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ORIGINAL ARTICLE

Correlations between the Functional Movement Screen (FMS), dynamic balance, and vertical jumping ability in men and women

Korelacje między Testem Funkcjonalnej Sprawności Fizycznej (FMS) a równowagą dynamiczną i zdolnością do skoków w pionie u mężczyzn i kobiet

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A – Koncepcja i projekt badania, B – Gromadzenie i/lub zestawianie danych, C – Analiza i interpretacja danych, D – Napisanie artykułu, E – Krytyczne zrecenzowanie artykułu, F – Zatwierdzenie ostatecznej wersji artykułu

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Abstract

Introduction and Objective. The currently-promoted method of studying movement for injury prediction takes into consideration overall movement patterns and functions, including balance, range of motion, strength, muscle flexibility and coordination that are necessary for achieving optimal sports results. The FMS concept allows for a comprehensive analysis of the quality of movement patterns, determining the existence of restrictions, asymmetry and compensation, as well as a global assessment of the activity of the musculoskeletal system and motor control. The aim of the study was to assess the relationship between the Functional Movement Screen (FMS) test and dynamic balance and vertical jumping ability in both men and women.

Materials and method. Twenty-two participants (11 females and 11 males) were included in the study. The subjects performed the FMS test, Drift Protocol (DP) test and the Countermovement Jump (CMJ) test. Parameters of dynamic balance and jumping were recorded using the Optogait optical measuring system.

Results. Analysis of FMS score revealed that females had slightly better results in active straight leg raise than males. There was significant correlation between the total FMS score and DB parameters in men, but not in women.

Conclusions. In terms of jumping abilities, total FMS score was related to the CMJ parameters (contact time, power, frequency) in males, but not in females. Some FMS component tests were associated with DP and CMJ in both males and females, but the topic requires confirmation in future studies and should be interpreted with caution.

Key words

motor screening, dynamic stability, sex comparison

Streszczenie

Wprowadzenie i cel pracy. Obecnie promowana metoda badania ruchu w celu przewidywania urazów uwzględnia ogólne wzorce i funkcje ruchowe, w tym równowagę, zakres ruchu, siłę, elastyczność mięśni i koordynację, które są niezbędne do osiągnięcia optymalnych wyników sportowych. Koncepcja FMS pozwala na kompleksową analizę jakości wzorców ruchowych, określenie występowania ograniczeń, asymetrii i kompensacji oraz całościową ocenę czynności narządu ruchu i kontroli motorycznej. Celem pracy była ocena związku testu Functional Movement Screen (FMS) z równowagą dynamiczną i zdolnością do wyskoków pionowych u kobiet i mężczyzn.

Materiał i metody. W badaniu wzięło udział 22 uczestników (11 kobiet i 11 mężczyzn). Badani wykonywali test FMS, test Drift Protocol (DP) oraz test wyskoku pionowego (CMJ). Za pomocą optycznego systemu pomiarowego Optogait rejestrowano parametry równowagi dynamicznej i skoków.

Wyniki. Analiza wyniku FMS wykazała, że kobiety uzyskały nieco lepsze wyniki w aktywnym uniesieniu wyprostowanej nogi niż mężczyźni. Istnieje istotna korelacja między całkowitym wynikiem FMS a parametrami DB u mężczyzn, ale nie u kobiet.

Wnioski. W zakresie zdolności skokowych łączny wynik FMS był powiązany z parametrami CMJ (czas kontaktu, siła, częstotliwość) u mężczyzn, ale nie u kobiet. Niektóre testy składowe FMS były związane z DP i CMJ zarówno u mężczyzn, jak i u kobiet, ale wymaga to potwierdzenia w przyszłych badaniach i takich interpretacji należy dokonywać z ostrożnością.

Słowa kluczowe

badania przesiewowe, równowaga dynamiczna, porównanie płci

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INTRODUCTION

Incomplete preparation before starting training may produce incorrect patterns that reinforce poor quality of movement, creating a greater predisposition to injuries [1]. There are no evidence-based guidelines for resuming physical activity [2]. The currently-promoted method of studying movement for injury prediction considers overall movement patterns and functions. These include balance, range of motion, strength, muscle flexibility and coordination [2, 3].

