Factor structure of physical efficiency in female judo competitors at various stages of long-standing training

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B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background: The main aim of the study is to determine a factor structure of the state of systems of energy provision for effort of judo athletes at various stages of long-standing training. In each group four factors determining the structure of the system of energy provision for the athletes' effort were identified, and their most informative indices were determined.

Material/Methods: The paper presents the results of factor analysis of the state of the energy system in three groups of female judo competitors: Polish national team representatives in the group of seniors, Polish national team and Pomerania Province team representatives in the group of juniors (16–18 years old), and Pomerania Province team representatives in the group of sub-juniors (13–15 years old). The anaerobic capacity was assessed using the 30-second Wingate test applied to the subjects' legs. To assess aerobic capacity at laboratory, the test of increasing load up to exhaustion was used.

Results: In each group the factor structure revealed specific characteristic properties. On the one hand, they indicate specific significance of relations between the indices of anaerobic and aerobic provision for the competitors' appropriate sports level. On the other hand, they indicate a greater significance of relative indices of anaerobic efficiency in comparison to their absolute values.

Conclusions: The presented results should be regarded from the perspective of their theoretical significance and from the perspective of practical application in further research connected with the issue of increasing the effectiveness of judo competitors' training process at various stages of long-standing sports training.

Key words: judo • women • energy system • factor analysis

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Background

One of the basic tasks of sports training is to achieve an appropriate level of the development of motor skills as well as the functional capabilities of an organism responsible for providing for the effort in a particular sports discipline. Performing this task takes place as part of physical preparation ensuring the formation of general and specific disposition and its realisation in competition conditions.

It is known that none of the above and other aspects of preparation (technical, tactical, mental) is manifested in an isolated way – they are integrated in a set of properties directed at achieving the best sports results [1,2]. The degree of incorporating various elements in such a set, their relations and cooperation, are determined by regularities of forming functional systems [3] directed at a desired effect of coaching and competitive activity characteristic of a given sports discipline.

It was presumed in this paper that a particular level of physical preparation, as one of significant components of athletes' general preparation, is determined by an appropriate level of development and revealing functional capabilities of an organism, and first of all by the state of

its systems of energy provision for a given physical activity. Therefore, the study of aerobic and anaerobic capability was investigated from the point of view of capacities resulting from determining their interdependence on the assessment of **judo** competitors' sports level at various stages of long-standing training.

Judo, women – an Olympic sports discipline practiced by women.

As it is known, judo belongs to sports disciplines of changeable intensity connected with a necessity to perform short-term but high-powered efforts realised in conditions of anaerobic energy gaining. Still, despite that, judo competitors should also be characterised by appropriate capabilities in the scope of aerobic efficiency ensuring the economy of performing exercises and the effectiveness of the course of regeneration processes after substantial physical loads.

That is why it is fully justified that in order to ensure a high level of physical preparation, as one of the most important factors of the effectiveness of sports training, judo athletes should exhibit an appropriate energetic potential (anaerobic and aerobic one). Indeed, as various studies confirm, highly-qualified judo athletes are characterised by sufficiently high anaerobic and aerobic efficiency indices [4–6]. However, these indices are manifested to a lesser extent in comparison with ones characteristic of representatives of sports disciplines of a strictly anaerobic character (short and medium distance races) or an aerobic one (marathon runs, ski running) [1]. Hence, it can be presumed that among athletes training judo there exists a certain optimal interdependence between the effectiveness of functioning of various **energy systems** taking place in the context of parameters not being maximal for these systems. It can also be presumed that the character of such interdependence is formed in the course of specific training and competition activity in consistence with mechanisms of vegetative formation of the component of motor impulses. This can depend on numerous factors, including also the level of athletes' preparation and their individual capabilities (age, sex, genotype, etc.).

The energy system (in an organism) – is the aggregate (total) of the biochemical mechanisms (anaerobic and anaerobic processes) that results in the recovery of ATP in organism

Factor analysis – a statistical method of result analysis.

