UNIVERSITY OF PÉCS

FACULTY OF HEALTH SCIENCES

DOCTORAL SCHOOL OF HEALTH SCIENCES

Head of Doctoral School: Prof. Dr. József Bódis, MD., PhD., DSc.

Leader of the program: Prof. Dr. Erzsébet Rétsági

Associate program leader of the program: Prof. Dr. Pongrác Ács

Supervisor: Prof. Dr. Ferenc Ihász

Anthropometrical, physiological and psychological characteristics among competitive rowers

Doctoral (Ph.D.) Thesis booklet

Zoltán Alföldi

Introduction

The importance of sport selection is indisputable. However, the focus is on the extent to which early specialization is necessary (allowed) and the extent and quality of general training. In addition to sport selection, however, there are general indicators whose measurement should be a fundamental requirement. These include conformation, motor learning traits, circulatory and respiratory system characteristics, the quality of physiological and psychological adaptation to exertion, motivation and social relationships.

Several prediction models predicted expected performance using anthropometric variables alone (height, sitting height, arm span) (r=0.82) and aerobic capacity (VO2max), which (r=0.93) showed a significant relationship with performance (Russel, le Rossignol & Sparow, 1998). Successful selection for rowing is a highly complex process. Its complexity is due, on the one hand, to the fact that the success of the task is influenced by the optimal use of a device and, on the other hand, by the fact that this activity must be performed in a sitting position (Mäestu, Jürimäe & Jürimäe, 2005).

For tool use, appropriate physiological traits and for extreme work in the seated position, an excellent oxygen delivery system is required, especially with regard to quality venous return and, thus, to enhance cardiovascular function. Thus, measurements of the metabolic and circulatory systems, as well as of the effort, show that training should simulate rowing in a boat as much as possible (Secher, 1983). This fact is confirmed by the work of Amy L. Woods and colleagues (Woods et. al., 2017), where they identify rowing as a unique challenge by pushing human capabilities to extreme limits.

This study aims to analyze the constitutional and circulatory characteristics that may qualify the selection of successful rowing trainees. Favorable anthropometric profiles, such as body height (BH), sitting height (SH), and arm spam (AS), should be considered as important criteria for sport selection.

Hypothesis

H1 We assume that the anthropometric characteristics are indeed dominant elements of the sport selection process.

H2 It is hypothesized that the estimated relative maximal aerobic capacity (e.r. VO2max) is the strongest predictor of rowing performance.

H3 It is assumed that strong relationship is obtainable between estimated relative maximal aerobic capacity (e.r. VO2max) and calculated relative power output (rW×kg-1).

H4 Psychological profile contributes significantly to better rowing performance.

Materials and methods

Two hundred and forty-five (n= 245), (n= 101); (17.24±1.38), female and (n= 144); (18.22±1.33), male of age were recruited from 16 rowing clubs in 10 Hungarian cities. In the study, sample selection was done to ensure that all subjects had an equal chance of being included in the sample. The requirements of the Declaration of Helsinki on Voluntariness and Parental Consent, as well as the willingness of the associations to cooperate, were taken into account and were met in all the required details. The minimum requirement for inclusion was the completion of planned, general and sport-specific exercises (at least three times a week, for at least 50 minutes, at 80-90% of maximum performance, outside compulsory PE lessons). Three age groups were created based on the considerations of Baxter-Jones A. et al. (Baxter-Jones & Mirwald, 2004)

Participants and data collection

The subjects of the cross-sectional studies presented in the following were groups of rowers from Hungarian rowing clubs of different sizes. The participants had a valid competition license and valid medical certificates, participated regularly in trainings and in national and/or international competitions. Furthermore, they did not limit their physical activity levels to the extent that could significantly affect their motor fitness. Data collection was conducted at several Hungarian rowing events 2020 in the Hungarian National Rowing Championships, the Hungarian National Rowing Ergometer Championships.

Anthropometric measurements and body composition estimations

For the anthropometric measurements Sieber-Hegner measuring instruments were used. Body height was measured with a calibrated Soehlne Electronic Height Rod 5003 (Soehlne Professional, Germany) according to standardized guidelines. Body mass (measured to the nearest 0.1 kg), BMI and body composition characteristics, such as body fat percentage (BFP) and skeletal muscle mass (SMM), were determined by bioelectrical impedance with an InBody 720 body composition analyzer. The remaining anthropometric characteristics, such as sitting height [cm], arm span [cm], limb length [cm] were measured with the use of the Weiner and Lourie methods (Weiner & Lourie, 1969) and the calculation of BSA [m^2] was conducted with the use of Mosteller's formula (Mosteller, 1987). Skin fold measurements (biceps, triceps, scapula, suprailiac, abdomen, thigh, lower leg) were obtained using a Harpenden cailiper.