The term that is used to define screening via movement analysis is 'Movement screen', used to detect dysfunction linked to increased risk of musculoskeletal injury or pathology [4]. There are many movement screens available that are designed to detect a weak movement pattern. Functional Movement Screen (FMS) is the only one that has consistently demonstrated good intra- and inter-rater reliability [5]. In many sporting activities the FMS is an inexpensive and quick tool for functional assessment [2, and is used to assess injury risk in athletic and non-athletic populations [4]. The FMS concept allows for a comprehensive analysis of the quality of movement patterns, determining the existence of restrictions, asymmetry, and compensation as well as a global assessment of the activity of the musculoskeletal system and motor control [6]. The seven tests of the FMS include a Deep Squat, Hurdle Step, In-line Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push Up, and Rotary Stability [7]. The final score of the test is the sum of the points of the seven motor tests [**2**]. The FMS is used to determine whether a person is able to perform patterns above the minimum standard set by scoring [**7**]. The balance assessed with the FMS consists of mobility and stability in which te ability of the neuromuscular system to move completely and painlessly, whereas stability is active muscle control

Dynamic balance is achieved when body stability is maintained during movements [8]. It is required for locomotion skills such as walking and running, and therefore dynamic balance is a key element in preventing sports injuries [9]. However, many studies of the relationship of the FMS and dynamic balance have been carried out using mainly the Y-Balance test and the Star Excursion [10–15]. In most studies, the tests used were based on the subject's immobile position, in which the subject reaches out with a limb or tilts the whole body in a certain direction [16]. To date, there is limited research on the relationship between FMS and the dynamic balance in which the base of support changes. Such a test could be The Drift Protocol (DP), a test that analyzes the dynamic stability during a series of single-leg jumps [16].

Counter-movement jump (CMJ) is a vertical jump that begins with standing then lowering eccentrically into a squatting position, followed by a concentric rising phase into take-off [17]. This is a valuable test for measuring functional performance. FMS and CMJ tests are both field tools that can be used for the benefit of athletes and exercisers to identify injury risk and to assess performance [18]. Gender-related differences in FMS performance were previously noted within physically fit adults and children; thus, according to up-to-date reports, these differences should be taken into consideration when designing specific exercise programmes [19, 20]. it is important to know the association between the assessed neuromuscular abilities to support the development of interventions that reduce the risk of injury [21].

OBJECTIVE

The study was aimed at people who want to start training or return to training after a long break, and to assess the relationship between the FMS test and dynamic balance and vertical jumping ability in both men and women. It was hypothesized that FMS is associated to DP and CMJ parameters in both men and women, but probably in different ways.

MATERIALS AND METHOD

The study was conducted on 11 female adult students (n = 11, median age – 19 ± 1.21) and 11 male adults (n = 11, median age – 19 ± 0.93). The participants did not report any pain and did not practice any sports professionally. All participants were right-footed (the leg preferred to kick the ball).

All respondents provided written consent to participate in the study which was approved by the Ethical Committee at the Medical University in Lublin (Approval No. KE-0254/93/2020), and conducted according to the Declaration of Helsinki. All participants were informed about the aims of the study and were given the opportunity to ask any questions and to withdraw from participation at any point. To collect anthropometric data, a questionnaires was completed at the start of the study by the tester, based on weight and heigh measurements. There were statistically significant differences in height (M=179.36 vs M=167.36, ES=2.23; p < 0.001) and weight (M=81.70 vs M=65.82, ES=1.29; p=0.01) between males and females, respectively. There were no statistically significant differences between males and females in Body Mass Index (BMI) and age (Tab. 1).

Table 1. Group characteristics

Variable	Females N=11		Males N=11		Statistics	
	M	SD	M	SD	t / Z	P
Age [years]	19.64	1.21	19.45	0.93	0.33	0.74
Height [cm]	167.36	5.52	179.36	5.26	-5.22	< 0.001***
Weight [kg]	65.82	12.14	81.70	12.53	-3.02	0.01**
BMI [kg/m²]	23.49	4.19	25.31	3.09	-1.16	0.26

M – means; Me – medians; SD – standard deviations; BMI – body Mass Index; t – Student's t test; Z – the Mann Whitney U-test.
* Significant difference (* – p ≤ 0.05; ** – p ≤ 0.01; *** – p ≤ 0.001)

All participants were first tested with the FMS test and then performed DP and CMJ. Both, DP and CMJ were captured using the optical system Optogait (Microgate, Bol-zano, Italy).

