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Factor Structure of Motor Abilities in Judo Athletes

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Abstract: *Regular judo practice over a long period of time affects the optimal development of athletes, improves the structure of their psychosomatic status, and affects their morphological characteristics and motor skills. This research was conducted on a purposive sample of respondents with the primary aim of determining the factor structure of the motor abilities of judokas, using a cross-sectional model. The sample consisted of members of the wider male judo national team of Serbia, specifically 25 cadet and junior competitors between the ages of 15 and 21, who were in final preparations for the European Championships in Lithuania and EYOF in Hungary. The weight categories included in the study ranged from 50 to 100 kilograms. A total of 9 variables were used to assess the motor abilities of judokas, namely: three variables for assessing repetitive strength (push-ups, bench press and trunk hyperextension), three variables for evaluating explosive strength (vertical jump with arm swing, vertical jump after a drop in depth and bench press) and three variables for evaluating isometric strength (arm dynamometry, isometric back strength and isometric leg strength). By applying factor analysis, orthogonal and Varimax solutions and the Guttman-Kaiser criterion, the structure of the examined motor abilities space was determined, which resulted in the extraction of two dominant factors: a mechanism for regulating the intensity of excitation and a mechanism for regulating the duration of excitation.*

Keywords: *judo national team, cadet and junior competitors, factor structure, motor abilities.*

Introduction

Movements during sports activities, as well as in everyday life, require a high degree of efficiency. These processes aim for greater synchronization, automation, and optimization. Typically, such movements are learned to a certain extent in order to perform the appropriate motor task and represent an appropriate way to achieve the required level of motor ability.

Judo falls into the category of polystructural acyclic activities, which are characterized by alternating periods of high load, such as rapid changes of direction, sudden pauses, and fast reaction times in response to changes in the opponent's movements. This requires not only a strong dynamic stereotype of throws and holds, but also the capacity to efficiently reorganize dynamic stereotypes and constantly create new programs. Due to the complex nature of this sport, young judokas must acquire a high degree of motor skills (Nurkić, M., Bratić, M., Mitić, D., & Kafentarakis, D. 2017). Modern judo requires that the fight progresses in a relatively short period of time, at a very fast pace, and includes a multitude of tactical and technical elements. Judo is characterized by a very large number of techniques and their complexity. Judo is excellent for the development and improvement of almost all physiological systems. It is recommended for all age categories, and even individuals with disabilities successfully practice it (Milošević N, et al. 2012). Judo practice has been linked to several health advantages, including as higher-than-average VO2max, better body composition, higher bone mineral density, and higher bone mineral content (Drid, P., et al 2021). The agonistic nature of judo as a sport contributes, in addition to the development of physical abilities, to the development of psychological abilities such as perseverance, concentration, communication, and control of aggression (Bratić, M. 2003). Regarding the societal importance of judo, it should be emphasized that the sports aspect of judo holds a special significance. Many attractive judo competitions attract significant attention from sports audiences and help recruit new members. In competitive judo, all performances (as well as shortcomings) of an athlete can be highlighted during training and even more so during the actual fight. By becoming familiar with them, athletes can learn to further develop them or, if necessary, correct them. Therefore, in many clubs, the fight is considered the ultimate goal of training, and all the efforts of coaches and athletes are focused on creating good fighters and achieving sports results. This approach is certainly useful, but it is not sufficient because the significance of judo is much broader and much greater. Judo training is about understanding the true meaning of life through mental and physical attack and defense training (Kostovski, 2017).

Regular practice of judo over a long period of time influences the optimal development of athletes, improves the structure of their psychosomatic status, affects their morphological characteristics and motor abilities, allows for the guidance and control of innate reflex movements, and has a significant impact on all anthropological domains (cognitive, conative, motor, functional, sociological, and health). According to Protić-Gava, B., Drid, P., & Krkeljaš, Ž. (2019) study, young judo athletes outperformed their classmates who did not practice judo in terms of shoulder alignment, chest development, and abdominal wall alignment, as well as improved strength, flexibility, explosive power, and motor coordination.

