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Relationships between the Functional Movement Screen Score and Y-Balance Test Reach Distances

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Abstract Background: The Functional Movement Screen (FMS) is used to evaluate key movement patterns, functional symmetry, and identify individuals that are at elevated risk of injury. The purpose of this study was to assess whether dynamic postural control is a significant component of the composite FMS score by comparing it with Y-Balance Test (YBT) reach distances. Methods: Seventy-eight participants (including 40 males) performed the standardized FMS protocol followed by the YBT. The YBT reach distances were normalized to leg length and averaged between sides and trials. The individual reach directions were evaluated, and were also summed to form an aggregate YBT distance (TotalY). Results: We observed weak correlations between the composite FMS score and normalized posterolateral reach, normalized posteromedial reach, and the TotalY ($r=0.36$, 0.37, and 0.36, respectively; all $p< 0.05$). There was no correlation between the composite FMS score and normalized anterior reach ($r=0.22$; $p=0.053$). Together these findings demonstrate partial correspondence between the two tests. Conclusion: This indicates that dynamic postural control is a small component of the aggregate FMS score.

Keywords Balance Testing, Dynamic Balance, Postural Control, Fitness Testing

1. Introduction

Movement screening tools are widely used in fitness, professional sports, and as methods of assessing participants to determine underlying weaknesses or predisposition to injuries [1]. As one example, the Functional Movement Screen (FMS) is used as a pre-season screening tool in sports and as a baseline measure to identify poor "movement competency" and "faulty functional movement patterns" (i.e., joint mobility and stability deficits [2]). Similarly, the Y-Balance Test (YBT), a modified version of the Star Excursion Balance Test (SEBT), is also used as a pre-participation screening tool and is designed to assess dynamic postural control due to poor movement patterns [3]. Both the FMS and YBT are commonly used by exercise professionals [4].

The FMS comprises seven functional movement tasks (Deep Squat (DS), Hurdle Step (HS), Inline Lunge (ILL), Shoulder Mobility (SM), Active Straight Leg Raise (ASLR), Trunk Stability Pushup (TSPU), and Rotary Stability (RS)) and three associated clearing tests [2, 5]. The clearing tests are designed to detect pain in specific ranges of motion that are related to the associated movement task [2, 5]. All movement tasks, apart from the DS and TSPU, are performed bilaterally. The seven movement tasks are scored from zero to three. The FMS is performed using a testing kit, which may be purchased (Functional Movement Systems, Lynchburg, VA, USA) or manufactured. The FMS is administered and graded using published, standardized verbal commands and procedures [2, 5]. Each of the tasks may be attempted three times. Coaching cues and/or corrections are not provided, nor are the specific grading criteria made known to those being assessed [6]. The clearing tests are each associated with a functional test: Shoulder Impingement with SM; Spinal Extension with TSPU; and Spinal Flexion with RS. If the participant reports pain on a clearing test, then the score for the related functional task is changed to zero. For bilateral tasks, such as the ILL, the lower score from the right and left task performances is recorded. The scores on the seven tasks are summed to create an aggregate score out of 21 [2, 5]. A detailed description of all FMS tasks and scoring procedures can be found elsewhere [2, 5].

The SEBT is a clinical and research tool which assesses dynamic postural control [7]. In this test, participants stand on a single leg and reach to eight directions with the other leg. The YBT is a reliable, instrumented variation of the SEBT [3]. The number of reach directions in the YBT is reduced to anterior, posterolateral, and posteromedial, and the instrumented apparatus increases repeatability [3]. It evaluates dynamic stability, coordination, neuromuscular control, and strength [8-11]. In order to account for different anthropometry, reach direction measurements can be normalized to leg length; this was the approach that was used for validation [3]. Images of the YBT reach directions are published elsewhere [3].

