The similarity of training experience and morphofunctional traits as prediction criteria of the sports level in subsequent stages of long-term women’s judo training

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Abstract

Background & Study Aim: In every sport in which success is determined by the body type and human physical characteristics, monitoring of morphofunctional traits is an essential element of effective selection of candidates and of management of the training process. However, it has been repeatedly proved that along with longer training experience, especially in combat sports and team games, some athletes achieve excellent results despite the fact that the results of laboratory tests confirm lower values of their morphofunctional indices in comparison to younger athletes. The purpose of the research is knowledge about the possibility of accurate prediction of athletes’ sports level on the basis of their morphofunctional traits in three consecutive stages of women’s long-term judo training.

Material & Methods: Thirty-nine Polish female judo athletes were tested (Group A – comprehensive training stage, n = 14, age 13-15 years, training experience 5.5±1.9 years; group B – directed training stage, n = 14, age 16-18 years, experience 7.2 ± 2.5 years; group C – special training stage, n = 11, age 25.2± 3.7 years, experience 14.2 ± 4 years). The athletes’ sports level was established on the basis of ranking lists of the Polish Judo Association from 2006 and 2007 as well as on coaches’ opinions. Somatic characteristics were based on the measurement of body height and on indices defining its mass and the composition of its components. To evaluate general physical fitness, the Test of Physical Fitness (TPF) was applied, and to evaluate special fitness – Special Judo Fitness Test (SJFT). Aerobic capacity was measured with a test of increasing load until refusal to continue work. Anaerobic capacity was measured with the Wingate Anaerobic Test (30-second version). The analysis of results was based on multivariate statistical methods.

Results: Five clusters (groups) of athletes were distinguished due to similarity of specific morphofunctional traits. The most numerous cluster (n = 13) comprised six athletes from groups A and B each, ranked in identical positions of sports achievement: 5, 9, 11, 12, 13, 14, and only one from group C (ranked 5th in this group). The most homogeneous group (n = 6) comprised 5 seniors from the special training stage (ranking positions in the group 1, 3, 4, 8, 10) and one junior (4th in the ranking). Morphofunctional indices of athletes participating in three different stages of judo training are connected, in a sense discreetly, with their sports level (ranking position in the group). Both leaders of sports performance (within individual groups and generally) and athletes qualified for low ranking positions can be characterised with very similar profiles of body composition, fitness and physical performance.
Conclusions: The results confirm a thesis that it is impossible to accurately predict the future sports performance even on the basis of a number of systematically monitored morphofunctional traits of judo athletes at each stage of training. The applied method allows, however, determining factors which at particular stages of judo training are most strongly associated with efficiency during the most important judo tournaments.

Key words: cluster analysis · ranking of athletic achievement · multiple regression · science of martial arts

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INTRODUCTION

In every sport in which success is determined by the body type and human physical characteristics, monitoring of morphofunctional traits is an essential element of effective selection of candidates and of management of the training process. Awareness of this regularity makes trainers, strategic advisors and scientists attach great importance to athletes’ physical preparation. The type and the level of this preparation is a result of natural development and deliberate shaping and improving motor skills [1, 2]. A training process of people, especially children and youth who dream of a sports career, is preceded by a screening stage, and then selection to a given sport or discipline. It happens that an adept begins training judo and achieves the greatest successes in other sports and vice versa – as, for example, Rafal Kubacki (Poland) – a double world champion in judo in the open category (1993 and 1997), who first successfully competed in swimming.

Sport theorists are trying to determine the impact of particular elements, hence also physical fitness, on the sports result in order to help coaches make decisions concerning the selection of a suitable variant for the sports training process [3]. A dynamic development of sports sciences in the second half of the last century resulted, among others, in determining an optimal model of long-term training [4, 5]. The judo and wrestling training system in Russia is based on a structure developed by Tumanian [6]: stage I – basic preparation (age 9–11 years old), stage II – special preparation (12–15 years old), stage III – deepened special preparation (16–19 years old), stage IV – the highest athletic achievements (over 20 years of age), stage V – stabilization of athletic achievements (up to about 28 years of age), stage VI – gradual retiring from training (>28 years old). In Poland a three-stage system of long-term judo training has been adopted: a comprehensive training stage (14–15 years old), a directed training stage (16–18 years old), and a special training stage (since 19 years old) [7].