One should assume that clarifying specific issues connected with the presented problem will help to form a certain idea regarding judo training and the significance of the state of mechanisms of energy provision for effort characteristic of this sports discipline as an important factor of the effectiveness of training at various stages of long-standing training.

In this respect the main aim of the study is to determine a factor structure of the state of systems of energy provision for effort of judo athletes at various stages of long-standing training.

Material and Methods

The study was carried out in the functional diagnostic laboratory at the Academy of Physical Education and Sport in Gdańsk at the end of the preparatory period (2007).

In order to determine the capability for anaerobic work (with the maximal power: W_{max} and $W_{max} \cdot kg^{-1}$; mean power: W_m and $W_m \cdot kg^{-1}$; overall work: KJ_Σ and $J_\Sigma \cdot kg^{-1}$; time to achieve the maximal power: TUZ; time to maintain maximal power: TUT; and the power decrease index: WSM), competitors performed the Wingate Anaerobic Test (WAnT) for lower limbs in the 30-second version [7]. To calculate mechanical indices computer software MCE v.2.0 was used [8].

To determine the capability for aerobic work, a cycling ergometer test with a gradually increased load until the athlete could no longer maintain the desired power in J. Thoden's version [9] was used. To register the HR the "Polar Sport Tester" was used and for breath indices – "Cosmed" (K4 B-2) exhale gas analyser. While testing, the following were registered: critical work power (W_{cr} and $W_{cr} \cdot kg^{-1}$), lung ventilation (VE), maximal oxygen intake ($V0_{2max}$ and $V0_{2max} \cdot kg^{-1}$), CO_2 volume in exhaled air (VCO_2), ventilatory oxygen equivalent (VE/VO_2), respiratory quotient (RQ), and O_2 pulse (VO_2/HR).

Mathematical and statistical elaboration of data – defining arithmetic means (M), standard deviation (SD), mean differences significance (p), correlation coefficient (r) and a **factor analysis** – was executed by means of computer analytic software "STATISTICA 6.0 PL".

Results

The key moment in the realisation of the main aim of the study was to determine the leading indices of anaerobic and aerobic capabilities of judo competitors.

As follows from the data presented in Table 1, competitors from the studied groups significantly vary among one another in three out of nine indices characterising anaerobic efficiency ($p<0.05$). These are indices of absolute power (mean and maximal) as well as the sum of work (absolute) performed in a 30-second test.

As expected, senior group competitors significantly exceed 16–18-year-old and 13–15-year-old competitors in relative values of the indices (calculated per kg of body mass), mean and maximal power, and the sum of work performed in the anaerobic test.

However, a comparative analysis of values of the mentioned indices in the groups of 16–18-year-old and

Table 1. Indices of anaerobic efficiency of judo competitors in the Wingate test, n=40 (statistically significant differences at p<0.05 with reference to: 1* – the senior group, 2* – the group of 16–18-year-old competitors, 3* – the group of 13–15-year-old competitors).

Groups of competitors	Statistical indices	Indices								
		W_{Avg}	W_{Avg} kg^{-1}	KJ_{Σ}	J_{Σ}·kg^{-1}	W_{max}	W_{max}kg^{-1}	TUZ s	TUT s	WSM W·kg·s^{-1}
Seniors (n=11)	M	477	7.63	14.20	220	589	9.10	4.63	3.20	0.202
	SD	50	0.72	1.60	22	72	0.91	0.60	1.25	0.043
	p	*2*,3**	*2*,3**	*2*,3**	*2*,3**	*2*,3**	*2*,3**	*3**		*2*,3**
Age 16–18 (n=15)	M	408	6.32	12.25	189	498	7.69	5.20	3.46	0.166
	S	66	0.50	1.97	15	85	0.54	1.43	1.43	0.058
	p	*1*,3**	*1**	*1*,3**	*1**	*1*,3**	*1**			*1**
Age13–15 (n=14)	M	354	6.50	10.61	196	431	7.98	5.66	3.82	0.161
	SD	55	0.70	1.64	21	66	0.92	1.15	1.13	0.041
	p	*1*,2**	*1**	*1*,2**	*1**	*1*,2**	*1**	*1**		*1**

Table 2. Indices of aerobic efficiency of judo competitors, n=40 (statistically significant differences at p<0.05 with reference to: 1* – the senior group, 2* – the group of 16–18-year-old competitors, 3* – the group of 13–15-year-old competitors).

