


Relationships between selected elements of physical and functional fitness and the competitive performance of judo athletes

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Abstract

Judo competitors at the highest sports skill level are characterized by a high level of physical fitness, mental toughness, and technical skills developed through years of training. The aim of this study was to reveal the relationship between selected elements of physical and functional fitness and the competitive performance of judo athletes from different age categories and competitive levels. Forty-six judokas aged 17 to 28 years took part in the study. For comparative purposes, the judokas were divided into two groups based on age (juniors and seniors) and sport level (medallists and non-medallists). Research tools were the Functional Movement Screen (FMS) test and two muscle strength tests: the bench press and the barbell squat. Data on the sports performance of individual athletes was obtained from the official website of the Polish Judo Association and the European Judo Union. There were no statistically significant differences in the overall FMS score of the junior and senior athletes. Statistically significant differences in total FMS score were found between medallists and non-medallists – in favor of medallists. Statistically significant differences were observed in muscle strength tests between the younger and older age group athletes. Strength tests results relative to body weight showed no significant differences between medallists and non-medallists. Judo training should therefore consider dealing with the functional limitations of the musculoskeletal system and the improvement of movement quality.

Keywords: Martial arts; combat sports; judo; functional assessment; strength test.

Relación entre determinados aspectos de la aptitud física y funcional y el rendimiento competitivo en atletas de judo

Resumen

Los competidores de judo de élite se caracterizan por un alto nivel de aptitud física, fortaleza mental y habilidades técnicas desarrolladas a lo largo de años de entrenamiento. El objetivo del estudio fue analizar la relación entre determinados elementos de la aptitud física y funcional y el rendimiento competitivo en judocas de diferentes categorías de edad y niveles competitivos. Participaron 46 judocas de entre 17 y 28 años, que fueron divididos en dos grupos según la edad (junior y senior) y nivel competitivo (medallistas y no medallistas). Las herramientas de investigación fueron la prueba *Functional Movement Screen* (FMS) y dos pruebas de fuerza muscular: press de banca y sentadilla con barra. Los datos sobre el rendimiento deportivo de cada deportista se obtuvieron de la página web oficial de la Asociación Polaca de Judo y de la Unión Europea de Judo. No se observaron diferencias significativas en la puntuación global del FMS entre los judocas junior y senior. Se encontraron diferencias significativas en la puntuación total del FMS entre medallistas y no medallistas, a favor de los primeros. Se observaron diferencias significativas en las pruebas de fuerza

Relações entre determinados aspetos da aptidão física e funcional e o desempenho competitivo dos atletas de judo

Resumo

Os praticantes de judo ao mais alto nível desportivo caracterizam-se por um elevado nível de aptidão física, resistência mental e competências técnicas desenvolvidas ao longo de anos de treino. O objetivo do estudo foi revelar a relação entre determinados elementos da aptidão física e funcional e o desempenho competitivo de atletas de judo de diferentes categorias etárias e níveis competitivos. Participaram no estudo 46 judocas com idades entre os 17 e os 28 anos. Para efeitos comparativos, os judocas foram divididos em dois grupos com base na idade (juniores e seniores) e no nível desportivo (medalhistas e não medalhistas). As ferramentas de investigação foram o teste *Functional Movement Screen* (FMS) e dois testes de força muscular: supino e agachamento com barra. Os dados sobre o desempenho desportivo de cada atleta foram obtidos a partir do site oficial da Associação Polaca de Judo e da União Europeia de Judo. Não se verificaram diferenças estatisticamente significativas na pontuação global do FMS entre os atletas juniores e seniores. Foram encontradas diferenças estatisticamente significativas na pontuação total do FMS entre medalhistas e não medalhistas – a favor dos medalhistas. Observaram-se diferenças significativas

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muscular entre los atletas junior y sénior. Los resultados de las pruebas de fuerza en relación con el peso corporal no mostraron diferencias significativas entre medallistas y no medallistas. El entrenamiento de judo debería tener en cuenta las limitaciones funcionales del sistema musculoesquelético y la mejora de la calidad del movimiento.