One of the most important dilemmas is two questions: 1) is the candidate’s high level of general physical fitness at the beginning of a long-term training period a condition for future achievement of high athletic performance? 2) does the athlete’s level of general physical fitness significantly increase with the development of sports championship?

The profile of physical fitness of Polish children and youth who take up training judo is well documented [8–10]. Results of Kalina’s et al. research [11] provide important empirical evidence that general physical fitness is not highly correlated with the results of test fights based on the sumo formula (in groups of 3 to 5 people) of both children starting judo training and adults enrolled in military training or being candidates for the security profession. The coefficient of determination ($R^2$) of both variables (the sum of points of the Test of Physical Fitness and the percentage of contests won) ranges from 2% to 15%. A modified experiment by Sertić et al. [12] (19–21-year-old male students conducted 5 fights each in a vertical judo posture – tachi waza, while physical fitness was measured with a battery of 15 motor tests) provided empirical evidence that, on average, only 15% of variation of the criterion variables was explained by the influence of motor variables.

In the available literature there is relatively ample information on body composition of adult judokas (men and women) [13–15], their physiological characteristics [16–19], and technical and tactical preparation [20–23]. There is, however, a lack of well-documented empirical data on changes in general physical fitness in the course of long-term judo.
training. However, it has been repeatedly proved that along with longer training experience, especially in combat sports and team games, some athletes achieve excellent results despite the fact that the results of laboratory tests confirm lower values of their morphofunctional indices in comparison to younger athletes.

The purpose of the research is knowledge about the possibility of accurate prediction of athletes' sports level on the basis of their morphofunctional traits in three consecutive stages of women's long-term judo training.

**MATERIAL AND METHODS**

**Participants**

Thirty-nine Polish female judo athletes were tested (Group A – comprehensive training stage, \( n = 14 \), age 15-15 years, training experience 5.5±1.9 years, representatives of the Pomeranian voivodeship; group B – directed training stage, \( n = 14 \), age 16-18 years, experience 7.2 ± 2.5 years, representatives of Poland in the juniors category and representatives of the Pomeranian voivodeship; group C – special training stage, \( n = 11 \), age 25.2± 3.7 years, experience 14.2 ± 4 years, representative of the Polish Olympic team or its direct backup). Particular tests were carried out in 2007, in identical periods of the annual training cycle (this met the criterion of similarity of training means influence on the body). The research was approved by the local Bioethics Committee.

**Methods**

The athletes' sports level was established on the basis of ranking lists of the Polish Judo Association from 2006 and 2007 as well as on coaches' opinions.

Somatic characteristics were based on the measurement of body height and on indices defining its mass and the composition of its components (body fat (\( \text{FAT} \) [kg], \( \text{FAT} \) [%]), fat-free body mass (\( \text{FFM} \) [kg], \( \text{FFM} \) [%]), while water content in the body (\( \text{TBW} \) [kg], \( \text{TBW} \) [%]) was measured with a Tanita Body Composition Analyzer, \( \text{TYP} \) TBF-410 HAS a III. Also BMI was calculated [\( \text{kg/m}^2 \)].

To evaluate general physical fitness, the Test of Physical Fitness (\( \text{TPF} \)) was applied [24], and to evaluate special fitness – Special Judo Fitness Test (\( \text{SJFT} \)) [25].

Aerobic capacity was measured with a test of increasing load until refusal to continue work [26]. Anaerobic capacity was measured with the Wingate Anaerobic Test (\( \text{WAnT} \)), 30-second version of full resistance of the flywheel from the beginning of the effort [27, 28].

The analysis of results was based on multivariate statistical methods using STATISTICA 6.0. But first, basic statistical indicators were calculated: the arithmetic mean (\( \text{M} \)), standard deviation (\( \text{SD} \ ± \)), the correlation coefficient (\( \rho \) (Pearson's)), the level of significance of differences between means (\( \rho \)). For each group of contestants and for each cluster of indices multiple regression was performed. Five clusters of indicators were taken into consideration (cluster 1: age, experience and somatic indices; cluster 2: the level of general physical fitness; cluster 3: the level of special physical fitness; cluster 4: the level of aerobic capacity; cluster 5: the level of anaerobic capacity). The applied multiple regression allowed examining correlations of the distinguished clusters of indicators with the athletes' sports level. The sports level was presented as the contestants' ranking positions in three experimental groups. In addition, cluster analysis was applied according to Ward [29], which enabled evaluation of certain similarities of the features (indices) of contestants from the three examined groups, taking into account their ranking position.