Groups of competitors	Statistical indices	Indices									
		VE_{max} *l·min^{-1}*	$VO_{2\,max}$ ml·min^{-1}	$VCO_{2\,max}$ *ml·min^{-1}*	$VO_{2\,max}$ *ml·kg^{-1} ·min^{-1}*	VE/VO_2	VE/VCO_2	RQ	HR_{max} sk·min^{-1}	$O_{2\,pulse}$ *ml*	W_{cr}	W_{cr}·kg^{-1}
Seniors (n=11)	M	103.5	2619	2981	41.0	44.3	41.3	1.20	181.5	15.2	252	3.9
	SD	18.3	311	482	6.4	15.4	7.7	0.17	7.6	2.6	32.5	0.70
	p	*3**	*2*,3**	*3**				*3**	*3**	*2*,3**	*2*,3**	*3**
Age16–18 (n=15)	M	94.7	2312	2603	35.4	48.3	41.3	1.23	182.6	13.1	216	3.8
	SD	19.4	294	405	7.8	12.3	6.1	0.14	8.4	1.6	25.2	0.60
	p	*3**	*1*,3**	*3**		*3**	*3**		*3**	*1*,3**	*1*,3**	*3**
Age13–15 (n=14)	M	74.9	2034	2161	37.8	38.6	36.9	1.11	192.0	10.7	179	3.3
	SD	14.3	260	325	3.1	7.9	3.8	0.14	5.6	1.4	30.8	0.49
	p	*1*,2**	*1*,2**	*1*,2**		*2**	*2**	*1**	*1*,2**	*1*,2**	*1*,2**	*1*,2**

13–15-year-old competitors did not reveal any statistically significant differences between them (p>0.05).

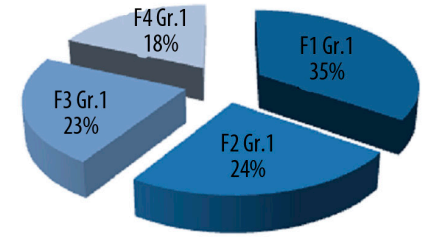
A similar situation took place in the case of mean values of the power decrease index (WSM). Its value in the group of seniors, statistically significantly exceeds the values in the group of 16–18-year-old and 13–15-year-old competitors with a simultaneous lack of such differences between the latter two groups. Likewise, no statistically significant differences were found in indices of maintaining the maximal power between all three groups of competitors.

Indices of achieving the maximal power are significantly higher in competitors from the senior group when compared with the values obtained in the group of 13–15-year-old competitors, yet statistically significant differences with the group of 16–18-year-old competitors were not revealed. This difference proved insignificant between the groups of 13–15-year-old and 16–18-year-old competitors.

Data presented in Table 2 prove that, just like in the case of judo athletes' anaerobic efficiency, in aerobic indices both statistically significant and insignificant differences between specific homonymous indices were found. Special attention should be paid to a distinct difference between all groups of studied competitors in indices of the absolute value of oxygen intake ($VO_{2\,max}$), critical relative power (W_{cr}) and O_2 pulse. However, it stands out that the difference between mean values of the oxygen intake index calculated per kg of the subjects' body mass in all groups proved statistically insignificant.

In the indices of relative critical power (W_{cr}·kg^{-1}) statistically significant differences between competitors of the senior group and 16–18-year-old competitors were not revealed. The group of 13–15-year-old competitors differs in a statistically significant way from the other groups as far as W_{cr}·kg^{-1} is concerned.