Palabras clave: Artes marciales; deportes de combate; judo; evaluación funcional; test de fuerza.

nos testes de força muscular entre os atletas juniores e seniores. Os resultados dos testes de força em relação ao peso corporal não revelaram diferenças significativas entre medalhistas e não medalhistas. O treino de judo deve, portanto, considerar o tratamento das limitações funcionais do sistema músculo-esquelético e a melhoria da qualidade dos movimentos.

Palavras-chave: Artes marciais; desportos de combate; judo; avaliação funcional; teste de força.

1. Introduction

Sports training focuses on developing the muscle groups and motor abilities that are most useful for performing competitive tasks in a given sport. However, excessive strain on one part of the musculoskeletal system can sometimes cause an imbalance between its various parts. This is often associated with regularly performing incorrect movement patterns during training, resulting in reduced mobility and stability and impaired coordination (Letafatkar et al., 2014; Adamczyk et al., 2015; Boguszewski et al., 2019; Chang et al., 2020). The key to preventing injury is adequate training that is adapted to the individual needs and abilities of the athlete. Adequate post-exercise recovery is also important (Cortis et al., 2010; Dupuy et al., 2018; Teyhen et al., 2020). However, preventive measures such as compensatory exercises, stretching and stabilisation require a diagnosis of functional limitations of the musculoskeletal system (Diaz-Lara et al., 2014; Barbado et al., 2016; Detanico et al., 2016; Hansen et al., 2016; Ahmedov et al., 2024).

In combat sports where the competition involves direct contact between two athletes, the aim of training is to optimize the development of motor skills. Judo is a sport that promotes all-round development. Training in this sport may improve athletes' locomotor skills, postural muscle efficiency and balance (Kalina, 2000; Lizis & Puszczalowska-Lizis, 2004; Maśliński et al., 2016; Boguszewski et al., 2024). Therefore, judo can be considered not only a sport, but also an element in the prevention of postural defects, obesity, and other diseases of affluence. Judo exercises are also used for therapeutic and rehabilitative purposes (Schwartz et al., 2015; Boguszewski et al., 2019; Walaszek et al., 2019). On the other hand, judo is also a very demanding sport. The highest-level athletes are characterised by a high level of physical fitness, mental toughness and technical skills, developed through years of training. Consequently, training for advanced judokas is very demanding and can result in acute and overload injuries (Kim et al., 2015; Akoto et al., 2018; Błach et al., 2021). (Kim et al., 2015; Akoto et al., 2018; Błach et al., 2021). A predisposition to injury can be identified through an appropriate functional assessment of the athlete (Kiesel et al., 2007; Teyhen et al., 2020).

Research on the relationship between functional fitness and sports performance has produced inconclusive results (Okada et al., 2011; Lockie et al., 2015; Schwartz et al., 2015). However, some authors emphasise the relationship between functional test results and certain aspects of physical fitness (Boguszewski et al., 2018; Koźlenia & Domaradzki, 2021; Krkeljas & Kovac, 2021). The Functional Movement Screen (FMS) was employed in this study as it is an objective method of analysing movement patterns. The FMS was developed in 1995 by Gray Cook and Lee Burton to analyse functional fitness and identify musculoskeletal deficits such as asymmetry, mobility limitations and muscle imbalance (Cook et al., 2006a; 2006b). According to Frost et al. (2012), tools such as the FMS can provide injury prevention and performance specialists with valuable insights, but further research is needed to explore the implementation and interpretation of the FMS in the context of exercise prescription and long-term progression, to ensure consistent, effective and sustainable training strategies. With this in mind, the main purpose of this study was to establish the relationship between functional fitness and the competitive performance of junior and senior judo athletes at different competition levels.

