

*Original Research*

# Correlations between Functional Movement Screening (FMS) Results and the Range of Motion of Lower Limb Joints Young Middle Distance Runners

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Submitted: 5 January 2022 Revised: 28 January 2022 Accepted: 24 February 2022 Published: 13 April 2022

## Abstract

**Background:** The relationship between range of motion (ROM) in lower limb joints and Functional movement screen still not clear. The aim of this study was therefore to investigate the correlation between Functional Movement Screening (FMS) results and ROM in lower limb joints. **Methods:** Forty-eight young middle distance runners (26 men and 22 women) performed an FMS test and a ROM test of the lower limb joints. Nonparametric testing was used to compare the ROM of left and right lower extremities, an independent-sample *T*-test was used to compare FMS test scores between left and right sides, and Spearman correlation was used to analyze relationships between FMS test results and ROM of lower limb joints. **Results:** A negative correlation was observed between left hurdle step and ROM of right knee flexion ( $r = -0.435, p < 0.05$ ), while a positive correlation was observed between right hurdle step and ROM of right ankle flexion ( $r = 0.392, p < 0.05$ ). A negative correlation was observed between left in-line lunge and ROM of left knee flexion ( $r = -0.508, p < 0.05$ ), while a positive correlation was observed between right in-line lunge and ROM of right hip extension ( $r = 0.445, p < 0.05$ ). A positive correlation was observed between left active straight-leg-raise and ROM of left hip flexion ( $r = 0.464, p < 0.05$ ), and a positive correlation between right rotary stability and ROM of right ankle extension ( $r = 0.393, p < 0.05$ ). The trunk-stability push-up and ROM of left ankle flexion was negatively correlated ( $r = -0.446, p < 0.01$ ). **Conclusions:** FMS test results were significantly correlated with ROM of hip, knee and ankle joints on the sagittal plane, with differences observed between the left and right sides. The ROM of flexion, extension of hip and extension of ankle were positively correlated with the FMS test results, while larger knee flexion and ankle flexion ROM were negatively correlated with FMS test results. We propose that excessive ROM of the knee and ankle could affect the development of stability. The results of this study should help to further our understanding of FMS.

**Keywords:** FMS test; range of motion; lower extremity; correlation

## 1. Introduction

Functional movement screening (FMS) is a system for systematically diagnosing basic abilities of the neuromuscular system, including accuracy, flexibility and stability, as well as for the standardization of motor control centered on basic movement functions of the human body [1,2]. The test consists of 7 functional movement modes including deep squats (DS), right and left hurdle step (HSr/HSI), in-line lunge (ILLr/ILLI), active straight leg raise (ASLRr/ASLRI), trunk-stability push-up (PU), rotary stability (RSr/RSI) and shoulder mobility (SMr/SMI) [3], as well as three pain screening tests. FMS is currently widely used in competitive sports as well as in other fields.

The action modes investigated by FMS are the flexibility and stability shown by the synergy of all joints in the body. The range of motion (ROM) of joints was also defined as flexibility [4]. Too much (hyperactivity) or too little (restricted mobility) ROM of the joint can negatively impact motion function and even cause injury [5]. The FMS and ROM screening tools contain symmetrical and

asymmetrical motor tasks that are based on observing different aspects of each task performance, but they also have some common features. Research has shown that static joint ROM affects the performance of dynamic joint ROM [6]. Some workers have postulated that ROM is an important factor that affects motion function [7–10]. Matthew [7] found that ROM of the hip joint affects the FMS total score, while Chimera [8] suggested the ROM of active lower limbs could predict the FMS total score. Diulian [9] found a correlation between the FMS test result and ROM of the hamstring muscle [10]. The FMS test involves multiple joint and plane motions. However, there is a lack of systematic research on the correlation between FMS test scores and the ROM for each joint of the lower extremity on each plane. This is critical for understanding the principle behind FMS.

Middle distance running is a cyclical sport of speed and endurance. The joints of the hip, knee, ankle, and feet are the main parts that bear the weight of the whole body [11]. In addition, the ROM of lower extremity joints is an important factor affecting the sport technique of middle and long-distance runners. The flexion angles of hip and knee



during running swing phrase, the angle of plantar flexion of ankle joints at the moment of lifting off the ground, and the ROM of ankle joint plantar flexion during the support phrase are all increase with the acceleration of the running speed [12]. Hoch [13] research showed that chronic ankle instability (CAI) patients have insufficient ankle flexion ROM, which has been proved to affect dynamic tasks such as jogging. Therefore, this study aims to explore the relationship between the movement patterns of the functional screening tests except the flexibility of the upper limbs and the ROM test of lower limbs among adolescent middle and long-distance runners.