Relative body fat content was calculated using the estimation by Pařízková (Pařízková, 1961).

Physiological measurements

The 2000 m rowing ergometer tests and different distances (3x100m, 60 sec, 500m, 2000m and 6000 m) were performed on certified rowing ergometer (Concept 2 D-model) and the power output in watts (W) was measured. The calculation of watts was performed as follows: First, the distance was defined: distance = (time / number of strokes) × 500. In the next step, the concept of a "split" was clarified: split = 500 × (time / distance). The watts were calculated as $2.8 / (split / 500)^3$. The estimated relative aerobic capacity (ErVO2) was calculated by using the formula of McArdle et al. (2006) for men: ErVO2 = (Y × 1000) / BM, where BM is body mass, and Y = [BM <75kg; 15.1- (1.5 × time)]; BM => 75kg; 15.7- (1.5 × time)]. The power delivered over 2000 meters was divided by body weight to obtain the relative performance (rW2k).

The power output of the lower extremities and the height attained by the center of body mass during vertical jumps were measured with a PJS-4P60S force plate ("JBA" Zb. Staniak, Poland) with a 400 Hz sampling rate (Batra et al., 2021; Gajewski et al., 2018). The force plate was connected via an analog-to-digital converter to a PC with the MVJ v.3.4 software ("JBA" Zb. Staniak, Poland). The amplifier was connected to a PC via an A/D converter. For measurement, the MVJ v. 3.4. software package ("JBA" Zb. Staniak, Poland) was used.

Psychological tests

Sport Competition Anxiety Test (SCAT) is a scale with 10 items specific to sport competition, which has adequate test-retest reliability and good internal consistency (Martens, Vealey & Burton, 1990).

Competitive State Anxiety Inventory-2 (CSAI-2) is a multidimensional state anxiety measure. The 27-item scale designed to measure cognitive and somatic state anxiety as well as self-confidence.

Athletic Coping Skills Inventory-28 (ACSI-28) contains seven sport-specific subscales. The scales can be summed to yield a score, which is assumed to reflect a multifaceted psychological skills construct.

Trait Sport Confidence Inventory (TSCI) consists of 13 items with no subscale components, utilizing a 9-point Likert scale anchored by 1 (low) and 9 (high) to assess how confident athletes generally feel when they compete in sport.

Statistical analysis

Measurements were statistically processed with Statistica PL, v. 13.5. Normality was verified with the Shapiro-Wilk test. It was checked that all tested features have normal distributions. Therefore, for comparisons of two arithmetic means, Student's *t*-test was used. To compare three arithmetic means, one-way analysis of variance (ANOVA) was used. If ANOVA indicated a significant difference, Tukey's Honestly Significant Difference (HSD) test was used for post-hoc analysis. Cohen's d was used as a measure of the effect size of differences between male and female rowers and interpreted according to modified thresholds (for sports sciences as trivial (0.2), small (0.21–0.6), moderate (0.61–1.2), large (1.2–1.99), and very large (<2.0). Statistical significance was set at $p \leq 0.05$. Additionally, the value of the Szopa dimorphism index was calculated.