2. Materials and methods

2.1. Participants

The study examined 46 male judokas aged 17 to 28 years. All participants held a master's degree (dan) in judo and were active competitors with a license from the Polish Judo Association.



There were athletes from all weight categories, 5 from 60 kg, 9 from 66 kg, 7 from 73 kg, 10 from 81 kg, 7 from 90 kg, 5 from 100 kg and 3 from +100 kg. The group included eight European Championship and World Cup medalists, and twenty-eight Polish Championship medalists from two sports seasons. The sample size was justified via a post-hoc power analysis using G*Power (version 3.1.9.7; Universität Kiel, Kiel, Germany) for a Mann-Whitney U test. Parameters included a type I error rate of 0.05, and an effect size of $f=0.65$, classified as large.

For comparative purposes, the judokas surveyed were divided into two groups based on age (juniors up to 20 years old and seniors aged 21 years and over) and sporting level. The first group consisted of medal winners at international tournaments and Polish championships. According to the classification of the Polish Judo Association, these athletes were either international or national Master Class athletes. The second group consisted of other judokas who were first or second class athletes, i.e. non-medalists. Biometric data was taken from the judokas' medical cards (see Table 1). Medical tests were performed before the preparation period.

Table 1. Characteristics of examined athletes

Groups	Seniors (n = 24)	Juniors (n = 22)	Medallists (n = 22)	Non-medallists (n = 24)
Age [years]	23.46 ± 4.05	18.45 ± 1.92	20.64 ± 3.49	20.63 ± 3.05
Body mass [kg]	81.33 ± 14.65	77.15 ± 12.01	80.74 ± 14.15	77.17 ± 12.43
Body height [cm]	177.79 ± 7.85	179.36 ± 6.59	180.27 ± 8.17	177.13 ± 6.33
Body Mass Index - BMI [kg/m ²]	25.90 ± 3.04	23.89 ± 2.25	25.11 ± 2.75	24.88 ± 2.93
Training experience [years]	13.25 ± 3.80	9.98 ± 2.99	11.95 ± 3.87	11.13 ± 4.08

Prior to conducting the tests, a medical history interview was conducted to identify any current musculoskeletal injuries that might have affected the results. Athletes who were currently injured and not participating in training or competitions were excluded from the study. Participation in the study was voluntary and anonymous (everyone signed a consent form to participate in the research). Competitors under 18 provided written consent from their parents or guardians.

This study adhered to the principles set out in the Declaration of Helsinki and was approved by the Research Ethics Committee at the Józef Piłsudski University of Physical Education in Warsaw (approval number SKE 01-38/2023).

2.2. Research tools and procedures

The Functional Movement Screen (FMS) was used to assess functional limitations. FMS consists of seven tasks assessing fundamental movement patterns: (1) Deep Squat (to assess symmetrical, bilateral, functional mobility of the hips, knees, and ankles); (2) Hurdle Step (to assess coordination and stability between the hips and trunk, bilateral functional stability and mobility of the hips, knees, and ankles); (3) In-line Lounge (to assess hip and ankle mobility and stability, flexibility of quadriceps femoris, and knee stability); (4) Shoulder Mobility (to assess bilateral shoulder range of motion); (5) Active Straight Leg Raise (to assess active hamstring and gastric-soleus flexibility); (6) Trunk Stability Push-Up (to assess stabilisation of trunk and symmetrical motion of upper limbs); and (7) Rotation Stability (to assess coordination and multi-plane trunk stability). Each test is scored on a four-point scale (0 to 3 points). There are also three elimination tests: (1) Impingement, (2) Press-up and (3) Posterior Rocking clearing tests. The occurrence of pain during the test was scored 0 points (accordingly for shoulder mobility, trunk stability push-up and rotary stability). The tests are performed three times and the technically best attempt is scored. Each score is characterized by its guidelines: 0 points – if there is pain during the movement, 1 point – if the athlete is unable to perform the exercise, 2 points – if compensation has been used during the test, 3 points – if the exercise is performed correctly. A total of 21 points can be scored for correct execution of all tests. The athletes with a score of less than 14 are more likely to suffer a serious injury than those with a score of 14 or higher. A serious injury is one by which an athlete may be excluded from further participation in sports training (Cook et al., 2006a; 2006b).