This study will test the following hypotheses: (1) FMS test scores correlate with the ROM of lower limbs on each plane; (2) since the ROM of left and right joints may be different, the correlation of ROM with FMS test results may also be different for left and right joints; (3) joint ROM that is too low or too high may have a negative impact on FMS test scores.

## 2. Subjects and Methods

### 2.1 Subjects

For this study, 48 young middle-distance runners from two sports schools were selected as subjects. The study cohort included 26 male athletes (age  $15.62 \pm 1.80$  yrs, height  $169.14 \pm 7.56$  cm, weight  $53.08 \pm 7.89$  kg) and 22 female athletes (age  $14.51 \pm 1.52$  yrs, height  $157.93 \pm 4.94$  cm, weight  $46.60 \pm 5.31$  kg). The training period was for 2–4 years and all athletes volunteered to participate in the study. The dominant side for all participants was the right side. The inclusion criteria included: (1) no trunk or limb joint injuries within the previous 3 months; (2) normal participation in training; (3) no pain during the screening process for the FMS test.

### 2.2 Methodology

#### 2.2.1 FMS Test

The FMS test procedure was performed strictly according to FMS test standards [14,15]. Scoring standards for the 7 tests range from 0 to 3, with 3 points for the perfect state (normal functional movement mode), 2 points for inaccurate completion or compensatory movements, 1 point for completing the test with the body out of balance, and 0 points for any pain during the test, and the maximum total score is 21 points. Correlation analysis was performed using the left and right unilateral FMS action scores and the ROM on both sides, except for squats and trunk stable push-ups.

#### 2.2.2 Measurement of the ROM of Lower Extremity Joints

ROM refers to the amount of rotation available for a joint. This is a measure of joint or bone kinematics and is usually represented by ROM [4]. Passive joint range of motion (PROM) or active joint range of motion (AROM) can also be tested. According to the characteristics of the

FMS action and running events to select the measurement of ROM in the lower extremity joints. Select the left and right hip joints flexion, extension, adduction, abduction, internal rotation, and external rotation [7] Flexion, extension, ankle dorsiflexion, plantar flexion range of motion [10], use a protractor to measure its active ROM [16], the unit is ( $^{\circ}$ ). The passive joint activity measurement selects the commonly used lower limb closed joint chain knee-to-wall test (the Knee-to-Wall test) ROM for measurement (cm).

Measurement of ROM of the Hip, Knee, and Ankle of the Lower Limb:

#### (1) Hip ROM measurement

For the hip joint flexion ROM measurement: in the supine position, the center of the angle ulnar is placed at the greater trochanter of the femur, the fixed arm is parallel to the mid-axillary line of the trunk, the moving arm is the longitudinal axis of the femur, and the hip joint is flexed to the maximum range. For measurement of the hip joint extension range: in the prone position, the center of the angle ulnar is placed in the greater trochanter of the femur, the fixed arm is parallel to the mid-axillary line of the trunk, and the moving arm is the longitudinal axis of the femur to extend the hip joint to the maximum range. For the hip joint abduction ROM measurement: in the supine position, the center of the angle ulnar is placed on the anterior superior iliac spine, the fixed arm is the connection between the left and right anterior superior iliac spine, and the moving bone is the longitudinal axis of the femur. For measurement of hip adduction ROM: in the supine position, avoid thigh rotation, contralateral lower limb abduction, the center of the angle ruler is placed on the anterior superior iliac spine, the fixed arm is the connection between the left and right anterior superior iliac spine, and the moving arm is the longitudinal axis of the femur. For hip joint internal rotation and external rotation ROM measurement: in the sitting position, hip and knee joints flexed at  $90^{\circ}$ , both lower legs droop naturally, the center of the angle ulnar is placed at the center of the patella, the fixed arm is the vertical line passing through the center of the patella, the moving arm is the tibia on the longitudinal axis, perform internal or external rotation of the calf to the fullest extent [17].

#### (2) Knee ROM measurement

For knee joint flexion and extension ROM measurement: in the prone position, the center of the angle ulnar is placed on the lateral femoral condyle, the fixed arm is the longitudinal axis of the femur, the moving arm is the connection between the fibular head and the lateral malleolus, flexion or extension of the knee joint to the maximum range [17].