Materials and Methods of Work

This research was conducted on a deliberate sample of respondents with the primary goal of determining the factor structure of the motor abilities of judokas, using a cross-sectional model. The sample consisted of members of the broader male judo national team of Serbia, specifically 25 cadet and junior competitors who were in their final preparations for the European Championship in Lithuania and the EYOF in Hungary. The respondents were between 15 and 21 years old. The weight categories included in the study ranged from 50 to 100 kilograms. The main criteria for participation in the study were that each respondent had undergone a medical examination, had no health issues in the 10 days preceding the testing, and had no injuries that could affect the test results. The following variables were used to assess the motor abilities of the judokas: For evaluating repetitive strength: Push-ups (PUSH-UPS), Trunk lifts on a bench (ABDOMINAL STRENGTH), and Trunk hyperextension (HYPEREXTENSION). For evaluating explosive strength: Vertical jump with arm swing (CMJ), Vertical jump after depth drop (DJ), and Bench press (BPRES). For evaluating isometric strength: Hand dynamometry (HAND), Isometric back strength (BACK), and Isometric leg strength (LEGS).

The data obtained in this research were processed using several programs based on the characteristics and size of the selected sample. The statistical package SPSS v.20 was used for data processing and analysis. The following measures were calculated for the study: Basic parameters of descriptive statistics for each variable. Verification of result distribution using the following parameters: Mean – arithmetic mean, Std.Dev. – standard deviation, Min. – minimum result, Max. – maximum result, Skew. – symmetry of result distribution, Kurt. – kurtosis of result distribution, K-S – Kolmogorov-Smirnov test, determining the normal distribution of results, Factor analysis, using orthogonal and Varimax rotation with the Guttman-Kaiser criterion to determine structure. H – the first principal component, explaining most of the total variance. λ – eigenvalue explaining the common variance of each isolated principal component. χ^2 – usefulness, indicating the proportion of explained total variance for each variable.

Results and Discussion

For this purpose, the basic descriptive statistical parameters were calculated for all applied variables in the study. These include: Arithmetic mean (X), Standard deviation (SD), Lower and upper range limits (min–max), Coefficient of variability (CV%), Coefficient of skewness (Skew), Kurtosis (Kurt) – measuring the peak or flatness of the distribution, Kolmogorov–Smirnov test (KS) – used to test the normality of distribution.

From Table 1, it can be observed that the skewness values for most motor tests in the initial measurement fall within the recommended range of -1 to +1, indicating that the distribution of results is approximately symmetrical. Positive skewness, or leptokurtosis (a higher concentration of results in the range of better values), was found in the motor test “trunk lifts on a bench” (Sk = 1.63). The kurtosis values (Table 1) show that most motor tests exhibit a flattened distribution (platykurtic distribution). Only the “trunk lifts on a bench” test shows a mesokurtic distribution (Kurt = 3.03).

The calculated coefficients of variability indicate that, in most motor tests, variability remains within normal limits, as the coefficient of variability is below 30%. However, a coefficient of variability above 30% was observed in the following motor tests: Bench press (CV = 31.60), Trunk lifts on a bench (CV = 31.20), Push-ups (CV = 59.19), Trunk hyperextension (CV = 35.07). The highest homogeneity (lowest coefficient of variability) was observed in the isometric leg strength test (CV = 14.13).

Table 1. *Descriptive statistics and normality of distribution of motor tests*

	Mean	Min	Max	SD	KV%	S.E.	Skew	Kurt	max D	K–S
BPRES	1170.62	578.50	1991.40	369.92	31.60	77.13	0.53	-0.36	0.130	p > .20
CMJ	34.05	24.60	48.50	4.92	14.45	1.03	0.83	2.33	0.111	p > .20
DJ	39.76	23.90	48.70	6.30	15.84	1.31	-0.51	0.16	0.087	p > .20
X	34.64	23.49	46.19	4.99	14.40	1.04	0.20	0.56	0.111	p > .20
BACK	1586.52	1224.00	2182.00	236.11	14.88	49.23	0.61	0.47	0.095	p > .20
LEGS	1418.70	1091.00	1834.00	200.46	14.13	41.80	0.09	-0.51	0.086	p > .20
HAND	420.22	326.00	575.00	67.36	16.03	14.05	0.69	-0.11	0.198	p > .20
PUSH-UPS	45.30	25.00	73.00	14.14	31.20	2.95	0.32	-0.73	0.105	p > .20
ABDOM.	105.74	40.00	300.00	62.58	59.19	13.05	1.63	3.03	0.181	p > .20
HYPER.	73.74	32.00	140.00	25.86	35.07	5.39	0.93	0.61	0.183	p > .20

Based on the values of the standard deviation (SD) and its relationship to the arithmetic mean (Mean), it can be concluded that in most motor tests do not exhibit statistically significant deviation of the results from the arithmetic mean.

