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Performance on the Functional Movement Screen™ is related to hop performance, but not to hip and knee strength in collegiate football players

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Abstract

Objective—To define the relationship between FMS™ scores and hop performance, hip strength, and knee strength in collegiate football players.

Design—Cross-sectional cohort.

Participants—Freshmen of a division I collegiate American football team (n=59).

Main Outcome Measures—The athletes performed the FMS™, as well as a variety of hop tests, isokinetic knee strength and isometric hip strength tasks. We recorded total FMS™ score, peak strength and hop performance, and we calculated asymmetries between legs on the different tasks. Spearman's correlation coefficients quantified the relationships these measures, and chi-square analyses compared the number of athletes with asymmetries on the different tasks.

Results—We observed significant correlations ($r=0.38-0.56$, $p=0.02$) between FMS™ scores and hop distance, but not between FMS™ scores and hip or knee strength (all $p=0.21$). The amount of asymmetry on the FMS™ test was significantly correlated to the amount of asymmetry on the timed 6m hop ($r=0.44$, $p<0.01$), but not to hip or knee strength asymmetries between limbs (all $p=0.34$).

Conclusions—FMS™ score was positively correlated to hop distance, and limb asymmetry in FMS™ tasks was correlated to limb asymmetry in 6m hop time in football players. No significant correlations were observed between FMS™ score and hip and knee strength, or between FMS™ asymmetry and asymmetries in hip and knee strength between limbs. These results indicate that a simple hop for distance test may be a time and cost efficient alternative to FMS™ testing in athletes and that functional asymmetries between limbs do not coincide with strength asymmetries.

Conflicts of interest: None

Keywords

American football; athletic training; injury prevention; kinesiology; functional movement screen; limb asymmetry

Introduction

Pre-participation physical examinations have become common practice to screen athletes, and often include anthropometric, flexibility, and strength measures, with the aim to predict injury risk. Recently, interest has grown in screenings that reflect neuromuscular control during basic motor skills. One method to quantify fundamental movements in athletes is the Functional Movement Screen (FMS™). The FMS™ was introduced as a ‘different approach to injury prevention and performance predictability’,¹ and consists of seven tasks. Scores on each task are based on execution criteria, including aspects of mobility, stability, and compensatory movements. The FMS™ aims to ‘pinpoint deficient areas of mobility and stability that may be overlooked in the asymptomatic active population’.²

Multiple studies have assessed performance on the FMS™ in different populations.^{3–6} Interestingly, some studies have reported that athletes with lower FMS™ scores are at increased risk of athletic injury.^{7–12} However, O’Connor and colleagues (2011) found that the risk of injury was also higher for subjects who had FMS™ scores 18.¹⁰ Moreover, the earlier studies were retrospective and the prospective studies did not always take into account the mechanism or type of athletic injury, and a recent review concludes that there is only moderate evidence for a relation between FMS™ score and injury risk.¹³

The FMS™ may be a valuable test for certain purposes, but it does possess potential flaws. First, the FMS™ requires specific equipment and training, which is not free of charge; a single FMS™ certification and FMS™ test kit cost \$600–\$1,000. Second, from a biomechanical perspective, it can be questioned whether the selected movement tasks adequately reflect actual measures of interest, especially with respect to injury prediction. For instance, the ‘trunk stability push-up’ is purported to ‘test the ability to stabilize the spine in an anterior and posterior plane.’ However, subjects with perfect trunk stability could not score high on this task when they have insufficient arm strength to perform a push up with their thumbs aligned with the top of their forehead (3pt) or chin (2pt). Also, the different FMS™ tasks do not appear to represent unitary constructs, which brings the use of the summed score into question.¹⁴ Moreover, the FMS™ score depends on the subject’s knowledge of the grading criteria.¹⁵ When testing a group of firefighters before and immediately after they received information about the scoring system of the FMS™, it was found that subjects performed significantly better after they learned about the grading criteria.¹⁵ This finding indicates that the FMS™ may not reflect true deficiencies in fundamental movement control.