Functional Movement Screen. The FMS consists of 7 movement patterns with 3 challenge tests. Each pattern is scored from 0 – pain occurring during the task, to 3 – making the movement according to the guidelines [2]. In order to evaluate the FMS, participants were individually asked to perform the following patterns: deep squat, hurdle-step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability test [14]. Instructions for the execution of each pattern were given orally. Each pattern was repeated 3 times to allow the investigator adequate observation from different angles. The best sample was assessed. In the case of bilateral tests, a lower value was given [6]. Each pattern was scored on a scale of 0–3: 3 points for correct performance of the pattern, 2 points when the execution of the pattern required compensation, and 1 point for an incorrect execution of the pattern or inability to correctly perform it. Participants who experienced pain during exercise or the provocation tests (active shoulder impingement, trunk flexion, and trunk extension tests) were scored 0 (2). The right and left sides were rated in 5 out of 7 tests (hurdle-step, in-line lunge, shoulder mobility, active straight leg, rotary stability test) [22].

In instances when one side was weaker than the other, the final score was the lower score. The FMS was assessed by a qualified physical therapist trained to evaluate the screening test. The maximum score in the FMS test is 21, and scores of ≤14 are associated with an increased risk of injury [23].

Dynamic balance and jumping abilities. After the FMS test, the subjects performed the DP and CMJ tests on the Optogate device. DP is a high quality, reliable diagnostic tool for assessing dynamic balance in both athletes and non-athletes [24]. Two Optogate bars with photocells were placed parallel to each other at a distance distance of approximately one-meter. The jumps were preceded by a 10-minute standardized warm-up, including vertical jumps with and without arm swings and stretching. DP jumps were repeated twice, keeping the foot parallel and perpendicular to the sensors. Participants were instructed to perform 5 jumps on the right leg and then on the left leg in random order after hearing the command to jump as fast as possible and as high as possible in one place [16]. After a 5 minute break, the participants were invited to perform vertical jumps. CMJ testing is a method of vertical jumping and demonstrates the explosive power that can be generated by the lower extremity muscles during sport tasks that also requires rapid development of strength and power [18]. The starting position was to stand upright with the gaze directed straight ahead. The subjects were instructed to keep their hands on their hips, before and during the jump. On the command: 'Jump as high as possible', the subject performed 1 jump [25]. Everyone made 3 jumps from which the average was calculated. The subjects then performed a series of CMJ without arm swing, consisting in as many jumps as possible within 15 seconds. The rest time between CMJ and CMJ-15 s was 2 minutes. The positions for the DP and CMJ are presented in Figure 1.

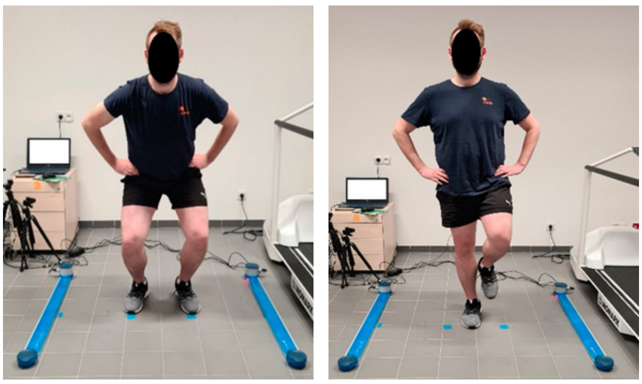

Figure 1 (a). Initial position for the DP; **(b)** initial position for the CMJ.
DP – drift protocol; CMJ – Countermovement Jump

During DP and jumping tests the following variables were analyzed: jump height (H), power (P), jump flight time (FT), ground contact time during jumps (CT), average displacement of the jumping point during jumps (drift) in the anteroposterior direction (DR-AP), average displacement of the jumping point during jumps (drift) in the mediolateral direction (DR-ML), standard deviation of the average drift in ML (SD-DR-ML), standard deviation of the average drift in AP (SD-DR-AP), and the area occupied during jumping (Area). All parameters were analyzed for both legs separately and described by R (right) and L (left) in the variable names.

Statistical analysis. Data analysis was conducted using Statistica software (ver. 13.1, TIBCO Software Inc., Palo Alto, CA, USA). The normal distribution of the data was verified with the Shapiro-Wilk test. For normally distributed data the independent t-test was used and for non-normally distributed data the Mann Whitney U- test was used to determine differences in FMS score and jump parameters between males and females. Effect sizes (ES) were determined for statistically significant results by the Cohen's d coefficient and the r correlation coefficient. Cohen's coefficient was interpreted as: small (0.2–0.5), moderate (0.5–0.8), or large (>0.8) and correlation r: small (0.1–0.3) moderate (0.3–0.5.) and large (>0.5) The Spearman rank correlation was used to examine the relationships between the FMS score and jumping parameters (0.3–0.5 -low, 0.5–0.7 moderate and <0.7 strong correlation). The data were presented as means (M), medians (Me), minimal (Min) and maximal (Max) values and standard deviations (SD). The significance level was set at p=0.05 [26].