#### (3) Ankle ROM measurement

For ankle flexion and plantar flexion ROM measurement: in the sitting position, the ankle joint has no varus or valgus, the center of the angle ulnar is placed at the intersection of the longitudinal axis of the fibula and the extension line of the fifth metatarsal, the fixed arm is the longitudinal

**Table 1. FMS test results (n = 48).**

Event/Exercise	Score for each action		<i>p</i>
Total score	15.06 ± 1.49		-
Deep squat	1.96 ± 0.51		-
Trunk-stability push-up	2.08 ± 0.65		-
	Left Side (Mean ± SD)	Right Side (Mean ± SD)	
Hurdle step	2.21 ± 0.41	2.21 ± 0.41	1
In-line lunge	2.25 ± 0.44	2.29 ± 0.46	0.814
Shoulder mobility	2.85 ± 0.41	2.90 ± 0.37	0.814
Active straight-leg-raise	2.21 ± 0.82	2.17 ± 0.83	0.443
Rotary stability	1.92 ± 0.40	1.98 ± 0.39	0.063

axis of the fibula, the moving arm is the first long axis of the five metatarsals, ankle flexion or plantar flexion to the maximum range [17].

(4) Passive ankle flexion range measurement: knee-wall test

The knee-wall test is a test of the joint ROM of the lower extremity closed kinematic chain and is also a passive measurement of ankle joint dorsiflexion (DFROM). It has been shown to have good repeat test reliability (ICC = 0.96–0.99), which exceeds the ROM angle measurement reliability (ICC = 0.85–0.96) [18]. Studies have shown that neither the length of the knee-wall test foot nor the length of the calf affects the results of ankle DROM assessment [19]. The subject stands in a lunge facing the wall, places the toes of the test foot 10 cm away from the wall, pushes forward to make the knee touch the wall, and then moves the foot along the tape measure according to the distance, facing forward or backward each time. The wall is moved 1 cm once until the heel cannot touch the wall with the knee without leaving the ground. Maximum weight-bearing dorsiflexion is the maximum distance between the toes and the wall (cm). The contact between the heel and the ground is to feel the ascending movement of the heel by manually palpating the contact surface between the heel and the floor. The tester takes a measurement of the joint movement of the lower limbs on each leg [20].

### 2.2.3 Statistical Analysis

The age, height, weight, training years and test index results of the subjects were descriptively presented using the mean and standard deviation (Mean ± SD). The scores for each FMS test were grade values. Total scores were not normally distributed, however results for the joint ROM test were normally distributed. Nonparametric tests were used to compare measurements for ROM between the left and right lower extremities, and independent-sample *T*-test was used for comparison of the FMS score between the left and right sides. The 95% confidence interval was used throughout. *p* < 0.05 was considered to be statistically significant, while *p* < 0.01 was considered to be highly statistically significant. This study used SPSS19.0 software (IBM Corp.,

Chicago, IL, USA). Spearman correlation was used to analyze the relation between FMS test results and lower limb joint ROM. A correlation coefficient (*R*) of 0–0.30 signifies low correlation, 0.31–0.60 signifies moderate correlation, 0.61–0.89 signifies high correlation, and 0.9–1 is considered as approximately linear correlation [21].

### 3. Results

There were no significant differences (*p* > 0.05) between the left and right sides for FMS test results (Table 1). However, some asymmetries were found in the FMS test results of young middle- and long-distance runners (Table 2). Six athletes (12.5% of total) showed left/right asymmetry for hurdle step, In-line lunge and shoulder mobility, while 17 (35.4%) showed asymmetry for active straight-leg-raise and 18 (37.5%) for body rotary stability. A previous study reported that functional asymmetry of ≤14 points was a risk factor for sports injury [22]. In the present study, 15 athletes had a total FMS score of ≤14 points (Table 2).

**Table 2. Unbalance on both sides of the FMS test and the total score is less than 14 points (n = 48).**

Event/Exercise	Number of athletes	Percentage
Hurdle step	6	12.5
In-line lunge	6	12.5
Shoulder mobility	6	12.5
Active straight-leg-raise	17	35.4
Rotary stability	18	37.5
Total scores ≤14	15	31.3

ROM test results for lower limb joints are shown in Table 3. The left and right sides were normal for the lower limb joint active ROM test [16], but the ankle flexion ROM of the left and right legs both exceeded the normal value (27.07 ± 6.95 and 26.83 ± 7.10, respectively, versus reference value of 0–20°). Hip abduction also occurred, with the left side being higher than the normal value (50.36 ± 6.10 and 46.83 ± 8.69, respectively, versus reference value of 0–45°). The ROMs for hip extension and hip abduction

