INTRA-RATER TEST-RETEST RELIABILITY AND RESPONSE STABILITY OF THE FUSIONETICS™ MOVEMENT EFFICIENCY TEST

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ABSTRACT

Background: A new functional movement assessment, known as the Fusionetics™ Movement Efficiency (ME) Test, has recently been introduced in the literature. Before the potential clinical utility of the ME Test can be examined, the reliability of this assessment must be established.

Purpose: To examine the intra-rater test-retest reliability of the Fusionetics™ ME Test.

Study Design: Cross-sectional.

Methods: ME Test data were collected among 23 (6 males, 17 females) university students (mean $\pm$ SD, age = 25.96 $\pm$ 3.16 yrs; height = 170.70 $\pm$ 9.96 cm; weight = 66.89 $\pm$ 12.67 kg) during sessions separated by 48 hours (Day 1, Day 2). All participants completed the seven sub-tests of the ME Test: 2-Leg Squat, 2-Leg Squat with Heel Lift, 1-Leg Squat, Push-Up, Shoulder Movements, Trunk Movements, and Cervical Movements. Overall ME Test scores and ME Test scores for each individual sub-test were calculated on a scale of 0 – 100 (worst – best) based on commonly observed movement compensations associated with each sub-test.

Results: Intraclass correlation coefficients (ICC_{3,1}) statistics indicated that the intra-rater test-retest reliability of the Overall ME Test and individual sub-tests ranged from *fair-to-excellent* (ICC_{3,1} range = 0.55 – 0.84). Statistically significant differences in ME Test scores were identified between Day 1 and Day 2 among the 2-Leg Squat with Heel Lift (p = 0.015) and Cervical Movements (p = 0.005) sub-tests. In addition, a large range in the standard error of the measure (SEM) and minimal detectable change values (MDC_{90%} & MDC_{95%}) were identified within individual sub-tests of the ME Test (SEM range = 7.05 – 13.44; MDC_{90%} range = 16.40 – 31.27; MDC_{95%} range = 19.53 – 37.25), suggesting that the response stability varies among these individual sub-tests. Prevalence-adjusted bias-adjusted kappa statistics (κ_{PABA}) suggest that 55 of the 60 (92%) individual movement compensations hold *moderate-to-almost perfect* intra-rater test-retest reliability (κ_{PABA} range = 0.30 – 1.00).

Conclusions: *Excellent* intra-rater test-retest reliability of the Overall ME Test score was identified, and thus, clinicians can reliably utilize the Fusionetics™ ME Test to assess change in functional movement quality across time. However, caution should be taken if utilizing an individual sub-test to assess functional movement quality over time.

Level of Evidence: 2b

Keywords: Functional movement quality assessment, movement screening, movement system, response stability, systematic bias

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INTRODUCTION

Previous research has identified relationships between functional movement quality and musculoskeletal injury risk, as well as athletic performance and fitness.¹ As a result, the utilization of various movement screening assessments by practitioners and clinicians to assess functional movement quality has grown tremendously over recent years.² Such assessments include: the Functional Movement Screen (FMS™), the Landing Error Scoring System (LESS), several different single-leg squat screens, and various drop and/or tuck jump assessments.³

Recently, a new assessment of functional movement quality has been introduced in the literature,^{4,5} known as the Fusionetics™ Movement Efficiency (ME) Test. This assessment was developed by Fusionetics, LLC (Milton, GA) and is associated with the Fusionetics™ Human Performance System. Similar to the FMS™,^{6,7} the ME Test utilizes seven sub-tests that require an individual to complete various movement patterns. However, the ME Test is graded based on the presence of specific movement compensations that are commonly observed during each sub-test. The Fusionetics™ Human Performance System then uses computer-based proprietary algorithms to generate a 0 – 100 (worst – best) score based on the movement compensations observed throughout the entire assessment, known as the Overall ME Test score, as well as an ME Test score for each individual sub-test.