Many other tasks that are used to quantify athletic performance require maximal effort. These tasks are characterized by simple and straightforward instructions (i.e. ‘go as far, fast, or high as you can’), and scoring criteria are known *a priori*. Another advantage is that maximal effort tests usually quantify an isolated outcome measure of interest (i.e. quadriceps

strength, hop distance, or run time). While some of these tests may require expensive equipment (e.g. dynamometers), other tests can be scored using a simple tape measure or stopwatch. Usually, maximal effort-based tasks are performed bilaterally, which allows for calculation of asymmetries between limbs as well. Limb asymmetries may be associated with increased injury risk,¹⁶ and are often considered in guidelines for return-to-sport after an athletic injury.¹⁷

The purpose of the current study was to define the relationship between FMS™ score and maximum effort-based measures of performance in athletes. Specifically, we studied how FMS™ scores were related to hop performance, isokinetic knee strength and isometric hip strength in a population of NCAA division I football freshmen. Since the FMS™ is supposed to measure fundamental movement control rather than pure strength, our primary hypothesis was that FMS™ scores would be positively correlated to hop test performance, but not to hip and knee strength measures. Our secondary hypothesis was that limb asymmetries in hip strength, knee strength and hop performance would coincide with asymmetries in FMS™ tasks.

Methods

Subjects

Fifty-nine freshmen of an NCAA division I football team (all male) participated in this study (age=18±0.6 years, height=1.86±0.06m, mass=106±20.2kg). The study protocol was approved by the Institutional Review Board, and all subjects (or parents for minors) provided written informed consent.

Data collection

The subjects rotated through each of the four data collection stations: FMS™, knee strength, hip strength and hop tests. To prevent any effects of fatigue, the order of rotation differed between subjects, and subjects were allowed to take a break between each station. The order of testing the dominant and non-dominant limbs varied between subjects and between stations to prevent any learning bias. All athletes were tested on Wednesday afternoon, prior to the pre-season, and the amount of physical activity prior to data collection was similar between all athletes.

FMS™—The FMS™ tasks were performed using the official testing kit, and exactly as described by Cook and colleagues.^{1, 2} Two raters (n=38 and n=21) were extensively trained in FMS™ testing and they observed the movements in different planes of motions. Rater 1 was a licensed athletic trainer with sound background in functional anatomy and motor learning, who obtained the official FMS certification. In order to limit any potential bias between raters, rater 2 was trained by rater 1. If the score on a task differed between limbs, the lower of the two was used to calculate the total FMS™ score, and the amount of asymmetry was recorded for a separate limb asymmetry analysis. Subjects received instructions about the tasks that they had to perform, but were not informed about the grading criteria to mimic a standard screening procedure.

Knee strength—Knee strength was measured on a Biodex System 3 dynamometer (Biodex Medical Systems, Shirley, New York). We tested maximal isokinetic quadriceps and hamstrings strength at two different speeds in both limbs. The lower speed was set at 60°/s, with five repetitions per trial, and the higher speed was set at 300°/s, with 10 repetitions per trial. Subjects were verbally encouraged to ‘kick out’ and ‘pull back’ as hard as they could over a range of 90° of knee flexion and extension and we recorded peak torques. Most athletes (n=39) performed one trial for each of the knee strength measures, and for athletes who performed two trials (n=18) the maximum peak torque was used for further analysis. Athletes had about 30 seconds rest between tests on one leg.

Hip strength—Maximal isometric hip abduction strength was assessed using a load cell between two straps that recorded maximal force between the distal ends of the thighs. We measured hip abduction and external rotation strength in side-lying and standing positions (Figure 1). Subjects were instructed to increase tension between the straps on a 1-2-3-count, and subsequently kick out as hard as they could for another 3 seconds. All values of peak force were averaged over the number of repetitions that each athlete performed, which was either two (n=28) or three (n=25). Between repetitions, athletes had a minimum of 10 seconds rest. If an athlete failed to perform the test according to the instructions, for instance when tension between the straps was not gradually increased, the trial was redone.

Hop tests—Figure 2 shows the set of four different hop tasks employed.¹⁸ Subjects were instructed to hop as far or as fast as they could, and performed the tasks bilaterally. Three of the hop tests were scored for distance (tape measure) and one was scored for time (stop watch). Subjects performed each hop task twice and the average performance was used for further analysis.