Using Ward's method, the athletes were grouped according to all the clusters of indicators (in the figure and the table, e.g. code 1A means a leader of the group of the youngest athletes, and code C11 an athlete classified in the final ranking position in the group of seniors). Due to editorial limitations, there is no detailed presentation of the study results. We have limited ourselves to the most general results of multivariate statistical analysis.

**RESULTS**

Five clusters (groups) of athletes were distinguished due to similarity of specific morphofunctional traits – the line of identification not greater than 16 (Figure 1). The most numerous cluster (\( n = 13 \)) comprised six athletes from groups A and B each, ranked in identical positions of sports achievement: 5, 9, 11, 12, 13, 14, and only one from group C (ranked 5th in this group) (Table 1). The most homogeneous group (\( n = 6 \)) comprised 5 seniors (group C) from the special training stage (ranking positions in the group 1, 3, 4, 8, 10) and one junior (4th in the ranking – group B). In the cluster comprising 6 people the greatest similarity of characteristics concerns contestants C1 and C3 (linkage below the 6th line of identification – Figure 1), namely the leader among seniors and an athlete classified in the third ranking position.
among them. A contestant with code 10C, namely the last but one in the ranking of achievements among seniors, is characterized by a close linkage of indicators with them (Figure 2-6) (linkage on the 7th line of identification – Figure 1). Among all the surveyed judo athletes, seniors 2C and 6C are characterized by the biggest similarity of indicators (8-person cluster of individuals with similar characteristics) – linkage on the 5th line of identification (Figure 1).

Table 1. Particular clusters of judo athletes (n = 39) most similar to each other in terms of the analysed indicators from three groups (with a distinguished ranking position in the group) eligible for various stages of training: A – comprehensive training stage (n = 14), B – directed training stage (n = 14), C – special training stage (n = 11)

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Figure 1. Designated by Ward’s method dendrogram of judo athletes (n = 39) the most similar to each other in terms of the analysed indicators, classified in particular ranking positions in groups that belong to the subsequent stages of training – colours designate the majority of the cluster of athletes from the given stage the judo training: green A – comprehensive training stage (the youngest athletes); yellow (B) – directed training stage (juniors); red C – special training stage (seniors)
Leaders of all three rankings and most athletes classified in top ranking positions (2 to 4) are grouped in contiguous clusters (sets) of persons in a given stage of judo training: $n = 9$ (majority of the youngest athletes – green colour) and $n = 6$ (majority of the oldest athletes – red colour) (Table 1). The similarity of characteristics of athletes of the two groups, however, is revealed only on the 34th line of identification, while of the other contestants on the 28th line of identification of the analysed indicators (Figure 1).

Morphofunctional indices of athletes participating in three different stages of judo training are connected, in a sense discreetly, with their sports level (ranking position in the group). Both leaders of sports performance (within individual groups and generally) and athletes qualified for low ranking positions can be characterised with very similar profiles of body composition, fitness and physical performance, which is proved by individual profiles of particular athletes (for example, three seniors – Figure 2-6) and generalized correlation results of the distinguished groups of empirical variables with a ranking position of contestants from three different stages of long-term judo training. The greater similarity of the characteristics of leaders (C1) and athletes classified in this group at 3 position in the ranking. The leader (C1) was different from most senior ranked on positions 3 and 10 in terms of special fitness indicators, with the exception of Index IJST (Figure 4). Tenth in the ranking of senior women the most differed from 1 and 3 in the C group in terms of somatic features (Figure 2).

The correlation of age, experience and somatic indices with the ranking position

Only in Group A (comprehensive training stage) with training experience extended by 1 year the ranking position increased by 1.41. The value of the coefficient of determination ($R^2$) amounted to 0.43, which means that 43% of the total variability in this correlation has been explained by the model. The value of the standard error of estimate 3.28.