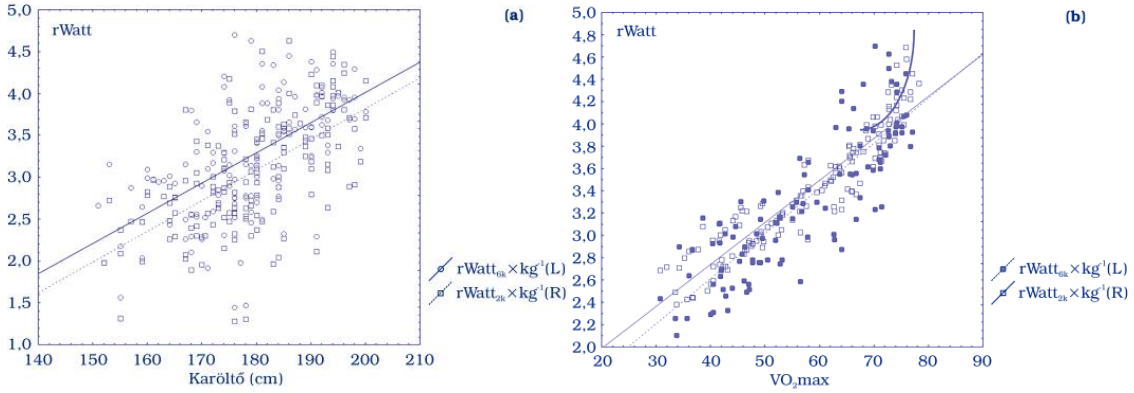
Results

Anthropometric and physiological characteristics based on age groups and gender

The difference in mean height (BH) between age groups BH (group I) =166.87±7.73-TM (group II) =171.27±5.68; ($p<0.05$) is significant in the female group. There was no real difference between the means of body mass (BM), body mass index (BMI) and body surface area (BSA). The means of the means of the arm spam (AS) are significant between groups one and three AS (group I)=167.13±9.50-AS. (GroupIII.)=173.42±4.62; ($p<0.05$), while for sitting height (SH), a real difference was found between groups one and two S(group I)=86.52±3.51-S(group II)=89.23±4.73, ($p<0.05$). Estimated relative aerobic capacity (e.r.VO_{2max}) was significantly different in all age groups. Differences in means between age groups are Group I-Group II ~5; Group II- Group III ~9 ($ml \times kg^{-1} \times min^{-1}$). Power per body weight (rWatt) for all six and two- kilometer rowing ergometer tasks showed a true difference between groups one and three and between groups two and three. As for the results of the same characteristics of the boys by age group, their differences, measured (BH, BM, AS, SH) and calculated (BMI, BSA), are real differences in all cases between groups one and two and between groups one and three. The difference between the means of the estimated relative aerobic capacity (e.r.VO_{2max}) is significant between groups one and two and between groups one and three ~9 ($ml \times kg^{-1} \times min^{-1}$). The power per body mass (rWatt) does not show a real difference between groups one and two and between groups one and two and between groups two and three for the six-kilometer rowing ergometer exercise, but does show a real difference for the two-kilometer distance. As for the comparison between sexes, there the difference between the means of the aerobic

capacities estimated at the peak of the exercise (e.r.VO2max), is almost double for 16 year olds, in favor of male; Group I female e.r.VO2max =37.54±9.27; Group I male e.r.VO2max =60.43±6.91 (ml×kg^{-1} ×min^{-1}); (p<0.000)

Figures 1.a/b Relationship of arm spam (AS) and estimated relative aerobic capacity (e.r.VO2max) to power output in the six-kilometer (rWatt 6k ×kg -1) and two-kilometer (rWatt 2k ×kg -1) rowing ergometer trials (unisex sample)



Legend: The horizontal axis (xj) in figure (a) is the arm spam (AS), (140-210cm) in figure (b) the horizontal axis (xb) [(0-90); (ml×kg -1 ×min -1)] is the relative aerobic capacity (e.r.VO2max) with power, on the left (yb) axis rWatt 6k×kg -1 , on the right (yj) axis rWatt 2k ×kg -1 [arm spam (cm): rWatt 6k ×kg -1 : r=0,5831; (p=0,0000)]; [arm spam (cm): rWatt 2k ×kg -1 : r=0,6012; (p=0,0000) [e.r.VO2max : rWatt 6k ×kg-1 : r=0,8531; p=0,0000; e.r.VO2max : rWatt 2k ×kg -1 : r=0,9306; p=0,0000]

In the full sample, the relationship between the two variables (arm spam and the two ergometric performances) is significant. The point set displaying the results shows a significant scatter between the two trend lines (**Figure 1/a**). The two trend lines run parallel to each other, equidistant from each other. The cointegration of the two averages (r6k =0.5831, (p=0.000); r2k=0.6012, (p=0.000), is rather moderate. The calculated common variance is only 35% which is not statistically or human-biologically significant.

Figure (**1/b**) shows the relationship between aerobic capacity and the performances of the two tests. The two trend lines run parallel, with a significant slope, with the same distance up to 40 (ml×kg-1×min-1) and then a steadily decreasing distance up to 70 (ml×kg^{-1} ×min^{-1}). From the 70-80 (ml×kg^{-1} ×min^{-1}) point, they continue to overlap. From the middle to the last third of the trendline, the points are located below the trendline rather than above it. Between 70 and 80 (ml×kg^{-1} ×min^{-1}) the points deviate from the linear and continue to increase almost exponentially, without exception above the trend line. The cointegration of the two means [(r6k =0.8531, (p=0.000); r2k =0.9306, (p=0.000)] is significant. The calculated joint variance is significant only for human biological content of ~80%.