Data analysis

In addition to the FMS™ scores, hop performance and hip and knee strength measures, we assessed limb asymmetries on the different tests. Subjects were categorized as ‘asymmetric’ on the FMS™ when their limbs scored differently on at least one of the tasks that involved the lower extremity. The amount of asymmetry on the FMS™ was calculated as the sum of the difference in scores between limbs. So when there was a 2-point difference between limbs in one task and a 1-point difference between limbs in two other tasks, the amount of asymmetry was 4 points. The shoulder mobility test was not included in this part of the analysis, as the upper extremity was not represented in the other tests. For each of the hop tests and hip and knee strength measures, the ratio of asymmetry was calculated (Equation 1). Subjects were categorized as ‘asymmetric’ in hop and strength test performance when their ratio of asymmetry exceeded 15% in at least one of the tasks. This cut off of 15% was chosen because it may increase the risk for athletic injury.¹⁶

$$\text{Ratio of asymmetry} = \frac{\text{abs}(\text{dominant} - \text{nondominant})}{\text{dominant}} * 100\% \quad (\text{Equation 1})$$

Statistics

We first assessed our outcome measures for normality by checking the histograms, QQ-plots, and Shapiro-Wilk test results. Because FMSTM scores were not normally distributed, we calculated Spearman's correlation coefficient to assess the relationship between FMSTM scores and the hop and strength measures. Missing values were discarded from analyses, as not all subjects completed all tasks.

To test the hypothesis that asymmetry on hop and strength tests coincides with asymmetry on the FMSTM, we performed chi square analyses. We also calculated Spearman's correlation coefficients to determine whether the amount of limb asymmetry on the FMSTM tasks was related to the ratios of limb asymmetry on the other tests. The level of significance was set at $\alpha=0.05$.

Results

None of the players reported any pain during the clearing exams or FMSTM tasks, and the mean total FMSTM score was 14.3 (± 2.2). Table 1 provides the means and standard deviations for the hop performance and hip and knee strength tests.

In line with the primary hypothesis, significant correlations were observed between FMSTM scores and performance on the hop tests, but not between FMSTM scores and hip or knee strength measures. Figure 3 shows that athletes typically hopped further (but not faster) when their FMSTM scores were higher. Correlations were highly significant for the single hop on the dominant leg ($r=0.436$, $p=0.016$), and for the triple and cross over hops on both legs ($r=0.38$ – 0.56 , all $p < 0.016$). The correlation between FMSTM score and single hop distance on the non-dominant leg did not reach significance ($r=0.351$, $p=0.057$), and no correlations were observed between FMSTM score and performance on the 6m timed hop (both $p > 0.157$). Figures 4–5 demonstrate the absence of significant correlations between FMSTM scores and hip or knee strength (all $p > 0.206$).

Fifty-nine percent of the athletes (35 out of 59) demonstrated limb asymmetry on at least one of the FMSTM tasks that involved the lower extremity. More than 15% asymmetry was more common in hip and knee strength measures than in hop test performance. Table 2 shows that the proportion of athletes with and without asymmetry in FMSTM performance was highly similar between groups with and without asymmetries on the strength and hop tests. However, a significant correlation was observed between the amount of asymmetry between limbs on the FMSTM tasks and on the 6m timed hop ($r=0.44$, $p=0.002$). So, athletes who obtained different scores for their left and right limb on the FMSTM also demonstrated a larger difference between limbs in the time they needed to complete a 6m hop test. No such correlation was found between FMSTM asymmetry and asymmetry on the other hop tests (all $p > 0.078$), knee strength (all $p > 0.345$) or hip strength measures (all $p > 0.592$).

Discussion

FMSTM scores were significantly correlated to hop test performance in collegiate football players. Athletes with higher FMSTM scores hopped further, but not faster, than athletes with

lower FMSTM scores. No correlation was observed between FMSTM scores and multiple hip and knee strength measures. These findings support the primary hypothesis and indicate that the FMSTM and hop tests for distance may provide similar information about an athlete's functional capacities, while hip and knee strength testing may provide additional, functionally different information. The secondary hypothesis, that limb asymmetries in strength measures and hop performance would coincide with asymmetries in FMSTM task performance, was only supported for the six meter timed hop task. The absence of a relationship between limb asymmetries on the FMSTM and limb asymmetries on the hip and knee strength tests indicates that differences in functional performance between limbs did not coincide with differences between limbs in strength.