RESULTS

Comparison of male and female FMS. Analysis of FMS score revealed that females had slightly better results in active straight leg raise than males (Me=2.00 vs Me=2.00, ES=0.61; p < 0.01). There were no other statistically significant differences between males and females in FMS scores (Tab. 2).

Table 2. Results of FMS test in males and females

Variable	Females; N=11			Males; N=11			Statistics	
	Me	Min	Max	Me	Min	Max	Z	p-value
Deep squat	2.00	1.00	3.00	2.00	1.00	3.00	1.16	0.25
Hurdle step	2.00	2.00	3.00	2.00	2.00	2.00	0.91	0.36
In-line lunge	3.00	1.00	3.00	3.00	1.00	3.00	1.34	0.18
Shoulder mobility	3.00	1.00	3.00	3.00	1.00	3.00	0.85	0.40
Active straight leg raise	2.00	2.00	3.00	2.00	1.00	2.00	2.90	< 0.01**
Trunk stability push up	2.00	1.00	3.00	3.00	0.00	3.00	-1.86	0.06
Rotational stability	2.00	1.00	2.00	2.00	1.00	2.00	0.07	0.95
Total FMS score	16.00	9.00	19.00	15.00	10.00	17.00	1.34	0.18

Me – median; Min – minimal value; Max – maximal value; Z – the Mann Whitney U-test.
* Significant difference (** – p ≤ 0.01)

Comparisons of DP and CMJ parameters between males and female. Analysis of DP parameters showed that only ground contact time of left leg was slightly greater in males than in females (Me=0.49 vs Me=0.36, ES=0.46, p=0.03). There

Table 3. Comparisons of DP, CMJ and CMJ-15 s parameters between males and females

DP	Females; N=11			Males; N=11			Statistics	
	Me	Min	Max	Me	Min	Max	Z	p-vaue
H L [cm]	6.46	2.51	12.26	8.15	6.73	15.44	-1.90	0.06
H R [cm]	6.94	1.63	11.33	8.85	6.60	16.31	-1.90	0.06
P L [W/Kg]	9.87	4.74	33.11	9.78	7.22	16.87	-0.07	0.95
P R [W/Kg]	9.42	3.35	12.87	11.29	8.20	17.98	-1.18	0.24
CT L [s]	0.36	0.30	1.06	0.49	0.32	0.75	-2.17	0.03*
CT R [s]	0.38	0.31	0.76	0.49	0.32	0.69	-1.44	0.15
DR-ML L [cm]	0.01	-6.00	3.50	-0.10	-3.10	1.50	0.36	0.72
DR-ML R [cm]	0.70	-1.80	6.10	0.40	-2.30	3.80	0.33	0.74
DR-AP L [cm]	0.20	-4.80	3.00	0.80	-3.80	3.50	-0.85	0.39
DR-AP L[cm]	0.40	-2.20	6.00	1.30	-4.80	4.10	-0.23	0.82
SD-DR-ML L [cm]	9.00	1.80	16.00	4.40	1.90	22.40	0.95	0.34
SD-DR-ML R [cm]	7.30	2.60	10.40	7.60	2.90	40.30	-0.76	0.45
SD-DR-AP L [cm]	5.70	3.80	12.00	6.60	2.50	14.90	-0.33	0.74
SD-DR-AP R [cm]	6.30	4.30	18.40	6.30	3.00	24.30	0.26	0.79
Area L [cm2]	177.60	43.60	698.20	174.90	30.50	504.10	0.46	0.65
Area R [cm2]	180.80	48.10	549.90	190.70	35.00	871.80	-0.79	0.43
Power density [W/Kg/dm2] L	5.09	2.33	27.56	8.69	2.34	37.64	-0.39	0.69
Power density [W/Kg/dm2] R	4.08	1.66	19.90	5.09	1.41	24.06	0.07	0.95
CMJ								
H [cm]	15.87	11.97	26.00	28.17	19.60	44.57	-3.41	0.001***
CT [s]	0.69	0.37	1.47	0.89	0.50	2.08	-0.98	0.32
P [W/kg]	12.38	10.85	24.57	19.48	12.94	24.07	-2.04	0.04*
CMJ- 15 seconds								
H [cm]	16.48	9.05	25.19	25.35	13.07	39.04	-2.56	0.01**
CT [s]	0.34	0.27	0.65	0.66	0.23	0.82	-2.36	0.02*
P [W/kg]	17.79	11.77	29.01	20.98	12.05	31.46	-0.98	0.32
Frequency [step/ s]	1.49	0.95	1.64	0.95	0.81	1.81	2.63	0.01**