Due to the utilization of discrete individual movement compensations in the scoring algorithms, the ME Test scores may be sensitive to changes in functional movement quality as a result of various corrective exercise interventions that address the specific movement compensations identified during the sub-tests. Due to previous research questioning the clinical utility of the FMS™ to monitor changes in movement quality,^{8,9} the ME Test may hold potential to be a more valid and/or clinically useful assessment of functional movement quality. However, before the validity or clinical utility of the ME Test can be examined, the reliability and response stability of the assessment must first be established.¹⁰ Therefore, the purpose of the current study was to examine the intra-rater test-retest reliability and response stability of the Fusionetics™ ME Test.

METHODS

Participants

Twenty-three participants (6 males, 17 females) with no prior exposure to the ME Test or the Fusionetics™ Human Performance System volunteered to participate in this study (mean $\pm$ SD, age = 25.96 $\pm$ 3.16 yrs; height = 170.70 $\pm$ 9.96 cm; weight = 66.89 $\pm$ 12.67 kg; body mass index = 22.80 $\pm$ 2.80 kg/m²). All participants were current students at the University of Wisconsin-Milwaukee (Milwaukee, WI). Participants were free of any musculoskeletal injury or muscular pain that required medical attention for the three months prior to participating in the study. All components of this study protocol were approved by the Institutional Review Board of the University of Wisconsin-Milwaukee and all participants provided written informed consent to this protocol prior to any data collection.

Protocol

All participants attended two data collection sessions (Day 1, Day 2) separated by 48 hours. To mitigate the potential influence of dehydration and/or muscle soreness, participants were instructed to not engage in any strenuous physical activity the 48 hours leading up to Day 1 of data collection, as well as in-between Day 1 and Day 2 data collection sessions. All ME Tests were administered, and subsequent data were collected, by the same researcher (K.T.E.) during both testing sessions. This researcher has been a certified athletic trainer (ATC) for 24 years, with greater than two years of prior experience administering the ME Test at the time of data collection. Participants were not informed of any test results between sessions.

ME Test

The ME Test was administered according to guidelines provided by Fusionetics, LLC (Appendix A). In brief, all participants completed the ME Test in athletic apparel and without shoes. Each participant completed each sub-test in the following order: 2-Leg Squat (Figure 1), 2-Leg Squat with Heel Lift (Figure 2), 1-Leg Squat (Figure 3), Push-Up (Figure 4), Shoulder Movements (Figure 5), Trunk Movements (Figure 6), and Cervical Movements (Figure 7). Participants were provided 5-10 trials of each sub-test and the most proficient trial (i.e., the least

Figure 1. 2-Leg Squat sub-test, A: Start Position (Front View); B: End Position (Front View); C: Start Position (Side View); D: End Position (Side View); E: Start Position (Back View); F: End Position (Back View).

Figure 2. 2-Leg Squat with Heel Lift sub-test, A: Start Position (Front View); B: End Position (Front View); C: Start Position (Side View); D: End Position (Side View); E: Start Position (Back View); F: End Position (Back View).

Figure 3. 1-Leg Squat sub-test, A: Start Position; B: End Position.

number of compensations) of each sub-test was used for scoring purposes.

Each sub-test was scored in real-time in a binomial (yes/no) fashion based on a standard set of movement compensations commonly observed during each sub-test (Appendix B). In total, 60 compensations are scored across all sub-tests of the ME Test. After scoring each sub-test, these binomial data were then entered into the Fusionetics™ Human Performance System. This online platform utilizes a proprietary algorithm to calculate a ME Test score for the overall assessment (i.e., the Overall ME Test score), as well as a ME Test score for each individual sub-test. These ME Test scores are considered interval-level data and range from 0 – 100 (worst – best).

Figure 4. 1-Push-Up sub-test, A: Start Position; B: End Position.