Similarly to critical power (W_{cr}·kg^{-1}), no statistically significant differences between the groups of seniors and 16–18-year-old competitors were revealed in reference to mean values of minute ventilation indices (VE_{max}), the volume of maximal exhaled carbon dioxide (VCO_{2max}),



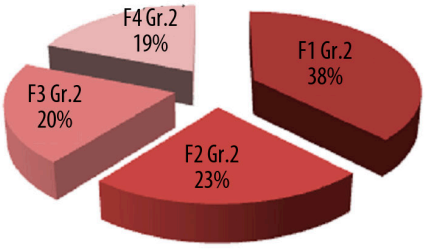
Group of seniors

1 – $\mathbf{F_{1\text{-}se}}$ – factor of anaerobic and aerobic maximal power relative interdependence

2 – $\mathbf{F_{2\text{-}se}}$ – factor of absolute maximal anaerobic power

3 – $\mathbf{F_{3\text{-}se}}$ – factor of absolute maximal oxygen intake

4 – $\mathbf{F_{4\text{-}se}}$ – factor of the effectiveness of lung ventilation



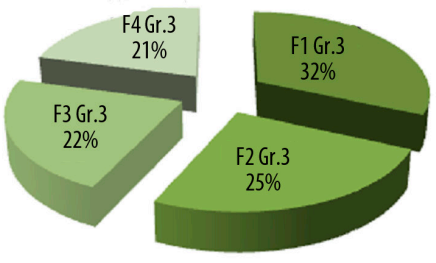
16–18-year-old judo competitors

1 – $\mathbf{F_{1\text{-}16\text{–}18}}$ – the factor of anaerobic and aerobic absolute efficiency interdependence

2 – $\mathbf{F_{2\text{-}16\text{–}18}}$ – factor of relative maximal anaerobic power

3 – $\mathbf{F_{3\text{-}16\text{–}18}}$ – factor of absolute interdependence of maximal anaerobic power with relative critical (oxygen) power

4 – $\mathbf{F4_{\text{-}16\text{–}18}}$ – factor of the effectiveness of lung ventilation



13–15-year-old judo competitors

1 – $\mathbf{F_{1\text{-}13\text{–}15}}$ – factor of absolute interdependence of anaerobic and aerobic efficiency

2 – $\mathbf{F_{2\text{-}13\text{–}15}}$ – factor of relative maximal anaerobic power

3 – $\mathbf{F_{3\text{-}13\text{–}15}}$ – factor of relative critical (oxygen) power)

4 – $\mathbf{F_{4\text{-}13\text{–}15}}$ – factor of the effectiveness of lung ventilation

Figure 1. The factor structure of the state of systems of energy provision for judo competitors' physical activity, n=40

the respiratory quotient (RQ) and maximal frequency of the heart beat (HR_{max}).

With reference to the obtained results a question arises: to what extent is each of the studied energy systems of judo athletes' organisms engaged in providing for their physical activity, and which of the studied indices can be the most informative for their characteristics? The answer to this question can be obtained be means of factor analysis as a method of mathematical classification and reduction of data. The application of this method allowed distinguishing four main factors in the overall structure of anaerobic and aerobic efficiency of the studied groups; their input in the general characteristics of the competitors' energy capabilities is situated at the level of 83–89% (Figure 1).

At the same time, while defining the value of coefficients of the studied indices in each of the selected factors, those of them which were the most informative were selected.

In consistence with the obtained results, the summary input of the selected factors in the overall sample dispersion in the seniors' group amounted to 89.0%. The greatest contribution in this characteristic (30.9%) belongs to **the first factor** (F_{1_se}), in which the highest values of coefficients were revealed by relative indices of both anaerobic and aerobic efficiency. Among them, the anaerobic maximal power index (W_{max} kg^{-1}) and the aerobic one (W_{cr} kg^{-1}) turned out to be the highest ones (0.97 and 0.94, respectively). Such a situation may be a basis to give F_{1_se} a working name of the *factor of anaerobic and aerobic maximal power relative interdependence,* and in characterising it to limit oneself to the analysis of the above mentioned indices.