Anthropometric and physiological characteristics male rowers

The anthropometric characteristics, body composition, motor performance and physiological characteristics of the male rowers in the following age categories: juniors (15-16 years), older juniors (17-18 years) and seniors (18-22 years). Senior and older junior rowers were significantly larger than junior rowers in terms of height and body mass (height: +6.25 and 4.32 cm, respectively; body mass: 14.32 and 6.88 kg. Seniors were also significantly heavier than older juniors (+7.44 kg; p =.011). Regarding BFP, seniors had a significantly higher value than juniors and older juniors (+4.28 and +3.83%, respectively; p = .006 and p = .014, respectively). FFM did not differ significantly between these groups. Although older groups had significantly higher BMI than younger groups, the values of all groups were within the norms (20.8 - 23.72 kg/m^2). Sitting height and arm span were significantly less in the youngest group than in the other two groups (for both comparisons, p < .001), but these measurements did not differ significantly between the older juniors and the seniors. Body surface area was also significantly larger in older groups than in younger groups (p-values ranged from p = .017 to p <.001), but the groups did not differ significantly in terms of limb length, skin fold thickness and body fat estimated by Pařízková`s formula. The seniors covered the 2000 m distance in a significantly shorter time than the older juniors and juniors (respective differences: 0.31 min and 0.95 min; p = .019 and p < .001), and older juniors covered this distance 0.64 min faster than juniors (p <.001). The peak power that was generated also differed significantly between these groups: seniors generated 45.4 W more than older juniors and 121.7 W more than juniors (p = .002 and p < .001, respectively); older juniors surpassed juniors by 76.3 W (p <.001). Senior and older junior rowers also had significantly higher maximal oxygen uptake than juniors (by 6.2 and 7.0 ml/kg/min; p = .002 and p < .001, respectively) and force max (by 263.4 and 169.8 N; p < .001 and p = .009, respectively). In terms of jump height, speed max and relative peak power (RPM), seniors and older juniors did not differ significantly, but these values were significantly lower in the juniors than in the older juniors (by 4.57 cm, 0.15 m/s, 3.98 W/kg; p < .001, p = .003 and p = .006, respectively).

Psychological and physiological aspects

Only the CSAI-self-confidence showed a statistically significant difference between genders as boys having higher score. Overall, SCAT (anxiety) scores were low in the sample, the vast majority (12) with normal anxiety and 3 with high anxiety. ACSI (coping capacity) scores were relatively high, averaging 71% of the total score (SD = 9.1%). CSAI Cognitive Anxiety and Somatic Anxiety scores indicated rather higher than moderate levels of anxiety, averaging

64.3% (SD = 16.6%) of the total score for cognitive anxiety and 64.8% (SD = 15%) for somatic anxiety. The CSAI self-efficacy score indicates greater than medium self-efficacy, with 68% (SD = 16.7%) of the total score. Sport self-confidence scores were relatively high across the sample, with the vast majority, 13 participants, showing high self-confidence and 2 participants showing medium self-confidence.

One of the criteria for regression models is multicollinearity, i.e. no correlation between independent variables above 0.5-0.7. Since arm span and watt (0.760); watt and ErVO2max (0.815); arm span and ErVO2max (0.595) do not meet the regression fit conditions, the solution was to choose the estimated aerobic capacity ErVO2max. The non- determistic is related to the dependent variable, so the solution may be to treat males and females together. In this scheme, the conditions are met: the model is significant ($F(4,10) = 8.831$, $p = 0.003$. Model power and prediction: 77.9% ($R^2 = 0.779$, $R^2ajd = 0.691$). Age is significant ($t(11) = -2.382$, $p = 0.007$). One-unit increase in age reduces time by -14.491. Gender×rVO2max is significant ($t(11) = 5.495$, $p < 0.001$).

Some independent variables, measuring very similar constructs, should be omitted from the model. Based on this consideration: Individual factors of CSAI are unsurprisingly correlated: cognitive anxiety - somatic anxiety: 0.805; cognitive anxiety - self-consciousness: -0.821; somatic anxiety - self-consciousness: -0.877. CSAI self-confidence and TSCI: 0.549, no relationship with other CSAIs. No relationship between ACSI and CSAI, no relationship between SCAT and TSCI.

Based on the above, it is recommended to include the following variables in the analysis: ACSI (coping capacity), CSAI cognitive anxiety, SCAT (~somatic anxiety), TSCI (~self-confidence), age and gender.

In this model, the conditions are met:

Model is significant ($F(5,9) = 11.912$, $p = 0.001$. Model power and prediction: 86.9% ($R2 = 0.869$, $R2ajd = 0.796$). SCAT is significant ($t(10) = -2.961$, $p = 0.016$). One unit shift in SCAT reduces time by -6.227. Of the two significant independent variables, non×cognitive anxiety has greater explanatory power: ($B = 0.883$; SCAT: $B = 0.389$).