Figure 5. Shoulder Movements sub-test, A: Shoulder Flexion – Start Position; B: Shoulder Flexion – End Position; C: Shoulder Internal Rotation – Start Position; D: Shoulder Internal Rotation – End Position; E: Shoulder External Rotation – Start Position; F: Shoulder External Rotation – End Position; G: Shoulder Horizontal Abduction – Start Position; H: Shoulder Horizontal Abduction – End Position.

Statistical Analyses

In order to assess the intra-rater test-retest reliability of the interval ME Test score data, two-way mixed effects model (3,1) intraclass correlation coefficients ($ICC_{3,1}$) were utilized.¹¹ In addition, to examine for potential systematic bias,¹² separate repeated measure analyses of variance (RM ANOVAs) were calculated between Day 1 and Day 2 ME Test scores. All $ICC_{3,1}$ statistics and RM ANOVAs were calculated

using IBM SPSS 22 software (IBM Corp., Armonk, NY) and an $\alpha \leq 0.05$ determined statistically significant differences for all RM ANOVAs.

The response stability of the ME Test scores were further examined by calculating the standard error of the measure (SEM) statistics.¹³ SEM statistics were calculated by taking the square root of the mean square of the residual term ($\sqrt{MS_E}$) from the RM ANOVAs.¹¹

Figure 6. Trunk Movements sub-test, A: Trunk Lateral Flexion – Start Position; B: Trunk Lateral Flexion – End Position; C: Trunk Rotation – Start Position; D: Trunk Rotation – End Position.

Figure 7. Cervical Movements sub-test, A: Cervical Lateral Flexion – Start Position; B: Cervical Lateral Flexion – End Position; C: Cervical Rotation – Start Position; D: Cervical Rotation – End Position.

Finally, minimal detectable change values at both 90% ($MDC_{90\%}$) and 95% ($MDC_{95\%}$) levels of confidence were calculated based upon the previously calculated SEMs ($MDC_{90\%} = SEM \times 1.65 \times \sqrt{2}$; $MDC_{95\%} = SEM \times 1.96 \times \sqrt{2}$, respectively) in order to provide practitioners with both a liberal and a conservative assessment of ME Test score change characteristics.¹³ $ICC_{3,1}$ statistics were interpreted according to guidelines previously suggested in the literature: *poor* ($ICC_{3,1} \leq 0.39$); *fair* ($0.40 \leq ICC_{3,1} \leq 0.59$); *good* ($0.60 \leq ICC_{3,1} \leq 0.74$); and *excellent* ($ICC_{3,1} \geq 0.75$).¹⁴

In order to assess the intra-rater test-retest reliability of the binomial movement compensation data of each individual sub-test of the ME Test, percent observed agreement (%) and kappa statistics were calculated.¹² However, to correct for asymmetrical distribution of the binomial data,^{15,16} prevalence-adjusted bias-adjusted kappa statistics (κ_{PABA}) were

calculated, opposed to standard kappa statistics.¹⁷ κ_{PABA} statistics were calculated using Diagnostic and Agreement Statistics (DAG_Stat, Parkville, Victoria, Australia) open source statistical software.¹⁸ κ_{PABA} statistics were interpreted according to guidelines previously suggested in the literature:¹⁹ *poor* ($\kappa_{PABA} < 0.00$); *slight* ($0.00 \leq \kappa_{PABA} \leq 0.20$); *fair* ($0.21 \leq \kappa_{PABA} \leq 0.40$); *moderate* ($0.41 \leq \kappa_{PABA} \leq 0.60$); *substantial* ($0.61 \leq \kappa_{PABA} \leq 0.80$); and *almost perfect* ($\kappa_{PABA} \geq 0.81$).