Me – median; Min – minimal value; Max – maximal value; Z – the Mann Whitney U-test; R – right; L – left; H – jump height; CT – ground contact time during jumps; P – power; DR-ML – average displacement of the jumping point during jumps (drift) in the mediolateral direction; DR-AP – average displacement of the jumping point during jumps (drift) in the anteroposterior direction; SD-DR-ML – standard deviation of the average drift in ML; Dd-DR-AP – standard deviation of the average drift in AP; Area – the area occupied during jumping.
* Significant difference (* – p ≤ 0.05; ** – p ≤ 0.01*** – p ≤ 0.001).

were no significant differences between males and females in other variables. CMJ height was significantly greater in males than in females (Me=28.17 vs Me=15.87, ES=0.72; p=0.001). Power was also greater in males than females during jumping (Me=19.48 vs Me=12.38, ES=0.43; p=0.04). Jump heights and contact times were greater in males than females during 15s of CMJ (Me=25.35 vs Me=16.48, ES=0.54; p=0.01; Me=0.66 vs Me=0.34, ES=0.50; p=0.02, respectively). The frequency of jumps was lower in males than in females (Me=0.81 vs Me=1.49, ES=0.56; p=0.01) (table 3).

Correlation between FMS and DP / Correlation of FMS with DP. In females, positive correlations were found between jump height and push-up (r=0.62, p=0.04); the area occupied during jumping – R and push-up (r=0.62, p=0.04). Negative correlations were found between average displacement of the jumping in the mediolateral direction – L and active straight leg raise (r=-0.61; p=0.04) and shoulder mobility (r=-0.64; p=0.04).

In males, positive correlations was found between power R and L and deep squat score (r=0.7, p=0.01; r=0.68; p=0.02); power L and lunge (r=0.67; p=0.02), standard deviation of the average drift in AP R and shoulder mobility (r=63; p=0.04), active straight leg raise (r=0.71; p=0.01) and total FMS (r=0.75; p < 0.01); the area occupied during jumping R and deep squat (r=0.63; p=0.04), total FMS (r=0.65; p=0.03). Negative correlations were found between ground contact time R and L and deep squat (r=-0.72; p=0.01; r=-0.72; p=0.01), lunge (r=-0.65; p=0.03; r=-0.81, p < 0.01) and total FMS (r=-0.70; p=0.02; r=-0.76; p < 0.01), average displacement during jumps (drift) in the anteroposterior direction R and shoulder mobility (r=-0.69; p=0.02) and active straight leg raise (r=-0.75; p < 0.01) (Tab. 4).

Correlation between FMS and CMJ without arms swing. In females, the jump height was strongly positively correlated with trunk stability push up (r=0.70; p=0.02). In males, power was significantly moderately correlated with deep squat score (r=0.64; p=0.04) (Tab. 5).

Correlation between FMS and CMJ-15 s. In females, a moderate positive correlation was found between jump height and shoulder mobility (r=0.61; p=0.046). In males, contact time was significantly, strongly and moderately negatively corelated with deep squat score (r=-0.62; p=0.04), push-up (r=-0.67, p=0.02) and total FMS score (r=-0, 76; p < 0.01).