The FMS test was carried out without a warm-up by a certified sports diagnostics specialist, assessor – FMS level 2 (with 15 years of experience in FMS testing). The assessment was done in two planes: sagittal and frontal. If there were doubts about the accuracy of the pattern, the participants received a lower score. The five exercises are bilateral, with each side assessed separately – the dominant side was tested first (Cook et al., 2006a; 2006b). The tests were conducted by athletes after the competition period, before the preparation period. They were not involved in a body weight loss process.

Two tests were performed to assess muscle strength: the bench press and the barbell squat. Each test was performed on separately training session. Each training session was preceded by a warm-up according to the RAMP protocol (Jeffrey, 2019), containing activation exercises, increasing the heart rate, active stretching and aimed at the training goal (recreating the structure of movement without load). The Rise phase included exercises such as jumping jacks, a stationary skip A, and dynamic upper and lower limb swings. The Activate phase included the following exercises: simultaneous leg extension and flexion of the opposite arm in a supported kneeling position (bird dog), hip raises in a supine position, and a deep squat with arm raises. In the Mobilize phase, participants performed the WGS, which involved a dynamic upper limb swing in a lateral position while supporting the opposite arm, and then transitioning to a front stance and returning to a standing position (inchworm exercise). The final phase, the Potentiate phase, included jumps and a stationary sprint. The warm-up lasted an average of 10 minutes.

Preparation to strength tests were conducted according to a heavy-duty training regimen. Athletes performed three repetitions at 80% of their maximum weight, two at 90%, and one at 100%. Rest periods between repetitions were a full 2-3 minutes. Bench press was performed in a supine position on a flat bench, with the buttocks and shoulder blades in contact with the bench and the feet resting on the ground. Grip width depended on the athlete's preference but it was wider than shoulder width apart, with the barbell held in an overhand grip. The athlete inhales and lowers the barbell to the chest, then with an exhalation, performs arm extension back to the position from which they started the movement. During the test, the athlete performs one repetition with maximum weight. They repeated the test to find the maximum weight. The squat was performed with the barbell resting on the nape of the neck near the top of the quadriceps. The hands held the barbell in an overhand grip. On an inhalation, the athlete tightens the abdominal press, tilts the pelvis forward, and removes the barbell from the racks. Then, he or she bends his knees so that their back does not arch. When the hip joint was lower than the knee joint, there was an extension at the knee joint and an exhalation at the end of the movement. During the test, the athlete performs one repetition (Rippetoe, 2018).

An additional research tool was a self-administered questionnaire, which included biometric data, information on training, injuries, and pain complaints.

Data on the sports performance of individual athletes was obtained from the official websites of the Polish Judo Association and the European Judo Union (<https://pzjudo.pl>; <https://www.eju.net>). Only fights from international competitions, such as the World Cup and the European Cup, and national competitions, such as the Polish Championships and Polish Cup Tournaments, were included in the analysis from two sports seasons. Information was obtained on the number of fights performed by competitors, the number of victories and defeats, places taken and medals won. The percentage of wins was calculated by dividing the number of wins by the number of fights.

2.3. Statistical analysis

Data were exported to Statistica 12 software (TIBCO software, Santa Clara, CA, United States). Due to the lack of normal distribution of the data, as verified by the Shapiro–Wilk test, further analyses of differences between groups were conducted using the Mann–Whitney U test. In the case of variables on the ordinal and nominal scales, we are only able to determine the strength of the relationship (effect) r and the statistical significance p of the relationship in the study. Spearman's r coefficient was used as a measure of the explained variability. A scale was adopted for the directly proportional strength of the effect r , i.e., $r > 0$: $r < 0.3$ being a weak relationship, $r < 0.5$ being a medium relationship, and $r > 0.5$ being a strong relationship. Associations between individual variables (e.g.