RESULTS

Descriptive statistics (mean $\pm$ SD) of Day 1 and Day 2 ME Test scores, as well as $ICC_{3,1}$, SEM, $MDC_{90\%}$, $MDC_{95\%}$ statistics are provided in Table 1. The $ICC_{3,1}$ statistic of 0.84 indicates *excellent* intra-rater test-retest reliability of the Overall ME Test scores. In addition, the $ICC_{3,1}$ statistics indicate that the intra-rater test-retest reliability of the individual sub-tests

Table 1. ME Test intra-rater test-retest statistics.						
Assessment	Descriptive Statistics (mean $\pm$ SD)*		Reliability and Response Stability Statistics			
	Day 1	Day 2	ICC _{3,1}	SEM	MDC _{90%}	MDC _{95%}
Overall ME Test Score	50.27 $\pm$ 12.20	47.63 $\pm$ 10.42	0.84	4.57	10.63	12.68
ME Sub-Test Scores						
2-Leg Squat	61.35 $\pm$ 16.94	61.79 $\pm$ 12.75	0.71	8.03	18.68	22.26
2-Leg Squat with Heel Lift†	74.64 $\pm$ 10.85	69.13 $\pm$ 11.41	0.60	7.05	16.40	19.53
1-Leg Squat	31.82 $\pm$ 12.92	31.53 $\pm$ 13.98	0.55	9.01	20.96	24.97
Push-Up	40.00 $\pm$ 24.12	43.48 $\pm$ 18.74	0.66	12.54	29.17	34.77
Shoulder Movements	44.02 $\pm$ 26.35	40.22 $\pm$ 23.82	0.71	13.44	31.27	37.25
Trunk Movements	22.83 $\pm$ 22.50	23.91 $\pm$ 27.67	0.80	11.28	26.24	31.26
Cervical Movements†	59.78 $\pm$ 35.94	47.83 $\pm$ 29.11	0.84	12.91	30.03	35.79
ME Test = Movement Efficiency Test; SD = standard deviation. ICC _{3,1} = two-way mixed effects model (3,1) intraclass correlation coefficient; SEM = standard error of measurement; MDC _{90%} = minimal detectable change at the 90% confidence level; MDC _{95%} = minimal detectable change at the 95% confidence level.						
*all are scored 0 – 100 (worst – best)						
†different at $p < 0.05$; results of repeated measures analyses of variance (RM ANOVAs).						

ranged from *fair-to-excellent* (ICC_{3,1} range = 0.55 – 0.84). However, results of the RM ANOVAs identified statistically significant differences in ME Test scores between Day 1 and Day 2 among the 2-Leg Squat with Heel Lift ($p = 0.015$) and Cervical Movements ($p = 0.005$) sub-tests, indicating potential systematic bias within these two sub-tests. No significant differences were identified between Day 1 and Day 2 among the Overall ME Test scores, as well as among the ME Test scores of the other individual sub-tests. The MDC_{95%} statistic of 12.68 associated with the Overall ME Test score indicates that a change in ME Test score of 12.68 points is required for this change in overall functional movement quality to be considered “real” (i.e., outside of the error associated with the measure itself).^{11,13} However, a large range in SEM and MDC statistics were identified within the individual sub-tests of the ME Test (SEM range = 7.05 – 13.44; MDC_{90%} range = 16.40 – 31.27; MDC_{95%} range = 19.53 – 37.25), suggesting that the response stability varies among the individual sub-tests.

The intra-rater test-retest reliability statistics of the binomial movement compensation data, and the associated interpretation of these statistics, are provided in Tables 2 – 8. In brief, the κ_{PABA} statistics suggest that the test-retest reliability of the individual movement compensations ranged from *fair-to-almost perfect* (κ_{PABA} range = 0.30 – 1.00), with an average observed agreement of 85.7% (range = 65% – 100%). Based on the guidelines of κ_{PABA} statistic interpretations

previously suggested in the literature:¹⁹ 22 out of 60 (37%) of the possible movement compensations have *almost perfect* reliability; 19 out of 60 (32%) of the possible movement compensations have *substantial* reliability; 14 out of 60 (23%) of the possible movement compensations have *moderate* reliability; 5 out of 60 (8%) of the possible movement compensations have *fair* reliability; and 0 out of 60 (0%) of the possible movement compensations have *slight* or *poor* reliability. Furthermore, these results suggest that 55 of the 60 (92%) individual movement compensations hold *moderate-to-almost perfect* intra-rater test-retest reliability, with 41 of the 60 (68%) individual movement compensations holding *substantial-to-almost perfect* intra-rater test-retest reliability.