The contribution of the **second** significant factor to the overall dispersion of the sample of indices of energy provision for physical activity of competitors from the senior group amounted to 21.6%. Here indices characterising absolute anaerobic capabilities are of the greatest significance, and among them the index of maximal absolute power in the Wingate test demonstrated the most significant coefficient (0.94). Thus, this index has the greatest informative capacity in the assessment of the second factor (F_{2_se}), which can be called here the *factor of absolute maximal anaerobic power.*

The third factor (F_{3_se}), whose contribution in the factor structure amounts to 20.2%, has been conventionally

called the *factor of absolute maximal oxygen intake,* as the most informative potential (0.89) is held by the VO_{2max} index ($ml \cdot min^{-1}$).

In the **fourth factor** (F_{4_se}), whose contribution to the overall dispersion of the sample is 16.3%, the most significant coefficient (0.85) was obtained by the index of oxygen ventilation equivalent determined by the ratio of the lung ventilation to the volume of oxygen intake. Hence, for the given factor, the VE/VO_2 index should be treated as the most informative, while the factor itself can be conventionally called the *factor of the effectiveness of lung ventilation.*

The overall contribution of the four selected factors in the structure of energy provision for effort of 16–18-year-old judo competitors was 83.0%.

In the **first factor,** defined as $F_{1\_16–18}$, the significance of aerobic efficiency indices prevails. In this one, just like in the F_{3_se} factor, the VO_{2max} index ($ml \cdot min^{-1}$) proved the most informative, as the value of its coefficient turned out to be the highest one (0.95).

However, in this case one should not neglect rather high (0.70) absolute values of indices of mean power (W_m) and overall work (KJ_Σ) performed in an anaerobic test. Taking the above into consideration, the $F_{1\_16–18}$ factor has been called *the factor of anaerobic and aerobic absolute efficiency interdependence.*

The contribution of the **second factor** amounted to 19.1%, and the index of relative maximal anaerobic power in the Wingate test ($W_{max} \cdot kg^{-1}$) turned out to be the most significant (0.95). The mentioned factor was marked as $F_{2\_16–18}$ and has been called here the *factor of relative maximal anaerobic power.*

The contribution of the **third factor** ($F_{3\_16–18)}$ in the structure of energy provision for effort amounted to 16.9% and has been conventionally called *the factor of absolute interdependence of maximal anaerobic power with relative critical (oxygen) power,* since the most informative in its case proved W_{max}, HR_{max} and $W_{cr} \cdot kg^{-1}$ indices (the values of coefficients were 0.73; 0.71 and 0.77 respectively). In this case the last index was selected to characterise this factor.

The contribution of the **fourth factor** ($F_{4\_16–18}$) in the structure of mechanisms of energy provision for the effort of 16–18-year-old competitors amounted to 15.8%. Just as in the F_{4_se} factor, the VE/VO_2 index has been presented as the most informative one. Therefore, it also has been conventionally called the factor of *the effectiveness of lung ventilation.*

The factor structure of the energy system of the provision for effort of 13–15-year-old competitors is also represented by four factors, whose contribution to the overall dispersion of the sample amounted to 85.7%.

The contribution of the **first,** main factor ($F_{1\_13–15}$) to the analysed structure came to 27.1%. The greatest weight, and which is directly connected with that – informative significance, was revealed in indices of absolute maximal anaerobic power (W_{max} 0.76) and maximal oxygen intake (VO_{2max} 0.97). Therefore, this factor can be conventionally called the *factor of absolute interdependence of anaerobic and aerobic efficiency.*

The **second** factor ($F_{2\_13–15}$), whose contribution to the studied structure came to 21.7%, has been conventionally called the *factor of relative maximal anaerobic power,* as such indices as: W_m (kg^{-1}), J (kg^{-1}) and W_{max} (kg^{-1}) had the greatest informative power (the coefficients were 0.93; 0.94 and 0.95 respectively). Thus, in order to fully characterise a given factor, it is justified to be guided by the W_{max} (kg^{-1}) index.