Conclusions

Modern Olympic and Professional sport is characterized by result orientation. This is due to the laws of the market such as contest for sponsorships and wide public appearance provided by the media (Johnston et al., 2018). Thus, talent identification at young ages is becoming an

increasingly urgent issue for national sport federations and club teams. Talent identification programs facilitate to involve young people in training work earlier (Johnston et al., 2018; Vaeyens et al., 2008). Theoretical researchers have already developed several selection methods, however, there are many studies which question the accuracy and applicability of these models and programs (Rongen et al., 2018; Till & Baker, 2020; Žvan & Čoh, 2018). Different sports demand different physiques and cognitive skills and abilities (Liu et al., 2021). The unique requirements of each sport claim for sport-specific instead of general talent identification models (Vaeyens et al., 2008). The identification of those specific characteristics which are beneficial in a given sport is needed to establish an appropriate selection models. Similar procedures have been established for coaches' team sports (Liu et al., 2021). As the selection is a long, difficult and extremely complex process, it includes many possibilities for error and it can be inaccurate (Johnston & Baker, 2020).

As for rowing, many examinations (investigating anthropometric, physiological and psychological parameters) have already been conducted among rowers from several nations searching those factors that influences rowing performance the most significantly and later should be kept in mind in the process of selection for this sport. Based on various principles, different selection models for rowing have already been created (e. g. Liu et al., 2021; Nurjaya, Abdullah, & Ma'munRusdiana, 2020). However, Hungarian rowers have not been subjected to such measurements and coaches did not applied talent identification programs so far. Based on these consideration, this doctoral dissertation aims to contribute to the improvement of Hungarian rowing both in national and international level.

Anthropometric and physiological parameters compared by age groups and their effect on rowing performance

245 rowers, 101 females (17.24 ± 1.38 years old) and 144 males (18.22 ± 1.33 years old) from 16 rowing clubs in 10 Hungarian cities were included in these examinations. 3 groups were formed according to age, namely the first group consist of 15-16 year olds, the second includes 17-18 year olds and the third 19-22 year olds.

H1 is True, our study found a relationship between anthropometric variables (height, sitting height, arm span) and performance.

Connection was found between the anthropometric variables (body mass, sitting height and arm span) and performance. Regarding the females' 3 groups most importantly the significantly greater values of sitting height and arm span showed parallelly increasing performance. Former investigations also came to this conclusion (Akça, 2014; Barrett & Manning, 2004; Mikulić,

2009; Mikulić & Ružić, 2008). The anthropometric characteristics of males are almost the same in the second and the third groups coupled with similar performance. There is no real difference between the means of body mass, nutrition index and body surface area in the whole sample. Formerly, some similar examinations indicated lean body mass as the most important anthropometric characteristic influencing performance (Cosgrove et al., 1999; Yoshiga et al., 2000). Among females the estimated relative aerobic capacity (e.r.VO2max) showed an ever greater significant increase in all age groups. Among males – in agreement with the anthropometric variables – the mean values of the second and third groups are almost the same, and increase can be observed only compared to the first group's mean values.

H2 is True: our regression analyses suggest that cardiorespiratory characteristics are stronger predictors than anthropometric variables.

Based our regression analyses the cardiorespiratory characteristics are better predictors than anthropometric variables. Consistently with previous studies (Cosgrove et al., 1999; Kendall et al., 2011; Mikulić & Ružić, 2008), estimated relative aerobic capacity is proved to be stronger predictor than performance referred to body mass. Close relationship was observed between performance per body mass (rWatt) and estimated relative aerobic capacity (e.r.VO2max). Former investigations drew similar conclusions (Cosgrove et al., 1999; Mikulić, 2009; Mikulić & Ružić, 2008; Yoshiga et al., 2000).

H3 partially True: power per body mass (rWatt) showed a medium correlation with estimated relative aerobic capacity (e.r.VO2max) in our sample.

In the 2000m rowing ergometer time trial the significantly greater estimated relative aerobic capacity observed in the whole sample means a significantly increasing performance per body mass (rWatt), except for the difference in performance of the females' first and second groups. Researchers have pointed out that maximal aerobic performance (in Watt) is an important predictor for the time result of the 2000m tests (Ingham et al., 2002; Jürimäe et al., 2000; Riechman et al., 2002; Womack et al., 1996). According to their opinion, it is essential to pay enough attention to include the anthropometric characteristics we examined in the process of future competitors' selection. All the more that cardiorespiratory system (which have significant relationship with performance and thus with success) of children with optimal attributes can be developed with appropriate training work.

The predictive value of the variables examined in our studies should be considered as important supplement among the purpose of talent identification for rowing. If the relations between body height, body mass, arm span and performance are taken into account, it is logical to use these variables in the early stages of talent identification.

In rowing, the results of the presented studies can be utilized in the latter part of the talent identification process as matured movement technique and athletic experience are required to perform the tests used for our examinations. Close relationship was observed between some anthropometric and physiological variables and performance. Consequently, the physical effects of these indicators should not be underestimated.

The role of psychological profile

Talent identification programs often ignore the role of psychological factors. However, these are important performance-influencing parameters, thus greater emphasis should be placed on them in the development of talent identification programs (Johnston et al., 2018; Macnamara, Button & Collins, 2010).