FMS test scores and age, training length, or training frequency) were established using Spearman's rho correlation analysis. The minimal level of statistical significance was set at $p \leq 0.05$.

3. Results

The judo athletes studied were moderately predisposed to bodily injury. There were no statistically significant differences in the overall Functional Movement Screen (FMS) scores of junior and senior athletes. However, the junior athletes scored significantly higher in test two (hurdle step) (Table 2).

Table 2. FMS results of seniors and juniors (Mann–Whitney *U* test)

Group	Seniors (n=24)	Juniors (n=22)	p	r
Deep squat	2.04 ± 0.86	2.06 ± 1.06	0.964	0.22
Hurdle step	1.75 ± 0.44	2.06 ± 0.42	0.028	0.12
In-line lunge	2.17 ± 0.64	2.33 ± 0.69	0.389	0.22
Shoulder mobility	2.17 ± 0.64	2.11 ± 0.58	0.771	0.22
Active straight leg raise	1.79 ± 0.41	1.89 ± 0.47	0.491	0.30
Trunk stability push-up	2.58 ± 0.72	2.44 ± 1.15	0.656	0.32
Rotary stability	2.38 ± 0.65	2.39 ± 0.50	0.938	0.40
Sum	14.88 ± 2.11	15.28 ± 2.05	0.538	0.25

Statistically significant differences in the total FMS score were found between medallists and non-medallists, in favour of the former. Medallists also achieved higher scores in the trunk stability push-up test (see Table 3). Ten athletes scored below 14 points, indicating a high susceptibility to injury: seven seniors, three juniors (two medallists and one non-medallist).

Table 3. FMS results of medallists and non-medallists (Mann–Whitney *U* test)

Group	Medallists (n=22)	Non-medallists (n=24)	p	r
Deep squat	2.29 ± 0.64	2.00 ± 1.00	0.279	0.49
Hurdle step	1.95 ± 0.50	1.90 ± 0.44	0.743	0.53
In-line lunge	2.24 ± 0.54	2.14 ± 0.65	0.610	0.11
Shoulder mobility	2.33 ± 0.58	2.10 ± 0.70	0.237	0.07
Active straight leg raise	1.90 ± 0.54	1.95 ± 0.59	0.786	0.16
Trunk stability push-up	2.95 ± 0.22	2.19 ± 1.03	0.003	0.45
Rotary stability	2.29 ± 0.46	2.33 ± 0.66	0.788	0.02
Sum	15.95 ± 1.72	14.62 ± 2.13	0.032	0.36

Statistically significant differences in muscle strength were observed between athletes in the younger and older age groups. These relationships applied to both absolute and relative performance (Table 4).

Table 4. Strength tests results of juniors and seniors (Mann–Whitney *U* test)

Group	Seniors (n=24)	Juniors (n=22)	p	r
Barbell squat [kg]	143.47 ± 24.78	112.21 ± 27.50	0.001	0.35
Bench press [kg]	113.71 ± 19.14	93.25 ± 22.14	0.004	0.12
Barbell squat [% body mass]	1.81 ± 0.21	1.47 ± 0.27	0.000	0.13
Bench press [% body mass]	1.41 ± 0.15	1.23 ± 0.20	0.003	0.05

Statistically significant differences were found in the squat results (absolute score) when considering the athletes' sport level. In contrast, results relative to body weight showed no significant differences (Table 5).