Table 2. *Intercorrelation matrix of motor tests*

	BPRES	CMJ	DJ	BACK	LEGS	FI ST	PUSH-UPS	ABDOM	HYPEREX.
BPRES	1.00								
CMJ	.72	1.00							
DJ	.53	.63	1.00						
BACK	.48	.36	.53	1.00					
LEGS	.34	.32	.65	.79	1.00				
HAND	.63	.58	.64	.78	.69	1.00			
PUSH-UPS	-.08	-.11	.04	-.02	.27	.06	1.00		
ABDOM.	-.28	-.22	.02	.05	.18	.11	.44	1.00	
HYPEREXT.	-.35	-.13	.23	.06	.27	.09	.52	.62	1.00

The value of the basic central and dispersion parameters of the applied motor tests, in the intervals of the minimum (Min) and maximum (Max) results, contains about four or more standard deviations (SD), based on which a satisfactory sensitivity of most variables can be determined. The results of the Kolmogorov–Smirnov test (Table 1) confirm that all motor tests exhibit a normal distribution.

The intercorrelation matrix (Table 2) illustrates the relationships between various motor tests. This matrix is symmetric, with ones on the diagonal, and is derived from the correlation coefficients between motor test results. The correlation coefficients indicate the degree of association between tests but do not imply causation. In this study, correlation significance was determined at the $p = 0.05$ level.

Key Observations from the Intercorrelation Matrix: A significant number of motor test pairs exhibit strong correlations, while some show weak relationships, and a few have negligible connections. A positive correlation was found between explosive strength tests (vertical jump with arm swing, bench press, vertical jump after depth drop) and isometric strength tests (isometric back strength, isometric leg strength, and hand dynamometry). A positive statistical correlation was also established among repetitive strength tests (trunk lifts on a bench, push-ups, and trunk hyperextension). A low negative correlation was observed between explosive strength tests (bench press and vertical jump) and repetitive strength tests (trunk lifts on a bench and trunk hyperextension). The results of the research conducted by Kostrzewa, M., et al. (2020), on correlation analyses between variables of explosive strength and endurance of the lower and upper extremities in elite male judokas also show positive statistically significant correlations at the $p < 0.05$ level.

By factorizing the intercorrelation matrix in a hyperdimensional space, latent dimensions (principal components) were extracted, explaining the underlying factor structure.

The Guttman–Kaiser criterion was applied to evaluate the significance of these latent dimensions. According to this criterion, only latent dimensions with eigenvalues equal to or greater than one are considered significant.

Results of Factor Analysis: Two principal components were identified, explaining 69.74% of the total variance in the system (Table 4). The first principal component accounts for 43.41% of the total variance and is strongly correlated with explosive and isometric strength tests. The motor tests with the highest projection on the first principal component include: Bench press, Vertical jump with arm swing, Vertical jump after depth drop, Isometric back strength, Isometric leg strength, Hand dynamometry. The second principal component explains 26.33% of the total variance and is primarily associated with repetitive strength tests. The tests with the highest projection on the second principal component include: Push-ups, Trunk lifts on a bench, Trunk hyperextension. These findings suggest that the motor tests used in this study can be grouped into two primary dimensions—explosive/isometric strength and repetitive strength, each contributing significantly to the assessment of judokas' motor abilities.

Table 3. *Characteristic roots and explained parts of the common variance of motor tests*