Both the YBT and FMS are purported to assess dynamic postural control, stability, mobility, movement patterns, functional symmetry, and identify individuals that are at elevated risk of injury [2, 5, 12]. Accordingly, we would expect that YBT reach distances and FMS scores should be correlated. This relationship has been indirectly investigated in several studies. For example, the FMS scores and YBT reach distances have been compared between student-athletes and general college students [13]. There was no significant difference between these groups in the aggregate FMS score; however female athletes reached further than general college students in all directions in the YBT [13]. Another study administered the FMS and the YBT in 200 NCAA Division I athletes and found that individuals with a self-reported history of injury or surgery had significantly lower aggregate FMS scores [14]. They also reported that female athletes had lower scores on some of the individual tests within the FMS (TSPU and RS) and higher scores on other tests (ILL, SM, and ASLR [14]). However, they did not observe statistically significant differences in the YBT reach distances between individuals with and without a self-reported history of injury or surgery, nor between male and female participants [14]. The YBT reach distances and FMS scores have also been combined in the Move2Perform algorithm [15]. This proprietary algorithm uses demographic information, injury history, and the FMS scores and YBT reach distances to assess injury risk by placing participants into four risk categories (normal, slight, moderate, and substantial). The efficacy of this tool was investigated in a group of NCAA athletes during one competitive season; they found a significant difference in lower extremity injury risk when the 'moderate' and 'substantial', and 'slight' and 'normal' were grouped together (reducing the number of risk categories to 'high risk' and 'low risk' [15]). Normative FMS and YBT data in a population of military personnel has also been reported [16]. That study found increased FMS, power, mobility, and balance scores in individuals younger than 30 years of age compared to those older than 30. They also reported that men had higher balance, power, and stability scores than women [16]. One recent study determined there was no correlation between individuals' scores on the FMS and YBT anterior right-left difference and composite reach directions in a military population [17]. Since these earlier studies have investigated the relationship between FMS scores and the YBT in college-aged students and military personnel, the purpose of the current study was to directly assess this relationship in a healthy, general population, in order to determine whether dynamic postural control is a component of the aggregate FMS score.

2. Materials and Methods

2.1. Selection and Description of Participants

Seventy-eight participants (40 males and 38 females; age= 28.1 ±9.1, age range 18-55, height 172.1cm ±11.4, and body mass 71.0 kg ±13.7, BMI =23.9 ±3.1) gave written, informed consent to participate in the protocol approved by the Institutional Research Ethics Board. Participants were eligible for inclusion if they were 18-69 years of age, had not performed or administered the FMS, and did not have any current health and/or joint problems (they answered "no" to all of the questions in the Physical Activity Readiness Questionnaire [18]).

2.2. Procedures

The FMS was administered by a single certified FMS practitioner according to standardized procedures, equipment (Functional Movement Systems, Lynchburg, VA, USA) and verbal commands [2, 5]. The participants were video-recorded from the frontal and sagittal planes and the trials were graded at a later time. This is a commonly used [6, 19-24], reliable[25] method for scoring the FMS. Participants were not familiarized with the FMS prior to testing as knowledge of the FMS scoring scheme affects performance [6].

Participants were familiarized with the YBT tool (Move2Perform, Evansville, IL, USA) and the movements that would void trials were explained (touching the floor, failing to return the moving foot to the centre of the apparatus, touching the top of the slider with any part of the foot, and using the slider poles for support). Participants performed four practice trials on each side in each direction (anterior, posterolateral, posteromedial) during which they were given verbal feedback if they performed a trial that would be voided; however coaching was not provided [26]. In order to allow the participants to recover prior to performing the test trials, a rest period of approximately three minutes was given, during which the length of their right leg was measured for normalization (right anterior superior iliac spine to medial malleolus [3]). The participants performed three test trials on each leg and in each reach direction. A trial was repeated if it was voided as described above.

2.3. Statistical Analyses

The mean of the six test trials in each reach direction of the YBT was calculated for each participant (i.e. three left and three right anterior reach distances were averaged). These mean reach distances were expressed as a proportion of leg length [3]. The individual directions were evaluated, and were also summed to form an aggregate YBT score (TotalY). This is similar to the approach used in previous research [13]. In this study, we chose to assess relationships between YBT reach distances and the aggregate FMS score because it was assumed based on the rationale originally provided[2,5], that deficits in joint mobility and stability (i.e., low composite FMS scores) would negatively influence dynamic postural control (i.e., short YBT reach distances). To determine the extent that the FMS aggregate score is related to the YBT, Pearson product-moment correlation coefficients were calculated between the FMS and YBT for each reach direction, and for the TotalY. These results are presented in the context of the power of the analysis, given the size of the sample. All statistical analyses were conducted in R [27].

3. Results

The mean ±standard deviation aggregate FMS score for our participants was 16.3 ±1.9 (range=11-20, skewness = -0.32). Table 1 shows the mean normalized YBT reach distances for all directions. Anterior reach distance was frequently less than the leg length of the participants (average normalized anterior reach of 0.7). The normalized reach distances in the posterolateral and posteromedial directions were similar, with average normalized reach distances of 1.1. Skewness was reasonable for all variables (ranging from -0.7 to 1.4, per Table 1), and so we proceeded with the use of parametric correlation calculations. We observed statistically significant correlations between aggregate FMS scores and normalized posterolateral reach distances, normalized posteromedial reach distances, and the TotalY (r=0.36, 0.37, and 0.36, respectively; p=0.001, 0.0008, 0.001, respectively), reflecting that between 5 and 14% of the variance is common between the reach distances and the FMS score. These correlations are considered “fair” [28]. The correlation between FMS scores and normalized anterior reach distances was not statistically significant (r=0.22; p=0.053). The relationships between these reach distances and FMS scores are presented in Figures 1-4. The power for these calculations was high for the posterolateral, posteromedial, and TotalY variables (0.907, 0.923, and 0.907 respectively) but low for the anterior reach (0.495).