**Table 3. The test results of lower limb joint range of young Middle distance runners (n = 48).**

Event	Left side (Mean ± SD)	Right side (Mean ± SD)	Reference value	<i>p</i>
Hip flexion ROM (°)	113.20 ± 8.71	113.6 ± 8.92	0–125	0.746
Hip extension ROM (°)	24.38 ± 6.77	27.16 ± 7.40	0–30	0.012*
Hip adduction ROM (°)	25.29 ± 5.82	27.70 ± 5.44	0–30	0.002**
Hip abduction ROM (°)	50.36 ± 6.10	46.83 ± 8.69	0–45	0.015*
Hip internal rotation ROM (°)	30.13 ± 5.88	30.89 ± 6.33	0–45	0.410
Hip external rotation ROM (°)	26.58 ± 6.71	25.41 ± 5.31	0–45	0.133
Knee flexion ROM (°)	122.98 ± 6.34	122.53 ± 6.97	0–135	0.570
Knee extension ROM (°)	0.00 ± 0.00	0.00 ± 0.00	0.00	-
Ankle flexion ROM (°)	27.07 ± 6.95	26.83 ± 7.10	0–20	0.959
Ankle extension ROM (°)	39.84 ± 9.21	38.04 ± 9.67	0–50	0.08

Note: \*,  $p < 0.05$  (significant); \*\*,  $p < 0.01$  (highly significant).

**Table 4. Results of the knee-to-wall test (n = 48).**

Event	Left leg (Mean ± SD)	Right leg (Mean ± SD)	<i>p</i>
Knee-wall test (cm)	10.72 ± 2.84	10.53 ± 2.99	0.334

were significantly different ( $p < 0.05$ ) between the left and right sides, while the left/right difference for hip adduction ROM was highly significant ( $p < 0.01$ ). ROMs for right hip extension and for right hip adduction were both higher than for the left hip, whereas ROM for left hip abduction was higher than for the right side. No significant difference between the left and right legs was observed for the passive ankle joint ROM knee-wall test (Table 4).

Left and right shoulder flexibility form part of upper limb flexibility, hence the correlation analysis was not carried out for this movement. Table 5 shows the correlations between FMS test results and lower limb joint ROM. The left hurdle step showed a significant negative correlation with right knee flexion ROM ( $r = -0.435$ ,  $p < 0.05$ ). The right hurdle step was negatively correlated with left knee flexion ROM ( $r = -0.494$ ,  $p < 0.05$ ), but positively correlated with right ankle flexion ROM ( $r = 0.392$ ,  $p < 0.05$ ). The left in-line lunge was negatively correlated with left knee flexion ROM ( $r = -0.508$ ,  $p < 0.01$ ), while the right in-line lunge was positively correlated with right hip extension ROM ( $r = 0.445$ ,  $p < 0.05$ ). Left active straight-leg-raise and left hip flexion ROM were positively correlated ( $r = 0.464$ ,  $p < 0.05$ ), as was the rotation stability of the right-side body with the right ankle extension ROM ( $r = 0.393$ ,  $p < 0.05$ ). Trunk-stability push-up and left ankle flexion ROM were negatively correlated ( $r = -0.446$ ,  $p < 0.01$ ).

#### 4. Discussions

The FMS total score for athletes in this study ( $15.06 \pm 1.49$ ) was lower than the mean of 16.51 points previously reported for middle-distance runners from Quanzhou colleges [23]. Total FMS scores for male runners in the studies by Agresta [24] and Loudon [25] were  $13.1 \pm 1.7$  and

$15.0 \pm 2.4$ , respectively. The pre-season FMS score for 46 professional football players was  $16.9 \pm 3.0$ . The FMS test results for athletes in the current research are therefore comparable to those of several previous studies [24,25], but lower than the average score of professional football players. This difference could be explained by the fact that cardio-respiratory endurance is the main need for middle-distance running, whereas for football players it is stability and strength [26].

Gray [27] believes that athletes ignore physical weaknesses during training. If these weaknesses are not identified and improved the body will compensate, resulting in inefficiency of movement, decreased performance and increased risk of injury. The FMS test results for the present study were an average of 1.96 points for deep squats, 2.08 points for trunk-stability push-ups, and 1.95 points for rotary stability. These indicate poor performance of the athletes' core and lower limb stability. Moreover, there may be problems with the ROM for some lower limb joints.