In Group B (directed training stage) the ranking position increased by 0.78 with an increase in the level of body water (TBW) by 1, and it increased by 1 with the BMI growth by 1. The value of the coefficient of determination 0.51 and the standard error of estimate 3.52.

In Group C (special training stage) the ranking position increased by 2.38 with an increase in the age by 1 year. The value of the coefficient of determination was 0.92, which means that 92% of the total variation of the ranking position variable has been explained by the model. The value of the standard error of estimate 1.29.
The correlation of general physical fitness with the ranking position

In a group of 13-15 year athletes (A – comprehensive training stage) from among 8 indicators of general physical fitness only the test bent arm hang verged on statistical significance. The ranking position in this group of athletes increased by 0.23 with an increase in the results of this test by 1 second. The value of the coefficient of determination 0.61 and the standard error of estimate 2.83.

In Group B (directed training stage) the ranking position increased by 0.36 with an increase in results of the hand grip test by 1 kg and it increased by 0.26 with an increase in results of the bent arm hang test by 1 second. The value of the coefficient
of determination 0.72 and the standard error of estimate 2.81.

In Group C (special training stage), similarly to Group A, only the indicator bent arm hang revealed a correlation on the verge of statistical significance. The ranking position of seniors increased by 0.22 with an increase in results of the bent arm hang test by 1 second. The value of the coefficient of determination 0.61 and the standard error of estimate 2.83.

*The correlation of special fitness with the ranking position*

In group A the ranking position increased by 2.65 with an increase in the number of throws in series B.
decreased by 0.15 with an increase in $VO_{2\text{max}}$.

The correlation of aerobic capacity with the ranking position

In Group A the ranking position increased by 4.73 with an increase in the maximum oxygen uptake ($VO_{2\text{max}}$) by 1. It increased by 0.86 with an increase in the ventilation equivalent of oxygen uptake ($VE\cdot VO_{2}^{-1}$) by 1, while it decreased by 0.59 with an increase in the maximum minute ventilation of the lungs ($VE_{\text{max}}$) by 1. It increased by 0.90 with an increase in the maximum heart rate ($HR_{\text{max}}$) by 1. It rose by 8.29 with increasing the aerobic heart rate ($O_{2}\cdot HR_{\text{max}}$) by 1. It decreased by 0.15 with an increase in $VO_{2\text{max}}$ by 1 and rose by 0.06 with an increase in the volume of exhaled carbon dioxide at maximum power ($VCO_{2\text{max}}$) by 1. In the studied group of athletes the variable critical power ($W_{cr}$) revealed a correlation on the verge of statistical significance. The ranking position increased by 0.66 with $W_{cr}$ growth by 1. The value of the coefficient of determination – 0.99 and the standard error of estimate 0.81.

In Group B the variable maximum oxygen uptake ($VO_{2\text{max}}$) was correlated with the ranking position on the verge of statistical significance. The ranking position in this group of athletes increased by 0.13 with $VO_{2\text{max}}$ growth by 1. The value of the coefficient of determination – 0.76 and the standard error of estimate 2.46.

In Group C, the variable critical power ($W_{cr}$) was located on the verge of statistical significance. The ranking position in this group of athletes increased by 2.58 with $W_{cr}$ growth by 1. The value of the coefficient of determination 0.48 and the standard error of estimate 2.86.

The correlation of anaerobic capacity with the ranking position

In Group A no significant correlations between the tested variables were found.

In Group B the variable time of maintaining maximum power in the Wingate test (TUT) was correlated with the ranking position on the verge of statistical significance. The value of the coefficient of determination 0.64 and the standard error of estimate 3.54.

In Group C the ranking position increased by 0.11 with an increase in total work by 1. The value of the coefficient of determination 0.57 and the standard error of estimate 0.60.

**Discussion**

Zbigniew Czajkowski, a very experienced fencing coach and a scholar, stressed that individual factors affecting performance in competitions vary with age and training experience. Other factors, characteristics and properties determine sports success at the initial stage of training, and other at the championship stage. He showed in his research that the more advanced the training stage, the less importance of general fitness as a basis for directed and special performance, and that the correlation coefficient between comprehensive (general) fitness and sports results significantly decreases with athletes’ age and experience [30]. Kalina’s et al. research [11] proved that the ability to win in very simple close combat is not highly correlated with general fitness. Continuing this concept of research, Sertić et al. [12] verified a hypothesis that performance and final success (victory) in judo vertical posture bouts strongly depends on motor features of the contestants involved. The obtained results indicate that there is a relationship between latent motor variables and both criteria evaluating performance in vertical posture bouts – the number of victories and technical efficacy points.