Table 1. Normalized reach distances (n=78) of the YBT. The distances were normalized using the participants' leg length

	Anterior	Posterolateral	Posteromedial	Total Y-balance
Mean	0.7	1.1	1.1	3.0
S.D.	0.1	0.1	0.1	0.2
Min.	0.6	0.9	0.8	2.3
Max	1.0	1.3	1.3	3.7
Skewness	1.4	-0.5	-0.7	0.1

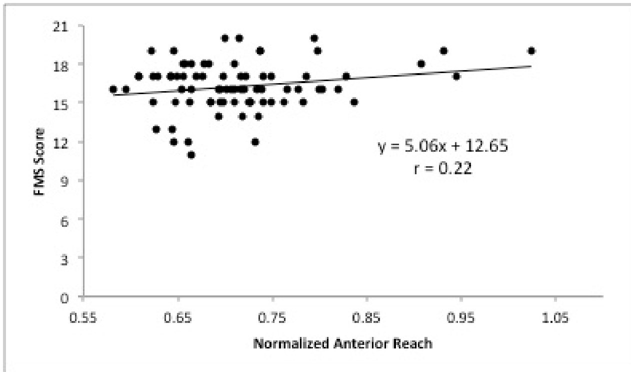

Figure 1. Relationship between the FMS score and the YBT anterior reach direction. All reach distances are normalized to the participants' leg length.

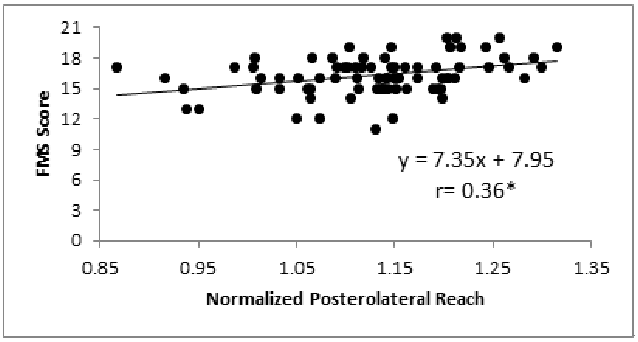

Figure 2. Relationship between the FMS score and the YBT posterolateral reach direction. All reach distances are normalized to the participants' leg length. *indicates that the relationship between FMS score and YBT reach distance is statistically significant.

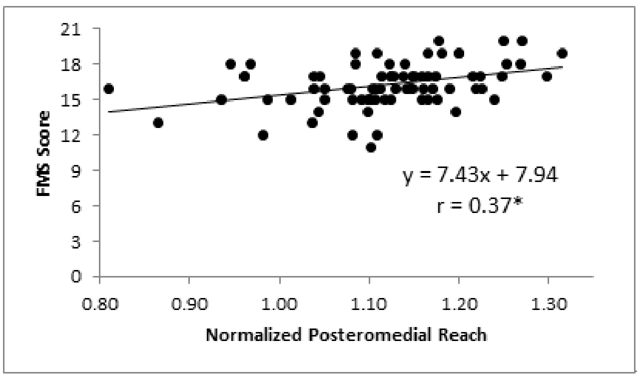

Figure 3. Relationship between the FMS score and the YBT posteromedial reach direction. All reach distances are normalized to the participants' leg length. *indicates that the relationship between FMS score and YBT reach distance is statistically significant.

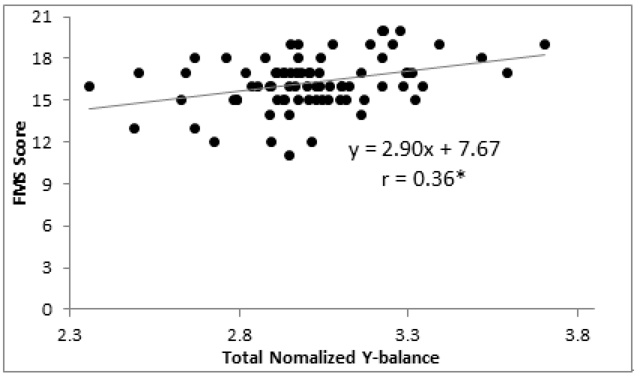

Figure 4. Relationship between the FMS score and the TotalY. All reach distances are normalized to the participants' leg length. *indicates that the relationship between FMS score and YBT reach distance is statistically significant.

4. Discussion

The purpose of this study was to examine the relationship between aggregate FMS scores and YBT reach distances to determine the extent to which the FMS quantifies dynamic postural control. We observed a fair relationship, demonstrating that there is some degree of overlap between what is measured by both instruments. However, the low level of explained variance (between 5 and 14% common variance) suggests that dynamic postural control is limitedly affected by joint mobility and stability deficits, if it is assumed that the YBT and FMS are valid tools to measure such constructs.