Previous studies have evaluated the relationships between FMSTM scores and other measures of performance. In golfers, no significant correlation was observed between FMSTM scores and sprint times, vertical jump height, agility or club head velocity.¹⁹ This is in line with recent statements on the misconceptions and myths of the FMSTM by its developers, that the FMSTM does not intend to measure athletic performance.^{20,21} However, in recreational athletes from various backgrounds, some significant correlations were observed between scores on single FMSTM tasks and agility, single leg squat and a backward throw.²² However, some of these correlations were negative, indicative of worse athletic performance with a higher score on a single FMSTM task. Unfortunately, the authors did not report any actual values of FMSTM or other test scores, and the total FMSTM score was not included in their correlation analysis.²² A significant correlation between FMSTM score and cross over hop distance was previously observed in active service duty members²³. The correlation coefficient in that study was lower than in the current study, which may be explained by the different distributions in FMSTM scores (15.7 ± 2.0) and cross over hop distance (4.28 ± 1.01 m) in that study compared to those in the present study.

The strongest correlations in the present study were observed between FMSTM score and cross over hop distance. This indicates that the cross over hop for distance may be an adequate, simple, and time-efficient alternative for the FMSTM. Athletes with higher FMSTM scores also performed better on the triple hop for distance, while the correlation between FMSTM score and single hop distance was only significant for the dominant limb. This information is relevant for coaches and athletic trainers, as screenings are typically designed with the aim to maximize the amount of relevant information gathered in a minimal amount of time. Ideally, each test should provide unique information about an athlete's motor skills and/or injury risk.

It is important to note that we calculated Spearman's correlation coefficients, while previous literature on the relationship between FMSTM and other measures of performance reported Pearson's correlation coefficients.^{19, 22} Those studies did not report whether data were checked for normality, but parametric tests were inappropriate for the present study. As FMSTM performance is usually summarized to a total score, this standard scoring system was employed for our main analysis. However, it could be argued that certain portions of the FMSTM (i.e. shoulder mobility) would not affect lower extremity strength or hop performance. Therefore, we performed a sub-analysis with the sum of three FMSTM tasks that specifically target the lower extremity: squat, hurdle step and in-line lunge. This sub-

score was significantly correlated with the triple and cross over hops for distance, but not to any of the hip or knee strength measures. Hence, the absence of correlation between FMS™ scores and lower extremity strength was consistent for both the total FMS™ score and for a sub-score of specific FMS™ tasks that target the lower extremity.

One of the limitations of this study was that while all subjects completed the FMS™, not all subjects performed all other hop and strength tests, due to strict time constraints of the data collections. Therefore, the number of athletes included in the correlation analyses differed per task. However, with a minimum number of 30 athletes for each task, we are confident that the results are representative of the population. As all athletes rotated through the screen stations in random order, we are confident that the missing values are not a source of potential bias. Another limitation is that the amount of resting time between the different tests was not standardized. Furthermore, no practice trials were included for the FMS™, while a recent review recommends a practice trial to reduce the ‘noise’ of a learning effect.¹³ Also, while the observed correlations between FMS™ scores and hop distance were highly significant, the magnitude of the correlation coefficients indicate that hop performance explained 15% to 31% of the variance in FMS™ scores. This implies that both tests also have a substantial amount of unique variance, and thus do not measure the same thing. These findings support recent developer’s statements on the misconceptions and myths of the FMS™ that additional tests are recommended for a complete assessment of readiness to compete or return to competition.²¹

A final limitation of this study may be the presence of body mass index (BMI) as a confounding factor. Athletes with higher BMI typically demonstrate lower FMS™ scores^{4, 24} and reduced athletic performance,^{25, 26} but higher muscle strength. We presented the raw (non-normalized) data, because body mass likely affected all of our outcome measures. Future studies are needed to assess how FMS™ scores are related to hop performance and lower extremity strength when BMI is controlled for.