Our research authenticates these conclusions. Application of multiple regression enabled a more in-depth examination of the correlation between training experience, and above all physical fitness (general and special) and physical capacity (aerobic and anaerobic) with athletes’ ranking positions based on sports achievements. These correlations are highly discrete. Sertić et al. [12] called them “latent motor variables”.

On the one hand, application of cluster analysis in our research enabled identifying athletes with similar morphofunctional characteristics and properties but differing, even extremely, in the ranking position of
athletic achievements. On the other hand, it showed that women with the highest sports successes, regardless of the stage of judo training, are characterized by a certain similarity of morphofunctional properties.

Ryguła [31] showed a high importance of the application of cluster analysis in sports sciences on the example of selection of handball competitors, while Rocznioł [32] demonstrated that multidimensional exploration techniques can be effectively used to assist the process of selection for sports swimming. Also Magiera [33], using multiple regression in research on sport climbing competitors, stressed that the most reliable results can be achieved by specifying predictive values of particular trials and tests from different areas of expertise, and then an optimal set of variables with the highest diagnostic and prognostic value. In our study, the results of multiple regression showed that in the tested judo athletes from among 8 indicators of general physical fitness only tests measuring muscle strength (bent arm hang and hand grip) are significantly correlated with the ranking position. Therefore, the recently published studies on judokas’ hand grip [34-36] must be regarded as an important direction of research.

Sterkowicz et al. [37] conducted research which was to determine whether the weight category, age and training experience, the degree of advancement, and the level of athletic achievement indeed differentiate judo athletes in terms of specific fitness tests. These studies showed, among others, that the total throws of SJFT (a test applied also in our study) significantly correlates with achievements in competitions.

These indicators have proven to be prognostic also in our research. In a group of athletes with the highest sports level the total number of throws performed in SJFT significantly correlated with the ranking position. Also the number of throws in the series B and the heart beat immediately after completion of the test had a significant relationship with the ranking position, but only in the group of the youngest athletes who implemented the comprehensive training stage (group A). In the third set of variables (aerobic capacity indicators), maximum oxygen uptake (in Group A and B) and critical power (in Group C) had the greatest correlation with the sports level. An analysis of the relationship between indicators of anaerobic capacity with the sports level showed that only in the youngest group of athletes there were no important correlations of any specific indicator. This result suggests a conclusion that only long-term judo training creates specific adaptive mechanisms manifested by a relationship of anaerobic capacity with sports achievements (a throw and counterattack requires a dynamic engagement of motor-neurons involved during these operations, similarly to a few seconds’ restraining of the opponent’s moves when fighting the horizontal posture, or ne waza – pinning techniques, strangle techniques, the joint techniques).

We believe that the most important generalization of discussion of our results against the background of the previously published research results of other authors can be narrowed down to three statements:

- it is the most important to determine early a judo adept’s talent for this sport, because the coach has no influence on talent, but he can either develop it (if he is qualified) or ruin the chances to achieve results at the level of the highest international competition (Olympic sport and World Championships) if he makes mistakes regarding long-term planning of training, the content of training sessions, and burdening the body with physical effort;

- it is possible that a person with outstanding aptitude for judo will be simultaneously characterised by unique morphofunctional and mental properties, which authorizes a prediction that he/she would well tolerate specific efforts, be less prone to injuries and more resilient to failure and a destructive impact of successes on the psyche in the long run;

- a person with a talent for judo fight but much more inferior to peers in terms of morphofunctional and mental properties should be provided with individualised training as soon as possible for the sake of his/her motor safety and effort safety.

**Conclusions**

The results confirm a thesis that it is impossible to accurately predict the future sports performance even on the basis of a number of systematically monitored morphofunctional traits of judo athletes at each stage of training. The applied method allows, however, determining factors which at particular stages of judo training are most strongly associated with efficiency during the most important judo tournaments.
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