secher i sur., 1982; Secher, 1983; Secher, 2000). Tu spoznaju možemo u ovom istraživanju primijeniti na objašnjenje razlika između seniorskih veslača različite kvalitetne razine. Steinacker (1993) navodi da je snaga zaveslaja pri anaerobnom pragu najbolji prediktor uspješnosti veslača. Elitni hrvatski seniori održavaju višu razinu snage zaveslaja pri anaerobnom pragu u odnosu na manje uspješne seniore (+ 31,8 W) te se čini da ta razlika u značajnoj mjeri objašnjava razlike u razini uspješnosti na veslačkim natjecanjima.

Zaključno, manje uspješni hrvatski veslači trebali bi u idućem razdoblju biti usredotočeni na povećanje maksimalnog primitka kisika te također na povećanje snage zaveslaja, kao i primitka kisika pri anaerobnom pragu. Profili (modeli) elitnih veslača, juniora i seniora, mogu se koristiti za identifikaciju talenata i za selekciju veslača. Kako su specifični podaci o antropološkim obilježjima relevantnima za veslačku natjecateljsku uspješnost prikupljeni na uzorcima elitnih juniora i seniora, u mogućnosti smo formirati model elitnog veslača koji se sastoji od kvantificiranih relevantnih karakteristika. Pod pretpostavkom da smo u mogućnosti predvidjeti rast i razvoj mladog sportaša, modelne vrijednosti mogu pomoći u selekciji i identifikaciji talenata. Prema rezultatima ove studije, poželjno bi bilo da senior bude visok najmanje 190 cm i težak 95 kg (od toga minimalno 80 kg bezmasne tjelesne mase) da bi mogao očekivati vrhunski rezultat na međunarodnim natjecanjima. U pogledu fizioloških kara-

kteristika, poželjna razina VO_2max u pripremnom periodu iznosi približno 5,7 L/min, sa snagom zaveslaja pri anaerobnom pragu od približno 350 W. Za veslače juniore, tjelesna masa mora iznositi minimalno 85 kg s udjelom bezmasne tjelesne mase od 75 kg. Vrijednosti VO_2max bi trebale dosegnuti 5,4 L/min sa snagom zaveslaja pri anaerobnom pragu od približno 300 W.

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