In the **third factor** ($F_{3\_13–15}$) – in which the contribution to the overall dispersion of the sample amounted to 19.1% – high values of coefficients connected with indices characterising the critical (oxygen) power per kg of the body mass ($W_{cr} \cdot kg^{-1}$) were revealed. This index was taken as the most informative for the given factor, and it has been called the *factor of relative critical (oxygen) power.*

A characteristic feature of the **fourth factor** ($F_{4\_13–15}$), whose contribution to the overall dispersion of the sample was 17.8%, was a domination of VE/VO_2 defining the effectiveness of lung ventilation. Its informative power came to 0.90. This gives grounds to call $F_{4\_13–15}$ here the *factor of the effectiveness of lung ventilation.*

Thus the results of the carried out analysis allowed isolating four factors in the structure of the system of energy provision for the effort of each of the studied groups of competitors. For each of them the most informative indices and corresponding to them mean values were defined (Table 3).

Discussion

The results of studies carried out in three empirical systems (judo competitors varying as to their age and the level of sports mastery) allowed defining the structure of mechanisms of energy provision for effort as components of general and special physical efficiency.

The choice of subjects, in our opinion, was adequate to the research tasks posed in the paper. Thus, the

Table 3. Factors in the structure of energy provision for the effort and their most informative indices for three groups of judo competitors, n=40.

Studied groups	Factors	Indices	Mean values (M±SD)
Seniors (n=11)	$F_{1\text{-}se}$ – factor of anaerobic and aerobic maximal power relative interdependence	W_{max} (kg^{-1})W_{cr}·(kg^{-1})	9.10±0.91 3.9±0.70
	$F_{2\text{-}se}$ – factor of absolute maximal anaerobic power	W_{max}	589±72
	$F_{3\text{-}se}$ – factor of absolute maximal oxygen intake	VO_{2max} (ml·min^{-1})	2619±311
	$F_{4\text{-}se}$ – factor of the effectiveness of lung ventilation	VE/VO_2	44.3 ±15.4
Age 16–18 (n=15)	$F_{1\text{-}16\text{–}18}$ – factor of absolute interdependence of anaerobic and aerobic maximal efficiency	W_{sr}, VO_{2max} (ml·min^{-1})	2312±294 408±66
	$F_{2\text{-}16\text{–}18}$ – factor of relative maximal anaerobic power	W_{max}·kg^{-1})	7.69±0.54
	$F_{3\text{-}16\text{–}18}$ – factor of absolute interdependence of maximal anaerobic power with relative critical (oxygen) power	$W_{max}W_{cr}$·kg^{-1}	498±75 3.8±0.60
	$F_{4\text{-}16\text{–}18}$ – factor of the effectiveness of lung ventilation	VE/VO_2	48.3±12.3
Age 13–15 (n=14)	$F_{1\text{-}13\text{–}15}$ – factor of absolute interdependence of anaerobic and aerobic efficiency	$W_{max}VO_{2max}$ (ml·min^{-1})	431±66 2034±260
	$F_{2\text{-}13\text{–}15}$ – factor of relative maximal anaerobic power	W_{max}·kg^{-1}	7.98±0.92
	$F_{3\text{-}13\text{–}15}$ – factor of relative critical (oxygen) power)	W_{cr}·kg^{-1}	3.30±0.49
	$F_{4\text{-}13\text{–}15}$ – factor of the effectiveness of lung ventilation	VE/VO_2	38.6±7.9

age and somatic indices of highly-qualified competitors were practically identical with the ones characteristic of the Olympic Team from 2004 [5]. Also somatic indices and the sports level of the groups of 16–18 and 13–15-year-old athletes were consistent with certain stages of long-standing training of representatives of this sports discipline [1].

As already mentioned, judo is a sports discipline of varying intensity. Due to the specificity of the competition effort, judo athletes should be characterised by an ability to perform short-term efforts, high-powered efforts as well as intensive efforts with longer duration [10]. Taking into consideration the duration of the fight and their number in a tournament, not insignificant is the aerobic function helping the economization of exercises and the effectiveness of the course of regeneration processes after substantial physical loads [4,11].