H4 partially True: the psychological profile does not contribute significantly, but has an effect on ergometer times.

If an athlete does not have adequate mental skills, it may happen that can not perform well in a decisive situation due to competitive anxiety (Peng & Zhang, 2021). Studies have already identified several psychological variables needed to reach success, which distinguishes successful athletes from their less prosperous opponents (e. g. determination, short- and long-term goals, focus, dedication, mental preparedness, self-confidence, motivation etc.) (Durand-Bush & Salmela, 2002; Gould, Dieffenbach & Moffett, 2002; Orlick & Partington, 1988).

Based on these considerations I find it essential to examine psychological factors in addition to anthropometric, cardiorespiratory and motoric characteristics. In terms of self- confidence, males reached significantly higher scores compared to females. Scores in case of SCAT tests show normal level of anxiety in our sample. With the increase of anxiety, the performance worsens, in agreement with results of former studies (Weinberg & Genuchi, 1980). In spite of the above mentioned results, in my opinion it is essential to conduct multidimensional examinations, which investigate both physical and psychological parameters, however, the overall conclusion can be drawn, that without adequate physical aptitude, a beneficial psychological profile is not sufficient to reach outstanding results in rowing.

Summary of the parameters suggested to be used in the process of selection

The studies presented in Chapter 4, 5, 6, 7 and 8 provides useful information that should be utilized for the selection of Hungarian rowers. This is all the truer, as no similar talent identification program has been developed so far.

This doctoral dissertation contributes to the existing literature in a novel way as it provides

information of the anthropometric and physiological characteristics of rather younger Hungarian athletes with ambitions to become successful rowers in the future. This is the first attempt to capture differences in the anthropometric and physiological characteristics of intermediate level rowers. According to my opinion this fact is the clear strength of this study, since the number of non-elite athletes exceeds substantially the fairly small group of champions. This approach contributes to the novelty of this dissertation, however, it is difficult to compare the results of the present study with former examinations, because the number of investigations that include intermediate level athletes is quite limited. The conclusions of this dissertation can be considered decisive with great certainty, as the size of the sample is relatively great than in similar studies (Klusiewicz et al., 2014; Mikulić, 2008).

To sum up, from the investigations included in this dissertation it can be concluded, that anthropometric characteristics should be examined in the early stage of talent identification for rowing, since unlike these attributes, the cardiorespiratory system of a young talented athlete with adequate physiological characteristics can be developed with appropriate training work. Great emphasis should be placed on different skills and needs of the athletes in different ages and genders while the training plans are being made

Summary of novel findings

The novelty of the research is that such a large sample study has not yet been carried out in this target group in Hungary.

1. Our study found a relationship between anthropometric characteristics (height, sitting height, arm span) and performance in the Hungarian sample.

2. Our findings suggest that cardiorespiratory characteristics are stronger predictors than anthropometric variables.

3. Based on our study the cardiorespiratory characteristics are more reliable predictors than anthropometric characteristics.

4. The psychological profile does not contribute significantly to better performance, but has an effect on ergometer times.

Limitations and future directions

Numerous investigations pointed out that current talent identification programs are yet insufficient and run into several problems, their credibility and validity are rather questionable and actually their applicability for predictive purposes is limited (Bailey & Collins, 2013; Till & Baker, 2020). Researchers invest great efforts to develop the right, eventually useful method

for talent identification.

Cross-sectional studies are often used to collect data, thus in the examinations presented in my doctoral dissertation this methodology was used. The drawback of this method is that athletes who seems to be promising talent at young age, later go through changes during maturation which effect their performance as well and thus not necessarily become successful in senior ages (Malina, 1994). In the future, it would be useful to conduct longitudinal studies on rowers, since researchers pointed out in connection with other sports that in different age categories different characteristics should be used as the indicators of performance (Vaeyens et al., 2008). In addition, the involvement of more variables in the examinations would be useful, as excellence in a sport is not corresponding to a standard set of physical characteristics or skills; it can be achieved in unique ways through different combinations of skills and capabilities. If only some selected factors are examined, then individuals who score low on one specific variable may be deselected from the talent pool (Vaeyens et al., 2008).

Acknowledgements

First of all, I would like to express my sincere gratitude to my supervisor, Prof. Ferenc Ihász, who helped this thesis and related research to be realized. He provided me the opportunity to join his team and he gave access to the laboratory and research facilities. Without his continuous support with professionalism, patience, motivation and knowledge, it would not have been possible to conduct this study.

Besides my supervisor, I would like to thank my academic colleagues, namely László Suszter, Imre Soós, László Kerner, Lili Kósa, Fernanda Forrás, Robert Podstawski, Zsolt Bálint Katona, Tamás Gyömörei, Dávid Veréb and Anna Ott.