In sum, we found that FMS™ scores were related to hop test performance, but not to hip and knee strength measures, in NCAA division I football players. These findings indicate that a triple hop for distance may be a time and cost efficient alternative to the FMS™ total score, and that the timed 6m hop may be particularly valuable for asymmetry screening in athletes. In addition to being quicker and less expensive, hop tests have a transparent scoring system, whereas FMS™ scores are affected by whether or not the athlete is familiar with the grading criteria.¹⁵ While limb asymmetry on the FMS™ was correlated to limb asymmetry on the timed 6m hop, no such relationship was observed between FMS™ asymmetry and strength asymmetry. So functional asymmetries do not necessarily reflect strength asymmetries, or vice versa.

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funder, had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Figure 1. The four different hip strength tests: side-lying abduction and external rotation (upper panel), and standing abduction and external rotation (lower panel). Note that standing external rotation strength was recorded for both limbs simultaneously, while the other strength tasks were measured for both limbs separately.

Figure 2.
Schematic representation of the four single leg hop tests. All hop tests were performed on both limbs.

Figure 3. Correlations between FMSTM scores and the different hop tests. The upper and lower panels represent the hop performance on the dominant (D) and non-dominant (ND) limbs, respectively.

Figure 4. Correlations between FMSTM scores and the different hip strength tests. The upper and lower panels represent the hip strength in the dominant (D) and non-dominant (ND) limbs, respectively.

Figure 5.

Correlations between FMSTM scores and the different knee strength tests. The upper and lower panels represent the knee strength in the dominant (D) and non-dominant (ND) limbs, respectively.

Table 1

Descriptive statistics of the different measures of athletic performance.

	Task		Mean $\pm$ SD	N
Hop performance	Single hop for distance	<i>Dominant</i>	1.92 $\pm$ 0.32 m	30
		<i>Non-dominant</i>	1.89 $\pm$ 0.31 m	30
	Triple hop for distance	<i>Dominant</i>	6.09 $\pm$ 0.87 m	39
		<i>Non-dominant</i>	6.06 $\pm$ 0.81 m	39
	Cross over hop for distance	<i>Dominant</i>	5.49 $\pm$ 0.84 m	51
		<i>Non-dominant</i>	5.38 $\pm$ 1.01 m	51
	6m timed hop	<i>Dominant</i>	1.75 $\pm$ 0.31 s	50
		<i>Non-dominant</i>	1.76 $\pm$ 0.32 s	50
Hip strength	Side lying abduction	<i>Dominant</i>	298 $\pm$ 84 N	51
		<i>Non-dominant</i>	288 $\pm$ 87 N	52
	Side lying external rotation	<i>Dominant</i>	311 $\pm$ 100 N	51
		<i>Non-dominant</i>	310 $\pm$ 98 N	51
	Standing abduction	<i>Dominant</i>	309 $\pm$ 89 N	51
		<i>Non-dominant</i>	315 $\pm$ 100 N	51
Knee strength	Standing external rotation	<i>Bilateral</i>	453 $\pm$ 116 N	55
	Quadriceps 60 deg/s	<i>Dominant</i>	273 $\pm$ 54 Nm	41
		<i>Non-dominant</i>	264 $\pm$ 61 Nm	41
	Hamstrings 60 deg/s	<i>Dominant</i>	144 $\pm$ 29 Nm	41
		<i>Non-dominant</i>	142 $\pm$ 30 Nm	41
	Quadriceps 300 deg/s	<i>Dominant</i>	171 $\pm$ 32 Nm	57
		<i>Non-dominant</i>	169 $\pm$ 37 Nm	57
	Hamstrings 300 deg/s	<i>Dominant</i>	114 $\pm$ 23 Nm	57
		<i>Non-dominant</i>	110 $\pm$ 23 Nm	56

Frequency tables and Fisher’s Exact 1-sided p-value for asymmetries on the FMS™ and hop performance, hip strength and knee strength tests.

Table 2

	Hop performance symmetry	Hop performance asymmetry	Total	Hip strength symmetry	Hip strength asymmetry	Total	Knee strength symmetry	Knee strength asymmetry	Total
FMS symmetry	18	4	22	9	12	21	9	13	22
FMS asymmetry	22	7	29	13	19	32	12	22	34
Total	40	11	$p=0.437$	22	31	$p=0.548$	21	35	$p=0.442$