	Λ	%	Cumulative %
1	3.91	43.41	43.41
2	2.37	26.33	69.74

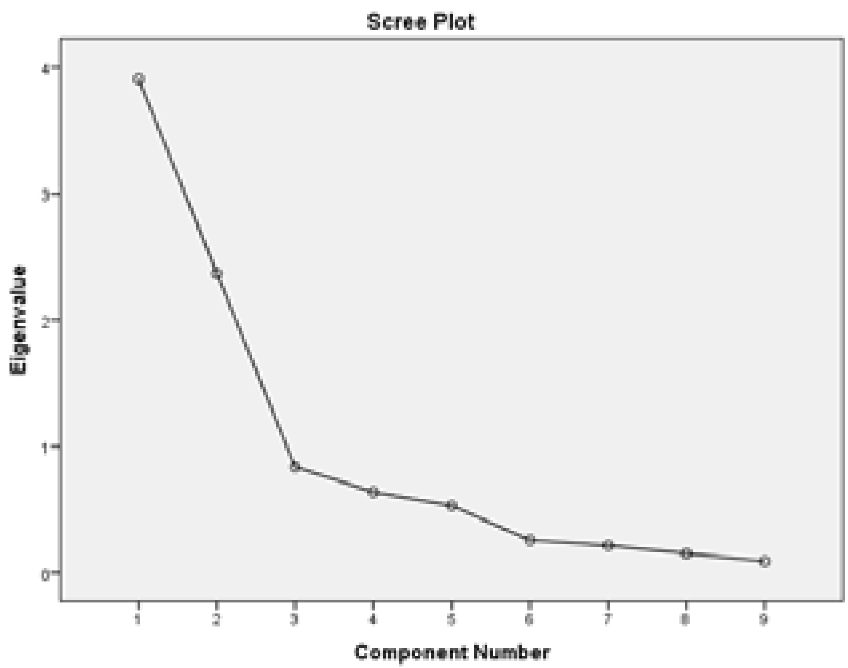

Chart 1.

Table 4. *Hotaling's method of testing main components*

Variables	H1	H2	χ^2
BPRES	.74	-.43	.74
CMJ	.73	-.34	.64
DJ	.83	.07	.69
BACK	.83	.08	.69
LEGS	.80	.34	.76
HAND	.90	.06	.82
PUSH-UPS	.06	.72	.52
ABDOM.	.00	.82	.67
HYPEREX.	.07	.87	.76

To achieve the simplest possible structure, the initial coordinate system was rotated using the Varimax method. This technique enhances the interpretability of factor loadings by maximizing the variance of squared loadings within each factor.

The first latent dimension shows high saturation in motor tests evaluating explosive and isometric strength, with the following loadings: Bench press: (.76), Vertical jump with arm swing: (.74), Vertical jump after depth drop: (.82), Isometric back strength: (.82), Isometric leg strength: (.79), Hand dynamometry: (.90). Among these, the tests with the highest projection (and thus the strongest diagnostic validity for this latent dimension) are: Hand dynamometry: (.90), Vertical jump after depth drop: (.82), Isometric back strength: (.82), Isometric leg strength: (.80).

According to the functional approach in defining motor abilities, the first factor can be interpreted as a mechanism for regulating excitation intensity. This suggests that it represents the ability to generate and sustain high levels of force and power, crucial for athletic performance in judo.

Table 5. *Varimax rotation of motor tests*

Variables	V1	V2
BPRES	**.76**	-.41
CMJ	**.74**	-.31
DJ	**.82**	.10
BACK	**.82**	.10
LEGS	**.79**	.36
HAND	**.90**	.09
PUSH-UPS	.04	**.72**
ABDOM.	-.02	**.82**
HIPEREXT.	.05	**.87**

The second latent dimension exhibits high projections in motor tests that assess repetitive strength, with the following loadings: Push-ups: (.72), Trunk lifts on a bench: (.82), Trunk hyperextension: (.87). Among these, the trunk hyperextension test has the highest projection (.87), making it the most diagnostically valid test for this latent dimension.

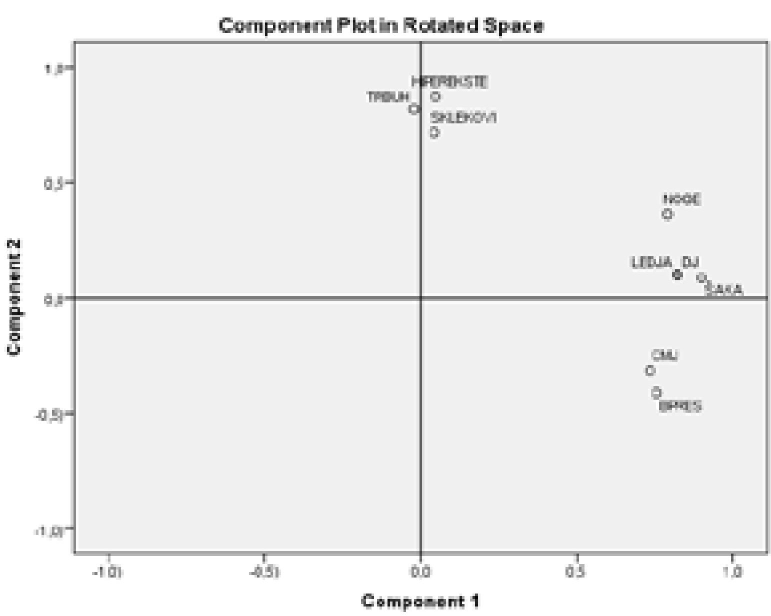

Chart 2.