I am also grateful to my employer, Oszkár Papp, president of the Győri Athletic Club.

My appreciation also extends to my coach colleagues, Szandra Biró-Lakó, Gábor Nagy, Dávid Forrai, Péter Lacsik, Péter Lacsik jr., Zsuzsa Szabó, Dezső Molnár, Attila Lőrincz, Borbála Pignitzky, Otto Cseh and colleagues at the Hungarian Rowing Federation, University of Pécs and Széchenyi István University.

Last but not least, I would like to thank my family, who supported me zestful and patiently throughout my studies. I must mention my wife, Viola Alföldi and my son, Hunor Alföldi, my mother Tünde Mecseki and my sister Diána Alföldi.

List of publications

PUBLISHED ARTICLES RELATED TO THE THESIS

Alföldi, Zoltán – Katona, Zsolt Bálint – Gyömörei, Tamás [et al.] (2022): Physiological and psychological characteristics among competitive rowers. In: *Stadium,* 5(1):2676.

Alföldi, Zoltán – Katona, Zsolt – Suszter, László [et al.] (2020): Kiválasztási kritériumok vizsgálata utánpótláskorú evezős leányok és fiúk körében=Examination of selection criteria among male and female of junior rowing age. In: *Magyar Sporttudományi Szemle,* 21(6):3-10.

Alföldi, Zoltan – Borysławski, Krzysztof – Ihasz, Ferenc [et al.] (2021): Differences in the Anthropometric and Physiological Profiles of Hungarian Male Rowers of Various Age Categories, Rankings and Career Lengths: Selection Problems. In: *Front Physiol*, 12:747781.

Podstawski, Robert – Borysławski, Krzysztof – Katona, Zsolt Bálint – **Alföldi, Zoltan** [et al.] (2022): Sex Differences in Anthropometric and Physiological Profiles of Hungarian Rowers of Different Ages. In: *Int J Environ Res Public Health,* 19(3):8115.

ARTICLE RELATED TO THE THESIS CURRENTLY UNDER REVIEW

Alföldi, Zoltan – Kósa, Lili – Soós Imre [et al.]: Anthropometric and physiologic characteristics of elite male female junior rowers Revista Brasileira de Medicina do Esporte

ADDITIONAL PUBLISHED ARTICLES "HEALTH SCIENCES"

Podstawski, Robert – Bielec, Grzegorz – **Alföldi, Zoltán** [et al.] (2022): Changes in the Blood Pressure, Heart Rate and Body Mass of Physically Active Menin Response to Thermal Stress. In: *Cent Eur J Sport Sci Med,* 37(1):65-76.

Suszter, L. - Ihász, F. - Szakály, Zs. - Nagy, D. - **Alföldi, Z.** [et al.] (2020): Effect of a five-week beta-alanine supplementation on the performance, cardio- respiratorysystem, and blood lactate level in well-trained rowing athletes: A double-blind randomized pre–post pilot study. In: *JPES,* 20(5):2501-2507.

Nagy, D. - **Alföldi, Z**. - Ihász, F. [et al.] (2020): The effects of a single dose of beta-alanine supplementation on the cardio-respiratory system ofwell-trained rowing athletes. In: *DHS,* 3(4):83-87.

Katona Zsolt - Kerner László - **Alföldi Zoltán** [et al.] (2021): Fizikai aktivitás, nyugalomban töltött idő és jóllét érzés a magyar középiskolások körében a Covid-19 második és harmadik hulláma során elrendelt távoktatási időszakban. In: N. Tóth Ágnes - Koós Ildikó [szerk.]: *Kutatások a COVID-19 pandémia idején*. Szombathely: Savaria University Press, pp. 31-42.

Katona, Zsolt - Takács, Johanna - Kerner, László - **Alföldi, Zoltán** [et al.] (2021): Physical Activity and Screen Time among Hungarian High School Students during the COVID-19 Pandemic Caused Distance Education Period. In: *Int J Environ Res Public Health,* 18(24):13024.

Podstawski, Robert - Żurawik, Marta - Borysławski, Krzysztof - Bukova, Alena - Masanovic, Bojan - **Alföldi, Zoltán** [et al.] (2021): State and status of physical education in tertiary institutions in selected European countries inthe second decade of the 21st century. In: *Acta Gymnica,* 51:e2021.013.

Podstavski, Robert – Finn, K. J. - Cain, C. T. Clark – Ihasz, Ferenc – **Alfödi, Zoltan** [et al.] (2021): The Intensities of Various Forms of Physical Activity in Physical Education Programs Offered by Universities for Male University Students. In: *Acta Kinesiologica,* 15(1):42-51.