Table 4. Correlation between FMS scores and drift protocol parameters

Variable	F/M	Deep squat	Hurdle step#	In-line lunge	Shoulder mobility	Active straight leg raise	Trunk stability push up	Rotational stability	Total FMS test
H L [cm]	F	0.47	-0.20	0.50	-0.03	-0.12	0.51	0.50	0.09
	M	0.35	-	0.52	0.28	0.06	-0.20	0.50	0.22
H R [cm]	F	0.47	-0.30	0.50	-0.03	-0.12	0.62*	0.50	0.14
	M	0.49	-	0.23	0.08	0.06	0.10	0.00	0.21
P L [W/Kg]	F	0.20	-0.30	0.50	-0.03	0.06	0.12	0.50	-0.15
	M	0.68*	-	0.67*	0.40	0.24	0.05	0.50	0.56
P R [W/Kg]	F	0.27	-0.30	0.50	-0.09	-0.12	0.51	0.50	0.02
	M	0.71*	-	0.58	0.29	0.18	0.22	0.20	0.54
CT L [s]	F	0.40	0.30	0.10	0.08	-0.17	0.27	0.10	0.23
	M	-0.72*	-	-0.81**	-0.27	-0.30	-0.27	-0.50	-0.76**
CT R [s]	F	0.27	0.00	-0.10	0.21	-0.06	-0.16	-0.10	0.03
	M	-0.72*	-	-0.65*	-0.41	-0.42	-0.14	-0.50	-0.70*
DR-ML L [cm]	F	-0.37	0.00	-0.15	-0.64*	-0.61*	0.27	-0.15	-0.39
	M	0.12	-	0.34	0.07	0.06	0.15	0.30	0.30
DR-ML R [cm]	F	-0.13	0.10	0.20	-0.14	-0.46	0.04	0.20	-0.31
	M	0.17	-	0.40	-0.14	-0.06	0.44	0.10	0.41
DR-AP L [cm]	F	0.30	-0.20	0.10	0.19	-0.20	0.29	0.10	0.09
	M	-0.22	-	-0.31	-0.30	-0.57	0.33	-0.40	-0.30
DR-AP R [cm]	F	0.07	0.20	0.20	0.38	0.23	-0.23	0.20	0.10
	M	-0.15	-	0.01	-0.69*	-0.75**	0.32	-0.35	-0.25
SD-DR-ML L [cm]	F	0.20	-0.20	0.10	0.08	-0.17	-0.08	0.10	-0.17
	M	0.08	-	0.05	0.51	0.27	-0.05	0.50	0.20
SD-DR-ML R [cm]	F	0.34	-0.40	0.30	-0.01	-0.35	0.35	0.30	-0.16
	M	0.30	-	-0.12	0.05	-0.18	0.26	-0.30	0.02
SD-DR-AP L [cm]	F	0.07	0.30	0.50	0.09	-0.23	-0.27	0.50	-0.29
	M	-0.42	-	-0.37	-0.13	0.06	-0.18	-0.20	-0.29
SD-DR-AP R [cm]	F	-0.07	0.10	0.00	-0.52	-0.46	0.43	0.00	-0.18
	M	0.41	-	0.23	0.63*	0.72*	0.32	0.40	0.75**
Area L [cm2]	F	0.20	-0.10	0.20	0.15	-0.17	-0.16	0.20	-0.19
	M	-0.07	-	-0.24	0.44	0.30	-0.10	0.40	0.07
Area R [cm2]	F	0.13	-0.20	0.10	-0.45	-0.52	0.62*	0.10	-0.16
	M	0.63*	-	0.21	0.41	0.36	0.38	0.40	0.65*
Power density L [W/Kg/dm2]	F	-0.27	-0.10	-0.10	-0.25	0.12	0.16	-0.10	0.02
	M	0.28	-	0.36	-0.23	-0.12	0.17	-0.30	0.16
Power density R [W/Kg/dm2]	F	0.07	0.30	0.20	0.56	0.52	-0.31	0.20	0.37
	M	-0.44	-	0.03	-0.38	-0.30	-0.48	-0.30	-0.55

M – males; F – females; R – right; L – left; H – jump height; CT – ground contact time during jumps; P – power; DR-ML – average displacement of the jumping point during jumps (drift) in the mediolateral direction; DR-AP – average displacement of the jumping point during jumps (drift) in the anteroposterior direction; SD-DR-ML – standard deviation of the average drift in ML; SD-DR-AP – standard deviation of the average drift in AP; Area – the area occupied during jumping.
There is no correlation to the male hurdles step due to the fact that all participants got the same score.
* Significant difference (* – $p \leq 0.05$; ** – $p \leq 0.01$*** – $p \leq 0.001$)

Positive correlations were found between power and deep squat ($r=0.75$; $p < 0.01$), lunge ($r=0.63$; $p=0.04$), FMS total score ($r=0.61$; $p=0.047$). Frequency was positively moderately and strongly correlated with deep squat score ($r=0.60$; $p=0.049$), push-up ($r=0.78$; $p < 0.01$) and FMS total score ($r=0.76$; $p < 0.01$) (Tab. 6).

DISCUSSION

The study investigated dynamic balance using the DP, and jumping ability using the CMJ tests. The results of the study confirmed the hypothesis that there is a relationship between the tested motor skills and FMS in some aspects, both in women and men. Individual parameters of the FMS test were analyzed.

The FMS analysis showed one statistical significance in the FMS results between men and women. Women performed better than men at actively lifting a straight leg. Similar data were obtained by Schneiders et al., whose results also indicated that women coped better in the test of active straight leg lifting [27]. The difference may be because women tend to be stretched much more than men [28]. The lack of differences in the other components of FMS may indicate that gender

Table 5. Correlation between FMS scores and CMJ parameters.