Table 5. Strength tests results of medallists and non-medallists (Mann–Whitney U test)

Group	Medallists (n=22)	Non-medallists (n=24)	p	r
Barbell squat [kg]	138.94 ± 30.70	116.26 ± 26.37	0.024	0.65
Bench press [kg]	106.47 ± 26.31	98.45 ± 20.38	0.292	0.16
Barbell squat [% body mass]	1.71 ± 0.27	1.56 ± 0.30	0.121	0.10
Bench press [% body mass]	1.30 ± 0.22	1.32 ± 0.20	0.813	0.01

There were no significant differences between juniors and seniors in terms of the number of bouts fought, the number of bouts won or lost, or the percentage of wins. However, the differences in the number of bouts and wins were almost significant, with juniors fighting a higher number of bouts (Table 6). Statistically significant differences were observed between medallists and non-medallists in terms of the number of bouts, the number of wins and the percentage of bouts won (Table 7).

Table 6. Characteristics of fights of seniors and juniors (Mann–Whitney U test)

Group	Seniors (n=24)	Juniors (n=22)	p	r
Number of fights	15.05 ± 6.30	20.89 ± 12.32	0.133	0.29
Wins	8.42 ± 3.48	14.16 ± 4.62	0.082	0.22
Losses	6.63 ± 3.01	6.74 ± 5.23	0.937	0.09
Percentage of wins	0.50 ± 0.28	0.59 ± 0.30	0.369	0.26

Table 7. Characteristics of fights of medallists and non-medallists (Mann–Whitney U test)

Group	Medallists (n=22)	Non-medallists (n=24)	p	r
Number of fights	23.61 ± 11.12	12.67 ± 4.55	0.006	0.56
Wins	17.22 ± 4.31	6.58 ± 3.91	0.001	0.19
Losses	6.39 ± 5.98	6.71 ± 5.50	0.808	0.38
Percentage of wins	0.71 ± 0.16	0.41 ± 0.32	0.000	0.13

Significant positive correlations were observed between the overall FMS score and the percentage of bouts won. This relationship applied to each study group. A positive correlation was also found between the FMS score and the number of bouts won among seniors and non-medallists. A strong negative correlation was found between the number of failures and the FMS score in the senior group (see Table 8).

Table 8. Correlations between fights characteristics and FMS (overall results) (Spearman's rho correlation)

Groups	All (n=46)	Seniors (n=24)	Juniors (n=22)	Medallists (n=22)	Non-medallists (n=24)
Number of fights	0.165	0.171	0.054	-0.145	0.308
Wins	0.319*	0.486*	0.154	-0.068	0.650***
Losses	-0.328*	-0.584**	-0.239	-0.309	-0.355
Percentage of wins	0.603***	0.732***	0.625**	0.410*	0.608**

Note: * p<0.05; ** p<0.01; *** p<0.001

There were significant positive correlations between the percentage of wins and the three FMS tasks: deep squat, in-line lunge and trunk stability push-up (in all groups and among medallists). Furthermore, strong positive correlations were noted in the second task (hurdle step) in the senior and medallist groups (Table 9). No significant correlations were observed between strength test scores and the number of bouts, wins, losses or the percentage of bouts won (see Table 10). A significant positive correlation was found between the barbell squat test and the sixth FMS test (trunk stability), while a negative correlation was found between the squat test and the fifth FMS test



(ASLR). However, there was a significant positive correlation between the bench press test and the seventh FMS exercise (rotational stability) (Table 11).

Table 9. Correlations between the efficacy of fights (percentage of wins) and the results of FMS tasks (Spearman's rho correlation)

Groups	All (n=46)	Seniors (n=24)	Juniors (n=22)	Medallists (n=22)	Non-medallists (n=24)
Deep squat	0.398**	0.283	0.510**	0.436*	0.193
Hurdle step	0.203	0.483*	-0.175	0.414*	0.184
In-line lunge	0.424**	0.699***	0.199	0.407*	0.552**
Shoulder mobility	0.168	0.330	-0.002	-0.112	0.152
Active straight leg raise	0.055	0.131	-0.052	0.128	0.076
Trunk stability push-up	0.552***	0.484*	0.705***	0.594**	0.274
Rotary stability	0.165	0.384	-0.124	-0.027	0.347

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 10. Correlations between fights characteristics and strength tests results (n=46) (Spearman's rho correlation)