Our relatively weak relationship between the two tests may be because the YBT explicitly tests only the lower body, whereas the FMS evaluates whole body movement. Additionally, only three of the seven tasks in the FMS explicitly test dynamic balance, namely the ILL, RS, and HS (these tasks involve unilateral or very narrow bases of support). These results are consistent with earlier work comparing individual FMS task scores with the SEBT [29]. They found a statistically significant relationship between the TSPU and ILL with the posteromedial reach direction, and between the TSPU and the anteromedial reach direction (that reach direction is not tested in the YBT); however they did not compare the SEBT reach distances with the aggregate FMS score [30].

Our results are partially consistent with a large military sample which did not exhibit a statistically significant relationship between the FMS and YBT anterior and composite reach directions [17]. That study used a method of YBT analysis that was different from ours (they examined the difference between right and left sides in the anterior reach direction and expressed their composite YBT using different procedures [17]), so it is not possible to directly compare the results. In our study, we observed a low level of common variance in the TotalY but not in the anterior direction. The differences between the two studies may be due to the analysis techniques or to the differences in the samples. The military population in the earlier study was younger (20.8 years and 20.9 years for males and females, respectively; our cohort was 28.1 years for males and females combined), mostly male (1434 males, 280 females), and active duty military personnel at the time of testing.

To date, much of the FMS literature has studied specific athletic and occupational populations. This study included a range of healthy participants sampled from a general population. An earlier study examined normative data in a general, healthy sample (n=209) and reported similar mean FMS scores as our group (15.7 ±1.9) [31]. The participants in that study were also similar to our cohort (age=21.9 ±3.7, BMI=24.4 ±3.1), which indicates that our sample was representative of a larger, healthy population. A study examining normative data for middle aged adults (age 50.91 ±10.80, range 21-82; BMI=26.02 ±3.88) reported a mean aggregate FMS score of 14.14 ±2.85 [32], which is lower than the current study. That study reported a negative association between age groups and BMI groups, and aggregate FMS scores. That negative association could explain the higher FMS scores in our study, as the mean age of our participants was lower and they had a lower BMI than the participants in the earlier work.

College-aged athletes and a general student population were compared previously using the FMS and YBT [13]. That study reported a mean FMS score of 14.2 ±0.2 for student-athletes and 14.1 ±0.2 for general college students. It is not clear why these FMS scores were so much lower than our sample, especially in the general college sample. Age does not seem to be responsible since the mean age was 20.3 ±1.5 and 21.3 ±1.6 for athletes and students respectively, which is younger than in our study, which suggests there should be higher FMS scores in that cohort than in our study. The YBT in that study was analysed using the best reach performance of the three attempts, compared to our approach averaging the YBT trials. We did not analyse our results using the best reach measure as the validation of the YBT was performed using a mean calculation across three trials [3].

Although it must be acknowledged that the restricted range of FMS scores (between 11 and 20) and relatively small sample size (n=78) may have somewhat limited our explanatory power [33], we believe that the structure of FMS and the way it is scored may shed light on why the correlations between aggregate FMS scores and YBT reach distances were low in our study. The FMS score is assumed to be a unidimensional construct since the individual task scores are combined into one aggregate score as a measure of global 'functional movement' competency. This may not be the case since three out of four factor analysis studies concluded that the FMS was comprised of two factors [34-36]. If the FMS has a two-factor construction, then it is not appropriate to interpret the aggregate score as a global metric of movement competency. The standard FMS guidelines state that the FMS is a screening tool, that aggregate scores should be calculated, and that individual components of the FMS tests should not be independently interpreted [2, 5, 37], which is why we chose to use that standard method of FMS scoring in the current study. Alternative grading schemes have been evaluated [22,38], and some studies have evaluated specific task scores in isolation[29]. It may be that we have observed weak correlations between YBT and FMS scores because the FMS scores do not represent a single hypothetical construct. To date, there have been limited attempts to directly and rigorously study the construct validity of instruments such as the FMS and YBT [39]. Given this knowledge gap and since the correlation between FMS and YBT scores were low in the current study, we conclude that until it is known what is measured by these tools, it may be best to combine results of both [15].

5. Conclusions

Functional training has been identified as an important element of an exercise program and the FMS is frequently used by exercise professionals to identify weaknesses, imbalances, and compensatory movement patterns that can be 'corrected' through training [4]. We observed partial correspondence between the FMS and the YBT; however, the relationship was not strong enough to consider them interchangeable. This indicates that dynamic postural control is not a large component of the aggregate FMS score, and thus combining results of both the YBT and FMS [15] is recommended until their construct validity has been established.

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