Variable	F/M	Deep squat	Hurdle step#	In-line lunge	Shoulder mobility	Active straight leg raise	Trunk stability push up	Rotational stability	Total FMS test
H [cm]	F	0.54	-0.40	0.50	-0.03	-0.12	0.70*	0.50	0.15
	M	0.34	-	0.16	-0.07	0.00	0.05	-0.20	0.06
CT [s]	F	0.34	0.00	0.10	0.60	0.40	-0.16	0.10	0.39
	M	-0.43	-	-0.23	0.39	0.12	-0.06	0.10	-0.07
P [W/kg]	F	0.20	-0.50	0.20	-0.37	-0.23	0.54	0.20	-0.15
	M	0.64*	-	0.39	-0.07	0.18	0.12	0.00	0.34

M – males; F – females; H – jump height; CT – ground contact time during jumps; P – power. There was no correlation between the male hurdles step due to the fact that all participants obtained the same score.
* Significant difference (* – $p \leq 0.05$; ** – $p \leq 0.01$; *** – $p \leq 0.001$)

Table 6. Correlation of FMS scores and CMJ-15s parameters

Variable	Female/ Male	Deep squat	Hurdle step#	In-line lunge	Shoulder mobility	Active straight leg raise	Trunk stability push up	Rotational stability	Total FMS test
H [cm]	F	0.40	-0.30	0.50	0.61*	0.35	0.08	0.50	0.26
	M	0.28	-	0.16	-0.12	0.06	-0.15	-0.30	-0.05
CT [s]	F	0.07	0.40	-0.10	-0.08	-0.35	0.08	-0.10	0.06
	M	-0.62*	-	-0.56	-0.13	-0.18	-0.67*	-0.10	-0.76**
P [W/kg]	F	0.27	-0.40	0.50	0.44	0.52	0.00	0.50	0.17
	M	0.75**	-	0.63*	0.17	0.36	0.24	0.00	0.61*
Frequency [step/ s]	F	-0.47	-0.40	-0.50	-0.38	0.17	-0.43	-0.50	-0.39
	M	0.60	-	0.39	0.06	0.12	0.78**	0.20	0.76**

M – males; F – females; H – jump height; CT – ground contact time during jumps; P – power. There was no correlation with the male hurdles step due to the fact that all participants obtained the same score.
* Significant difference (* – $p \leq 0.05$; ** – $p \leq 0.01$; *** – $p \leq 0.001$)

has no effect on the assessed aspects of physical fitness. Thus, the usefulness of the test for the assessment of representatives of both genders is confirmed.

In women, positive correlations were found between the height of the jump and the push-up. There was no correlation between total FMS and DP. Research shows that there is a significant relationship between FMS and DP and CMJ in child tennis players [29]. Mobility disorders, and thus balance disorders, may increase the risk of injuries even in healthy children [8, 30]. Incorrect stabilization on the part of the myofascial system leads to excessive stress on the locomotor system. In an inefficient kinematic chain, the acting forces are dissipated ineffectively or the weakest link of the chain is damaged, which may be associated with micro- and macro-injuries [7, 30].

Leili et al. investigated whether dynamic neuromuscular stabilization (DNS) training could improve FMS scores by assigning participants to 2 groups. They found that a 6-week DNS training had a much better effect on improving FMS than the physical fitness training performed by a second group [31]. Based on the current study, it is proposed that the stabilization and neuromuscular control also significantly influences the result in the DP of the Optojump system. The same view is shared by Słomka et al. [32]. The DP is expressed as the displacement of the jump point during 5 consecutive vertical jumps. The result is considered satisfactory when the participant controls high-power jumps and is able to minimize body displacement. Sharma et al. reported an improvement in volleyball players' jumping performance after a 9-week exercise programme [33]. This requires adequate stabilization and control of the neuromuscular system and provides evidence for the benefits of stabilization training. Research supports the thesis that control of the dynamic balance might be affected by central stabilization (core stability) [34], defined as the ability to stabilize, ensuring proper balance, stance and energy distribution [7]. This speaks for the benefits of stabilization training. However, Ozmen did not show that core stability has a significant impact on DP [9]. Despite the small amount of evidence, the inclusion of a trunk stabilization programme in the training reduces the number of injuries [35].

The results of the current study show no significant correlation between total FMS scores and DP scores in women. In men, on the other hand, there was a statistically significant correlation between the total FMS score and the standard deviation of AP displacement on the dominant right leg, which leads to the conclusion that there is a relationship between core stability and dynamic equilibrium. The observed lack of correlation between the total FMS score and the DB in women requires confirmation in future studies.