According to Laskowski's data [5], the mean value of VO_{2max} in competitors from the judo Olympic Team was determined at the level of 51.8 ml·min^{-1}·kg^{-1}. Mickiewicz et al. [10] showed the mean values of this index in training women at the level of 49.9 ml·min^{-1}·kg^{-1}. The results obtained in our study (the group of seniors 41.0±6.4 ml·kg^{-1}·min^{-1}) were also lower in comparison with representatives of such sports disciplines as volleyball (47.3–48.1 ml·min^{-1}·kg^{-1}) [12] or basketball (47.0–48.0 ml·min^{-1}·kg^{-1}) [13]. Even higher results of relative indices of maximal oxygen intake were obtained by athletes of typically aerobic character. The VO_{2max} index in long-distance runners amounted to 63.3 ml·min^{-1}·kg^{-1} [14].

According to Belotti et al. [15], the maximal anaerobic power decides about the effectiveness of a judo athlete's competition effort. Especially the mean power per kg body weight (W/kg), also may be considered a good indication of judoists' velocity predisposition, which is governed by anaerobic capacity [16]. Mean values of the maximal anaerobic power in studies by Zdanowicz et al. [17] and Mickiewicz et al. [10] were determined at the level of 9.63 W/kg. Even higher values of this index (10.9 W/kg) were obtained by judo Olympic Team athletes [5], while Polish national team handball players achieved the values of 9.78–10.2 W/kg [18].

The results of factor analysis provide valuable information on the properties of the state of energy provision for effort in the studied groups of female judo competitors. In effect, for each of the studied groups four factors defining the structure of these systems were identified. The algorithm of factor analysis allowed selecting the most informative coefficients for each factor, which largely limited their number and allowed a more rational interpretation of results. A noteworthy result of the study is the fact that the factor structure of energy systems of provision for effort in the three groups turned out to be diversified and has its characteristic properties in each group. In the group of seniors, the factor characterised

by a mutual relationship of indices of relative maximal anaerobic and aerobic power proved the most dominant, while in the groups of 13–15-year-old and 16–18-year-old competitors – the one characterised by a mutual relationship of indices of absolute anaerobic and aerobic efficiency. However, while the relationships of indices of relative maximal power (anaerobic and aerobic) in the group of seniors appear in the first, dominant factor, then in the group of 16–18-year-old competitors – in the third, less significant one. The second characteristic property was the fact that in the seniors' group in the second factor absolute maximal anaerobic power was the most informative, while in the groups of 13–16-year-old and 16–18-year-old competitors – relative values of this index. It is also characteristic that in the third factor, with a correspondingly smaller contribution to the overall characteristic of the studied energy system of the seniors' group, maximal oxygen intake (VO_{2max}) turned out to be the most informative. In the groups of 16–18-year-old and 13–15-year-old competitors this index is one of the most significant ones in the first dominating factor, and it reflects a significant relationship with the indices of anaerobic power in the Wingate test. The revealed properties indicate, on the one hand, a specific significance of relationships between indices of anaerobic and aerobic provision of a high sports level of judo competitors and, on the other hand, a greater significance of relative indices of anaerobic efficiency in relation to their absolute value.

The presented results should be regarded from the perspective of their theoretical significance and from the perspective of practical application in further research connected with the issue of increasing the effectiveness of judo competitors' training process at various stages of long-standing sports training.

Conclusions

1. Judo competitors from the senior group, and 16–18-year-old and 13–15-year-old athletes differ significantly from each other in three out of nine indices of the Wingate test, characterising the competitors' anaerobic efficiency, such as: mean and maximal power as well as the volume of performed work.
2. Between competitors from the senior, 16–18-year-old and 13–15-year-old judo competitors a significant difference in indices of absolute volume of VO_{2max}, critical power and oxygen pulse were revealed. However, a relative difference between mean values of oxygen intake in all three groups proved statistically insignificant.
3. In each of the studied groups of judo competitors four factors defining the structure of the state of energy provision for effort were identified. For each factor the most informative coefficients and corresponding with them mean values were determined. In each of the groups the factor structure has certain characteristic features which indicate on the one hand, specific significance of relationships between indices of anaerobic and aerobic provision of the high sports level of judo competitors and, on the other hand, a greater significance of relative indices of anaerobic efficiency in relation to their absolute values.

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