A previous study showed that FMS can screen for limitations and asymmetry in movement patterns [27] and therefore it is frequently used to predict the risk of sports injury. The current study found no significant difference in FMS test results between the left and right lower extremities. However, from the perspective of a single movement there is a general asymmetry on both sides, especially for active leg raising and body rotation stability movements. In all, 17 and 18 athletes, respectively, showed asymmetry for these movements, accounting for about 38% of the athletes in this study. Symmetrical perform best in middle- and long-distance running events. To prevent sports injuries, attention should be paid to the balanced development of both sides. The present study included a large number of athletes with asymmetrical functions on both sides, weak core stability and poor coordination of the closed joint chain of the lower limbs, making them at risk of sports injury.

Test results for the young middle-distance runners in this study showed a relatively normal ROM for the left and right joints. However, the ROM for ankle flexion of the left and right legs exceeded the normal value ( $27.07 \pm 6.95^\circ$



**Table 5. Correlation between FMS test results and lower limb joint range of motion (n = 48).**

	HS-L	HS-R	ILL-L	ILL-R	ASLR-L	RS-R	PU
L-Hip flexion ROM	-0.291	-0.132	-0.091	-0.046	0.464*	0.132	-0.122
R-Hip flexion ROM	-0.243	0.026	0.043	-0.006	0.168	0.053	-0.022
L-Hip extension ROM	0.378	0.293	0.287	0.327	0.150	0.084	-0.061
R-Hip extension ROM	0.201	0.182	0.250	0.445*	0.275	0.124	0.184
L-Knee flexion ROM	-0.385	-0.494*	-0.508**	-0.280	0.176	-0.167	-0.008
R-Knee flexion ROM	-0.435*	-0.366	-0.354	-0.250	0.305	-0.157	-0.116
L-Ankle flexion ROM	0.205	0.292	0.215	0.156	0.142	0.146	-0.446*
R-Ankle flexion ROM	0.323	0.392*	0.300	0.324	0.135	0.190	-0.130
L-Ankle extension ROM	0.265	0.188	0.065	-0.039	0.230	-0.028	-0.252
R-ankle extension ROM	0.153	0.293	0.317	0.110	0.064	0.393*	-0.117

Note: L, left leg; R, right leg; \*,  $p < 0.05$  (significant); \*\*,  $p < 0.01$  (highly significant). DS, Deep squats; HS-R/HS-L, hurdle step; ILL-R/ILL-L, in-line lunge; ASLR-R/ASLR-L, active straight raise; PU, trunk-stability push-up; RS-R/RS-L, rotary stability; SM-R/SM-L, shoulder mobility. This table only presents data that have significant correlation.

and  $26.83 \pm 7.10^\circ$ , respectively, versus a reference value of  $0-20^\circ$ . Too much flexibility (hyperactivity) or too little flexibility (restricted mobility) can have negative effects and cause injury [28]. If the muscle contracts within a wide normal ROM, it can produce greater energy and thereby improve the sports performance [5]. In the present study, there was a significant difference between hip adduction ROM and hip abduction ROM. Right hip adduction ROM was also better than left hip adduction ROM, whereas left hip abduction ROM was better than right hip abduction ROM. Previous research showed that weakening of hip and ankle strength reduces the stability of muscles of the lower limbs, leading to adduction of the hip and valgus rotation [29]. However, it is still not clear whether the difference in the degree of movement of adduction and abduction on both sides is related to the imbalance of strength development on both sides.

The aim of this study was to investigate the correlation between FMS test results and the ROM of lower limb joints. It shown in Table 5, only the active ROM of the sagittal plane of the lower limb joint was significantly correlated with FMS test scores. Moreover, the deep squats, right active straight raise and left rotary stability were not significantly correlated with any lower limb joint ROM. Joint ROM was positively correlated with some FMS test results, but negatively correlated with others, thereby supporting one of the hypotheses of this study.

The right active ROM of the sagittal plane of the lower limb joint was significantly correlated with the FMS test scores. The FMS test involves multi plane motion, such as in-line lunge, but no correlation was found between FMS test results and the joint angles of other motion axes. This could be because the rotation angle and the internal and external angles created by the action were not large.

The right active straight raise and left rotary stability were not significantly correlated with any lower limb joint ROM, but the other two sides of the same movement were

related with ROM. This confirms one of the other hypotheses of this study, i.e., that the correlation between ROM of the left and right joints and the FMS results is different for the two sides. Apart from the differences for the joint angles on both sides, there may also be different movement strategies and force methods between the two sides [30]. The left active straight-leg-raise was positively correlated with left hip flexion. In fact, moving the leg is similar to the measurement method for hip joint flexion ROM, except that it adopts a different measurement method. Verall [31] found that limited ROM of the hip joint could lead to chronic groin injury, which is a potential risk factor for the development of this injury. Ibrahim [32] also confirmed that adductor muscle strain can occur after reduction of hip joint ROM in football players. Rotary stability of the right side of the body was positively correlated with the ROM of right ankle extension. Rotary stability of the body is a test of the rotation stability of the cores on both sides. The back is required to be straight, then the elbows are bent and the knees are flexed. The correlation between the two may be related to flexion of the ankle.