Strenght Test	Number of fights	Wins	Losses	Percentage of wins
Barbell squat	-0.013	-0.030	0.038	0.054
Bench press	-0.034	-0.033	-0.015	0.025

Table 11. Correlations between FMS tasks results and strength tests results (n=46) (Spearman's rho correlation)

Strenght Test	Deep squat	Hurdle step	In-line lunge	Shoulder mobility	Active straight leg raise	Trunk stability push-up	Rotary stability	Sum
Barbell squat	0.185	-0.048	-0.197	-0.129	-0.317*	0.334*	0.109	0.058
Bench press	0.092	0.065	0.130	-0.192	-0.272	0.175	0.403**	0.145

Note: * $p < 0.05$; ** $p < 0.01$

4. Discussion

Combat sports and martial arts are forms of physical activity involving direct contact with an opponent. To be successful in judo, athletes must be highly physically fit, possess specific technical and tactical skills, and be able to react adequately to their opponents' actions. This study aimed to identify the relationships between judoka performance effectiveness and selected elements of physical and functional fitness. Research at the highest level shows that sports success is not only determined by a high level of physical fitness (Kalina et al., 2005). Preparing an athlete for the wide range of activities required in a sport necessitates incorporating fundamental movement analysis into the screening process prior to deciding to undertake sports training. It is necessary to determine whether the athlete can perform basic functional patterns correctly. In this regard, the FMS is an evaluation tool that allows athletes to be assessed from functional and dynamic perspectives. It offers a different approach to injury prevention and allows a degree of predictability of outcomes. Incorporating the FMS into a comprehensive assessment could lead to more personalised, specific and functional recommendations for motor preparation in judo. One cause of abnormal movement patterns is past injury. One possible reason for this is a reduction in proprioception that has not been rehabilitated or has been rehabilitated incorrectly. This can result in asymmetry, reduced stability or mobility and lead to compensatory movement patterns. Analysing scores earned in the FMS can help identify individuals at higher risk of injury and inform injury and judo training prevention strategies (Boguszewski et al., 2019; Simenko, 2019; Garcia-Luna et al., 2020).

The exercises used in the FMS test are primarily performed in the sagittal plane. However, in sports, most movements are multiplanar. Furthermore, FMS tasks are performed relatively slowly.

Perhaps other screening tools that emphasise different planes of movement and a faster tempo will be more effective at differentiating between physical fitness and skills, as demonstrated in the study. The relationships between the results of individual FMS tasks and the victory rate are interesting. Strong positive correlations were noted for the deep squat, hurdle step, in-line lunge and trunk stability tests among all groups. The deep squat test may indicate the ability to fight effectively in *tachi-waza* (standing techniques) a movement used in techniques such as *seoi-nage*. The hurdle step and in-line lunge tests require a high level of balance, which is useful for *ashi-waza* (leg techniques) such as *uchi-mata* and *o-soto-gari*. A high score in the trunk stability push-up test may indicate skill in *ne-waza* (ground techniques) fighting, particularly in *osae-komi-waza* (immobilization) techniques. These techniques are characterised by their effectiveness (Boguszewski, 2016). The differences in FMS between medalists and non-medalists can be explained by the technical advancement of judokas. In judo, techniques are usually practised bilaterally. Performing judo techniques on both sides demonstrates sporting ability and technical proficiency. Less advanced judokas tend to practise on their preferred side more often (Stefanovsky et al., 2025). However, the way in which competitors resolve their fights was not analysed, which could be an interesting area for future research.