According to the functional approach in defining motor abilities, the second factor can be described as a mechanism for regulating the duration of excitation. This suggests that it represents the ability to sustain prolonged muscle contractions, which is essential for endurance-based strength performance in judo. In the context of the obtained results, the research of Zekrin, A., et al. (2024) is also connected, which determined the factor structure of the physical and functional readiness of judokas determined by correlation analysis (Spearman's rank correlation method), according to which the greatest contribution to sports results is made by the factors of speed and strength abilities, endurance, coordination, cardiovascular and respiratory capacities.

Judo is classified as a polystructural acyclic activity, where the final outcome is a binary variable: win or lose. The main goal of training in judo is to perfect the techniques that will be performed in competition against an opponent.

Judo is a sport where the dominant motor abilities include: Balance, Coordination, Strength, Speed, Endurance (Bratić, M. 2003). The complex structure of judo is further influenced by its weight category system, as different categories require specific technical and tactical adaptations, as well as distinct physiological and morphological characteristics (Drid et al., 2012). Additionally, the vast number of techniques and their effective, timely application in combat—which varies depending on the opponent—creates a significant challenge for coaches in defining the key abilities needed for success.

A higher diversity of techniques in a given sport increases the importance of coordination (Lech et al., 2014). This is especially evident in higher weight categories, where, alongside maximum strength, which enables dominance over the opponent, a high level of coordination facilitates the execution of techniques in all directions.

The technical preparation of a judoka involves developing motor habits, including: Throws, Holding techniques, Locks, Chokes, their combinations which are all applied in competitive matches.

During beginner training, judokas learn basic technical elements, while advanced training focuses on refining techniques for real combat scenarios. In this stage, the range of techniques expands significantly, along with the development of motor skills and specific coordination abilities.

The process of refining motor habits follows a structured approach, where technical mastery can be divided into: Basic technical preparation – Forming fundamental motor habits through various technical solutions in controlled conditions. Specialized technical preparation – Developing motor habits under realistic combat conditions, directly linked to tactical execution and focused on achieving optimal performance (Mikić & Redžić, 1995).

A complex set of specific motor exercises has a positive transfer effect on the development of sport-specific motor abilities and judo technique quality. Therefore, coaches are encouraged to integrate these exercises into their training process to enhance performance.

Conclusion

This study follows a transversal model and was conducted on a deliberate sample of elite judo athletes. The research employed appropriate methodological procedures, aligned with the subject, goals, and tasks of the study, with the primary objective of determining the structure of motor abilities (strength) in judokas.

By analyzing previous research on this topic, it is evident that gathering as much relevant information as possible is crucial for providing reliable support to coaching practice. Achieving elite-level performance in judo is possible when the key abilities for success reach their optimal level and are in balanced relationships with one another. Thus, a key research question arises: Which motor abilities are dominant in judokas, and what is their optimal level across different weight categories (Sterkowicz et al., 2011).

Through factor analysis, using orthogonal Varimax rotation with the Guttman–Kaiser criterion, the structure of the examined motor ability space was determined, resulting in two dominant factors: Mechanism for regulating excitation intensity, Mechanism for regulating excitation duration

These factors align with the functional approach to defining motor abilities, emphasizing how strength and endurance manifest in judo performance.

Objective measurement data not only aid in monitoring, directing, and adjusting the training process but also serve as a tool for self-assessment of subjective coaching observations. Additionally, the results of this study allow for comparative analysis of motor ability dimensions: Between different sports, between elite athletes and the general population (Lolić & Nurkić, 2012). Also, in the study conducted by Kuvačić, G. et al. (2017), where the motor abilities of Croatian judokas in the cadet age category were tested, it was identified which physical and anthropometric factors contribute most to success in judo: explosive strength, agility and grip strength were the most important discriminators of competitive success.

In judo training, great emphasis is placed on the development of motor abilities, including: strength, speed, coordination, balance, endurance and flexibility.

Although these abilities are likely the most crucial for success in judo combat, determining which one is the most important and should be prioritized in training remains a challenge (Lulzim, 2012).

The study assessed the importance of throwing techniques in relation to key characteristics of judo combat and the applicability of motor abilities. The findings can assist: Coaches in selecting the most effective technical and tactical preparation strategies, Trainers in developing new methodological approaches, and sport scientists in making evidence-based recommendations for optimizing training programs.

Furthermore, the results of this research can aid in rational planning, programming, and organization of judo training**,** providing direct practical contributions to enhancing performance and training efficiency**.**

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