Michalis, M. - Finn, K. J. - Podstawski, R. - Gabnai, S. - Koller, Á. - Cziráki, A - Szántó, M. - **Alföldi, Z.** [et al.] (2020): Differences in cardiorespiratory responses of young and senior male endurance athletes tomaximal graded exercise test. In: *Physiol Int,* 107(3)444-454.

ABSTRACTS RELATED TO THE THESIS

Alföldi Z. - Soós I. - Katona Zs. [et al.] (2020): Magyar evezős utánpótlás válogatott sportolók antopometriai és teljesítményélettani vizsgálata [előadás]. *X. Tudományos Fórum,* Pécs. 2020 október 20-21.

Alföldi Z. - Ihász F. (2019): Halmozott fáradtság vizsgálata elit evezős férfiak körében, versenyhelyzetben (Pilot study) [előadás]. *PTE ETK Egészségtudományi Doktori Iskola és az MTA TAB Egészségtudományi Munkabizottság IX. Tudományos fóruma*, Pécs. 2019. november 22.

Alföldi Z. - Bauer R. - Ihász F. (2019): Halmozott fáradtság vizsgálata elit evezős nők körében, versenyhelyzetben (Pilot study). In: *Magyar Sporttudományi Szemle,* 20(5):47.

Katona Zs. - **Alföldi Z.** - Soós I. (2020): Utánpótlás válogatott evezősök antropometriai és evezésmechanikai jellemzői, versenyhelyzetben [előadás]. *X. Tudományos Fórum,* Pécs. 2020. október 20-21.

Alföldi Zoltán - Ihász Ferenc (2020): Utánpótláskorú evezős leányok és fiúk antropometriai és keringési jellemzőinek bemutatása. In: *Magyar Sporttudományi Szemle,* 21(3):33-33.

ADDITIONAL ABSTRACTS "HEALTH SCIENCES"

Boda-Ujlaky Judit - **Alföldi Zoltán** - Ihász Ferenc (2021): Hang alapú visszajelzés a mozgásszervi fejlesztésben és evezésben. In: *IV. Sport és Innováció Nemzetközi Konferencia, SPORTINNO 2021*. Budapest: Testnevelési Egyetem, pp. 143-144.

Bauer R. - Ihász F. - **Alföldi Z.** (2019): 6 hetes felkészülési időszak lokomotorikus és mechanikai terhelésének nyomon követése utánpótláskorú (15 éves) labdarúgók körében Polar Team Pro® rendszerrel. In: M*agyar Sporttudományi Szemle,* 20(5):48-49.

Soós I. - Gyagya A. - **Alföldi Z**. (2020): Fiziológiás jellemzők hatása az eredményességre, labdarúgásban [előadás]. *PTE ETK Egészségtudományi Doktori Iskola és az MTA TAB Egészségtudományi Munkabizottság X. Tudományos Fóruma. MS. TEAMS online platform,* Pécs. 2020. november 20.

Kerner L. - **Alföldi Z**. - Katona Zs. (2020): Az ügyességi terepmotorkerékpározás néhány terhelésélettani érdekessége versenyterheléshatására (Pilot study) [előadás]. *X. Tudományos Fórum*, Pécs. 2020. október 20-21.

Katona, Zsolt - **Alföldi, Zoltán** – Boda-Ujlaky, Judit (2020): Health-conscious behaviour and exercise awareness study in distance physical educationamong secondary school students in West Hungary. In: Csiszár, B. [szerk.]: *IX. Interdiszciplináris Doktorandusz Konferencia 2020. Absztraktkötet: 9th Interdisciplinary Doctoral Conference 2020 Book of Abstracts*. Pécs:

Pécsi Tudományegyetem Doktorandusz Önkormányzat, p. 61.

Katona Zs. - **Alföldi Z.** - Vajnorák M. (2020): Élsportolói mentorprogram a Széchenyi István Egyetemen. In: Katona Zsolt [szerk.]: *Egészség Sport Gazdaság IV. Konferenciakötet*. Győr: Mobilis Közhasznú Nonprofit Kft, pp. 10-23.

Katona, Zs. - Forrás, F. - Kósa, L. - **Alföldi, Z.** [et al.] (2021): Dynamic lower limb power development by core stabilization and interventional strengthexercises. In: *2nd Virtual Conference on Physiotherapy, Physical Rehabilitation & Sports* Medicine. Dubai. April 12-13, p. 23.

Alföldi Z. – Boda-Ujlaky J. - Katona Zs. [et al.] (2020): Egészségtudatos viselkedés és testedzés tudatosság vizsgálat a távolléti testnevelés oktatás során a Nyugat-magyarországi általános- és középiskolás tanulók körében. In: *Magyar Sporttudományi Szemle,* 21(5):13.