The variety of training methods used and their technical complexity can predispose athletes to overuse injuries. In our study, ten players (22%) scored 14 points or fewer out of a possible 21, indicating an increased risk of injury (Bunn et al., 2019). Based on a review of studies, Bunn et al. (2019) concluded that high-risk individuals (with scores of 13–14 points or less) were up to 51% more likely to be injured than others. A study by Kiesel et al. (2007) based on footballers showed that athletes with scores of 14 points or less and a history of injuries were up to 15 times more likely to be injured than athletes with higher scores (Kiesel et al., 2007). Although there is much research in the area of combat sports and martial arts, the issue of competitive efficiency undoubtedly requires further scientific exploration (Boguszewski et al., 2019; Jaworski et al., 2020; Branco et al., 2022; Öztürk et al., 2022; Demirci et al., 2023; Dopico-Calvo et al., 2024).

The quality of movement patterns may reflect not only susceptibility to injury and musculoskeletal pain, but also physical conditioning. Adamczyk et al. (2015) and Barbado et al. (2016) indicated the relationship between the sports skill level of athletes and postural muscle fitness, quality of movement and degree of functional limitations.

One element of the assessment (as part of the FMS) is the occurrence of pain during exercise. Therefore, it can be supposed that athletes who experience pain are less effective at completing the movement tasks involved in their sport. However, some authors emphasise that the relationship between FMS test scores and physical fitness is weak (Okada et al., 2011; Lockie, 2015a, 2015b; Armstrong, 2021; Krkeljas & Kovac, 2021). The present study found a significant correlation between strength tests and selected single FMS tests (trunk stability, push-up and rotational stability). However, no correlation was found in most tests. There were also no significant correlations between strength tests and the efficacy of judo matches. It should be noted, however, that the conditions of a sporting contest and a strength test are significantly different. During a fight, a judoka must make quick decisions and perform advanced techniques in response to their opponent's actions. Therefore, strength tests are not good predictors of success in judo.

The strongest correlations were found between the FMS score and the competitive performance of judokas, such as the percentage of wins and the number of bouts won. The effectiveness of fitness tests depends to some extent on the ergonomics of movement. Therefore, more successful athletes tend to have lower levels of functional limitations (Boguszewski et al., 2017). The strongest correlations were found in three tasks: deep squat, in-line lunge and trunk stability push-up. These tasks require strong core muscles. Furthermore, maintaining balance between the spine and upper (trunk stability push-up) and lower (deep squat, in-line lunge) limb muscles is important.

There are many factors that affect sporting performance, especially in non-quantifiable sports such as combat sports. Although the FMS is a subjective test, it can be a useful tool for assessing not only the risk of injury, but also the athlete's potential (Kullman et al., 2020; Kovac et al., 2021; Boguszewski et al., 2023). Therefore, it is advisable to continue with FMS testing, especially in sports where there is a high incidence of injury. This will enable coaches to prepare training schemes that



avoid injury, which often brings careers to a premature end. The low cost and the ability to assess multiple dimensions of movement rather than particular fitness indicators may be considered advantages of the test.

The limitations of the study were the subjectivity of the functional tests. However, the FMS test is one of the main methods used by physiotherapists to assess movement quality, symmetry, and asymmetry; functional limitations of the musculoskeletal system; and the risk of injury in sport. Each FMS score is clearly defined. Moreover, each task can be repeated twice (to ensure accuracy of assessment). Another advantage of the FMS is its simplicity and the fact that it can be performed anywhere (e.g. in a sports hall) during a training session without the need for any special tools. Another limitation of the study was the small sample size, which affects type II error and study power; therefore, the results should be interpreted with caution. However, these participants were intentionally selected – they were high-level Polish judo competitors.

5. Conclusions

Judokas with higher competitive performance scored better on the FMS test. Therefore, judo training should take into account the functional limitations of the musculoskeletal system and focus on improving movement quality. Low correlations were found between muscle strength test results and competitive performance. It can therefore be assumed that this motor ability is not critical in judo. Most professional judo players had a limited range of joint movement. This may be evidence of insufficient stretching during training. Therefore, special attention should be paid to this element of training. Physiotherapeutic functional assessment tests can be useful in identifying muscle imbalances, mobility restrictions or asymmetry, and in applying appropriate interventions to address these issues, thereby helping to prevent injury and improve sports performance.

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