The deep squat was not significantly correlated with any lower limb joint ROM. Butler [33] showed that as the hip joint ROM increases, the deep squat improved. The squat action is related to the stability of the upper limbs and the trunk, as well as to the mobility of the lower limb joints in the closed kinematic chain. This research found that athletes generally have weak core stability and poor trunk control, which may be caused lower score in squats. That was reason for no correlated with ROM of lower. Yasuhi [34] found that hip flexion, ankle flexion, and knee flexion ROM were highly correlated with the active ROM of the hip, knee and ankle joints during squatting. The present study did not find a significant correlation and this may also be related to the deep squat score being reduced for poor trunk control and excessive forward leaning.

Joint ROM has a positive impact on FMS test results, but also a negative impact on some movements. This confirms another research hypothesis of our study. For some actions, ROM may have a negative impact on FMS test scores. In this study, the left hurdle step was negatively correlated with the right knee flexion ROM, while the right hurdle step was negatively correlated with left knee flexion ROM and positively correlated with right ankle flexion ROM. The hurdle step is used to evaluate the functional mobility of bilateral hip joints, knee joints and ankle joints [35]. A low hurdle score may be due to poor stance leg stability or poor hurdle leg flexibility [25]. In the present study, the left side hurdle step used the left leg as the supporting leg, the right leg was the hurdle leg, and vice versa for the right side hurdle step. Good dynamic control ability of the supporting leg is required when crossing the hurdles. To avoid touching the hurdles, they should be in the state of hip flexion, knee flexion, and ankle flexion. but the research results are opposite. This may be related to the better flexion ROM of the left and right knee joints of athletes (both at 122° on the left and right sides, Table 3). However, the knee joint is a stable joint and better flexibility may affect the stability of the supporting leg. The athlete's supporting leg was found to sway significantly during the test process. This suggests that young middle- and long-distance runners should also pay attention to the development of stability of the lower limbs and knee joints. The right hurdle step was positively correlated with right ankle flexion ROM. When the right hurdle step and the left leg cross the hurdle, the ankle strategy of the right supporting leg may be used to maintain balance. There was no correlation between the hurdle step and the ROM of left ankle flexion. Earlier studies showed specific differences in the posture control strategies of the left and right lower limbs [30]. Yasuhiro [36] postulated that the side with smaller ROM hinders the overall movement. Perhaps related to this, the flexion mobility of the left ankle joint was lower than the mobility of the right ankle joint.

This study found that the left in-line lunge correlated negatively with the left knee flexion ROM, and the right in-line lunge correlated positively with the right hip extension ROM. In addition to the flexibility and stability of the ankles, knees and hips, the in-line lunge also takes into account the stability of the trunk and the flexibility of the quadriceps [28]. In this study, the left in-line lunge is the left leg behind, while the right in-line lunge is the opposite. When the right side has completed, the hip joint of the back leg is in a state of extension. The right straight leg squat is same. However, the left in-line lunge was negatively correlated with left knee flexion, which may be related to the higher requirements for hip extension ROM and the need to stabilize the knee joint. This is related to the hurdle step and knee flexion. The finding of a negative correlation between the ROM and the knee joint are consistent, again confirming that the better ROM of knee joint flexion may affect its

stability.

The above analysis indicates that FMS test results from this study are related to the ROM for the hip, knee, and ankle joints of the lower limbs on the sagittal plane. This demonstrates the importance of sagittal joint ROM for the FMS test. Our results also show there is a difference in the correlation between the functional movements of the left and right sides of the body and the ROM of the lower extremity joints. This difference ROM may be cause the difference of correlation between them on the left and right sides. In addition, the above research showed that the flexibility of hip and ankle joints has a positive effect on functional movements, but excessive knee flexion and ankle flexion ROM may affect the stability of the joint, thereby also affecting performance. Possibly related to this, middle- and long-distance runners suffer more injuries of the knee and ankle joints. Therefore, while developing ROM for the lower extremity joints, athletes should also increase their training to develop stability of the knee and ankle joints.

This research study has certain limitations. The subjects were limited to adolescent middle- and long-distance runners. Correlation analysis of the test data alone cannot fully determine the specific impact of the lower extremity joints on the FMS test. The study population will be expanded in future work. This study found that female athletes performed better for lower limb flexibility. However, the gender difference for the correlation between ROM and FMS test results was small, hence the results for men and women were not presented separately.