The correlation of FMS and CMJ between women and men is presented in Table 3 which shows that women jumped lower than men, and also had shorter flight times and weaker power. This may be because women have weaker leg muscles [36] and is related to the different muscle structure in men and women [37]. This is in agreement with previous research which also showed different neuromuscular control and jump performance in men and women [37–39]. Although there was no relationship between the total FMS score and the CMJ, there were some relationships between the CMJ and functional testing. In women, a positive correlation was found between the height of the jump and the push-up, while in men there was a positive correlation between the power of CMJ and the deep squat test. Squat depth during CMJ is not standardized; however, McMahon, when examining athletes, found that a lower centre of gravity shift translates into greater concentric contraction and a higher jump [40]. Jump height increases with increasing squat depth due to more time available for generating muscle strength [41]. Conlon generalizes that it is possible that someone may perform poorly on the vertical jump if they have a low score on the FMS Deep Squat [18].

The purpose of the push-up test is to check torso stabilization and core stability. The improvement of central stabilization is based on the activation of stabilizing muscles in order to improve the functionality of the body. This affects the quality of the movement generated by the torso, generating greater range, strength and reducing the risk of injury [7]. Core stability can affect the height of the CMJ [18]. Plyometric training (PT) also contributes to the improvement of stabilization and gives positive results in injury prevention rehabilitation of certain types of injuries [42]. Additionally, PT training improves vertical jump height in healthy people [43]. Relationships of FMS and CMJ-15 s shows that in males, positive correlations were found between power and deep squat, lunge and FMS total score. As in the deep squat, the In-Line Lunge also requires hip flexion to complete the task. The ability to perform the correct In-Line Lunde translates into better execution of the maximum vertical jump [18].

In females, a moderate positive correlation was found between jump height and shoulder mobility. The shoulder mobility test's primary effect on a CMJ relates to the level of shoulder extension during an arm swing that one can utilize during the eccentric loading phase [18]. However, in the current study, the participants did not use the arm swing in the test. The mobility of the arms in the FMS test may be affected by the functionality of the superficial anterior tape, which begins with the latissimus dorsi muscle. The latissimus dorsi muscle begins, ***inter alia,*** from the thoracolumbar fascia [44]. This fascia is the link that connects the upper limbs with the lower limbs. Correctly exercised thoracolumbar fascia improves the elastic rebound [45].

Limitations of the study. One of the limitations of this study was the small study group. It is therefore recommended repeating the research on a group of athletes. However, the study demonstrates that dynamic balance during single leg jumping, as well as parameters of two-leg vertical jumping, are associated to FMS scores. This should be taken into consideration when functional tests because the jumping and balance abilities of males and females are differently related to FMS score. It is noteworthy that the relationship between FMS component tests and dynamic balance or jumping ability is more common in males than in females. The deep squat score seems to be especially associated with vertical jumping abilities in males. Moreover, total FMS was also related to balance or jumping parameters only in males.

CONCLUSIONS

The correlation between the total FMS score and DP parameters was observed only in males, and refers to right leg drift in the anteroposterior direction and the area occupied by right foot. This is more importance for men and can be used as a test to assess the strength of the lower limbs. In terms of jumping abilities, total FMS score was related to the CMJ parameters (contact time, power, frequency) in males, but not in females. Some FMS component tests were associated with DP and CMJ in both males and females, but the topic requires confirmation in future studies and should be interpreted with caution. The presented study shows that the particular results obtained in the FMS test can be related to the parameters of dynamic balance and vertical jumps, and should be taken into account for both men and women. However, the total FMS score seems to be related to dynamic balance and jumping abilities only in males, which can have practical implications. It will help in designing preventive injury training, for example, by focusing on central stabilization and lower limb power training which increasing dynamic balance and jumping ability. It can also be a recommendation for people who want to start physical activity.

Abbreviations

Area – area occupied during jumping; **CMJ** – Counter-movement Jump; **CT** – ground contact time during jumps; **DP** – Drift Protocol; **DR-AP** – average displacement of jumping point during jumps (drift) in the anteroposterior direction; **DR-ML** – average displacement of jumping point during jumps (drift) in the mediola-teral direction; **FMS** – Functional Motion Screen; **H** – jump height; **L** – left; **M** – means; **Me** – medians; **PT** – plyometric training; **R** – right; **RSI** – Reactive Strength Index; **SD** – standard deviations; **Sd-DR-AP** – standard deviation of average drift in AP; **Sd-DR-ML** – standard deviation of average drift in ML; **SEBT** – Star Excursion; **YBT** – Y-Balance test [1]

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