## 5. Conclusions

The results of this study on middle-distance runners showed that only the ROM of the sagittal plane of the lower limb joint was significantly correlated with FMS test scores. The correlation with functional movements was different between the left and right sides of the body and the ROM of the lower extremity joints. Some of the joint ROMs were negatively correlated with the FMS score. This may be due to the contradiction between flexibility and stability. While developing ROM of the lower limbs, young middle- and long-distance runners should also strengthen their training to achieve stability of these limbs, and especially the stability of knee and ankle joints.

## Author Contributions

Corresponding author: QT—Provide writing ideas and participate in organizational testing, as well as funding support. First author: YXM—Directly related to manuscript, provide writing ideas, participate in organizational testing, complete data collection and complete article writing. Second author: AR—Collect materials and translate the articles into English. Second author: YZF—Responsible for modification.

## Ethics Approval and Consent to Participate

All subjects gave their informed consent for inclusion before they participated in the study. The institutional ethical committee of the Capital University of Physical Education and Sports approved all procedures and protocols (approval number: 2021A11).

## Acknowledgment

Not applicable.

## Funding

This research was funded by Chongqing Normal University Doctor Start Fund Project, grant number 21XWB041.

## Conflict of Interest

The authors declare no conflict of interest.

## References

- [1] Paole K, Madole K, Garhammer J, Lacourse M, Rozenek R. Reliability and Validity of the T-Test as a Measure of Agility, Leg Power, and Leg Speed in College-Aged Men and Women. *Journal of Strength and Conditioning Research*. 2000; 14: 443–450.
- [2] Santana CJ. *Functional Training* (pp. 131–132). HumanKinetics: United State. 2015.
- [3] Schneiders A, Davidsson A, Horman E, Sullivan S. Functional movement screen normative values in a young, active population. *International Journal of Sports Physical Therapy*. 2011; 6: 75–82.
- [4] National Strength and conditioning Association. In Miller T (ed.) *Nsca'S Guide to Tests and Assessments* (pp. 271). The People's Posts and Telecommunications Press: Beijing. 2018.
- [5] Werner SL, Suri M, Guido JA, Meister K, Jones DG. Relationships between ball velocity and throwing mechanics in collegiate baseball pitchers. *Journal of Shoulder and Elbow Surgery*. 2008; 17: 905–908.
- [6] Denton J, Willson JD, Ballantyne BT, Davis IS. The Addition of the Protonics Brace System to a Rehabilitation Protocol to Address Patellofemoral Joint Syndrome. *Journal of Orthopaedic and Sports Physical Therapy*. 2005; 35: 210–219.
- [7] Jenkins MT, Gustitus R, Iosia M, Kicklighter T, Sasaki Y. Correlation between the Functional Movement Screen and Hip Mobility in NCAA Division II Athletes. *International Journal of Exercise Science*. 2017; 10: 541–549.
- [8] Chimera NJ, Knoeller S, Cooper R, Kothe N, Smith C, Warren M. Prediction of Functional Movement Screen™ Performance from Lower Extremity Range of Motion and Core Tests. *International Journal of Sports Physical Therapy*. 2017; 12: 173–181.
- [9] Medeiros DM, Miranda LLP, Marques VB, de Araujo Ribeiro-Alvares JB, Baroni BM. Accuracy of The Functional Movement Screen (Fmstm) Active Straight Leg Raise Test to Evaluate Hamstring Flexibility in Soccer Players. *International Journal of Sports Physical Therapy*. 2019; 14: 877–884.
- [10] Silva B, Clemente FM, Martins FM. Associations between functional movement screen scores and performance variables in surf athletes. *The Journal of Sports Medicine and Physical Fitness*. 2018; 58: 583–590.
- [11] Ye RQ, Wu YL. Middle-distance race athletes damage survey in fujian province colleges and universities. *Fujian Sports Science and Technology*. 2006; 34: 46–48.
- [12] Cui XY, Ren ZB. Influence of Running Speed on Gait of the Middle and Long Distance Runners. *Journal of Shenyang Sport University*. 2014; 33: 123–126.
- [13] Hoch MC, Staton GS, Medina McKeon JM, Mattacola CG, McKeon PO. Dorsiflexion and dynamic postural control deficits are present in those with chronic ankle instability. *Journal of Science and Medicine in Sport*. 2012; 15: 574–579.
- [14] Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function-part 2. *International Journal of Sports Physical Therapy*. 2014; 9: 549–563.
- [15] Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. *North American Journal of Sports Physical Therapy*. 2006; 1: 62–72.
- [16] Wang AL. *Exercise rehabilitation technology* (pp.23–25). Beijing Sport University Press: Beijing. 2015.
- [17] Wang AL. *Sports rehabilitation technology* (pp.23–25). Beijing Sports University Press: Beijing. 2015.
- [18] Konor MM, Morton S, Eckerson JM, Grindstaff TL. Reliability of three measures of ankle dorsiflexion range of motion. *International Journal of Sports Physical Therapy*. 2012; 7: 279–287.
- [19] Rudi AM, Zachary CM, John W, Sonja C. Foot to shank ratio: Does it influence ankle dorsiflexion range of motion in the knee-to-wall assessment technique? *New Zealand Journal of Sports Medicine*. 2016; 6: 65–69.
- [20] Jaffri AH, Newman TM, Smith BI, Vairo GL, Denegar CR, Buckley WE, *et al.* Dynamic Leap and Balance Test: Ability to Discriminate Balance Deficits in Individuals with Chronic Ankle Instability. *Journal of Sport Rehabilitation*. 2020; 29: 263–270.
- [21] Lockie RG, Callaghan SJ, Jordan CA, Luczo TM, Jeffriess MD, Jalilvand F, *et al.* Certain Actions from the Functional Movement Screen do not Provide an Indication of Dynamic Stability. *Journal of Human Kinetics*. 2015; 47: 19–29.
- [22] Kiesel K, Plisky P, Voight M. Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal of Sports Physical Therapy*. 2007; 2: 147–158.
- [23] Jiang QH. Study on the Correlation Between FMS and Sports Injury of Middle and Long Distance Runners in Quanzhou Universities. *Sichuan Sports Science*. 2017; 36: 36–38.
- [24] Agresta, C, Slobodinsky, M, and Tucker, C. Functional movement Screen™—Normative values in healthy distance runners. *International Journal of Sports Medicine*. 2014; 35: 1203–1207.
- [25] Loudon JK, Parkerson-Mitchell AJ, Hildebrand LD, Teague C. Functional movement screen scores in a group of running athletes. *Journal of Strength and Conditioning Research*. 2014; 28: 909–913.
- [26] Jacob JJ, Craig LS, Bradley TH, *et al.* Correlation between Ankle Dorsiflexion, Hip Flexion Range of Motion and the Functional Movement Screen Hurdle Step Score. *Journal of Sport Rehabilitation*, 2015; 24: 133–137.
- [27] Gray C. *Movement—Functional movement systems* (pp. 21). Beijing Sport University Press: Beijing. 2011.
- [28] Chimera NJ, Knoeller S, Cooper R. Prediction of functional movement screen™ performance from lower extremity range of motion and core tests. *International Journal of Sports Physical Therapy*. 2017; 12: 173–181.
- [29] Schoenfeld BJ. Squatting kinematics and kinetics and their application to exercise performance. *Journal of Strength and Conditioning Research*. 2010; 24: 3497–3506.
- [30] Tang Q, Zhang HZ. Research on the Correlation of Dynamic Balance Ability and Bilateral Knee Joint Strength and Lower Limb Explosive Force in Comprehensive Sport Athletes. *China Sport Science and Technology*. 2019; 55: 65–71.

- [31] Verrall GM, Slavotinek JP, Barnes PG, Esterman A, Oakeshott RD, Spriggins AJ. Hip joint range of motion restriction precedes athletic chronic groin injury. *Journal of Science and Medicine in Sport*. 2007; 10: 463–466.
- [32] Ibrahim A, Murrell G, Knapman P. Adductor Strain and Hip Range of Movement in Male Professional Soccer Players. *Journal of Orthopaedic Surgery*. 2007; 15: 46–49.
- [33] Butler RJ, Plisky PJ, Southers C, Scoma C, Kiesel KB. Biomechanical analysis of the different classifications of the Functional Movement Screen deep squat test. *Sports Biomechanics*. 2010; 9: 270–279.
- [34] Endo Y, Miura M, Sakamoto M. The relationship between the deep squat movement and the hip, knee and ankle range of motion and muscle strength. *Journal of Physical Therapy Science*. 2020; 32: 391–394.
- [35] Cook G, Burton L, Hoogenboom B. Pre-Participation Screening: The Use of Fundamental Movements as an Assessment of Function. *North American Journal of Sports Physical Therapy*. 2006; 1: 62–72.
- [36] Hertel J. Functional instability following lateral ankle sprain. *Sports Medicine*. 2000; 29: 361–371.