DISCUSSION

The purpose of the current study was to examine the intra-rater test-retest reliability and response stability of a relatively new functional movement assessment, known as the Fusionetics™ ME Test. Results of this study suggest that the Overall ME Test score holds *excellent* intra-rater test-retest reliability and that the individual sub-tests hold *fair-to-excellent* intra-rater test-retest reliability (Table 1). These results imply that the ME Test holds adequate intra-rater test-retest reliability for use among practitioners and clinicians. In addition, the ICC associated with the Overall ME Test in the current study (ICC_{3,1} = 0.84) is similar to the intra-rater test-retest ICCs associated with the FMS™ composite scores

Table 2. Intra-rater test-retest agreement of movement compensations observed during 2-Leg Squat sub-test of the ME Test.

Compensation	Observed Agreement	K _{PABA}	K _{PABA} Interpretation*
Right Foot Out	70%	0.39	Fair
Left Foot Out	70%	0.39	Fair
Right Foot Flattens	83%	0.65	Substantial
Left Foot Flattens	87%	0.74	Substantial
Right Knee Moves In	96%	0.91	Almost Perfect
Left Knee Moves In	91%	0.83	Almost Perfect
Right Knee Moves Out	78%	0.57	Moderate
Left Knee Moves Out	83%	0.65	Substantial
Excessive Forward Lean	96%	0.91	Almost Perfect
Low Back Arches	65%	0.30	Fair
Low Back Rounds	100%	1.00	Almost Perfect
Arms Fall Forwards	87%	0.74	Substantial
Right Heel of Foot Lifts	100%	1.00	Almost Perfect
Left Heel of Foot Lifts	100%	1.00	Almost Perfect
Right Asymmetrical Weight Shift	87%	0.74	Substantial
Left Asymmetrical Weight Shift	83%	0.65	Substantial
ME Test = Movement Efficiency Test; K _{PABA} = prevalence-adjusted bias-adjusted kappa statistic. *K _{PABA} interpretation based on guidelines provided by Landis and Koch ¹⁹			

Table 3. Intra-rater test-retest agreement of movement compensations observed during 2-Leg Squat with Heel Lift sub-test of the ME Test.

Compensation	Observed Agreement	K _{PABA}	K _{PABA} Interpretation*
Right Foot Out	87%	0.74	Substantial
Left Foot Out	96%	0.91	Almost Perfect
Right Foot Flattens	96%	0.91	Almost Perfect
Left Foot Flattens	96%	0.91	Almost Perfect
Right Knee Moves In	100%	1.00	Almost Perfect
Left Knee Moves In	96%	0.91	Almost Perfect
Right Knee Moves Out	91%	0.83	Almost Perfect
Left Knee Moves Out	83%	0.65	Substantial
Excessive Forward Lean	78%	0.57	Moderate
Low Back Arches	74%	0.48	Moderate
Low Back Rounds	100%	1.00	Almost Perfect
Arms Fall Forwards	91%	0.83	Almost Perfect
Right Asymmetrical Weight Shift	74%	0.48	Moderate
Left Asymmetrical Weight Shift	83%	0.65	Substantial
ME Test = Movement Efficiency Test; K _{PABA} = prevalence-adjusted bias-adjusted kappa statistic. *K _{PABA} interpretation based on guidelines provided by Landis and Koch ¹⁹			

in the FMS™ literature. Specifically, Bonazza et al.²⁰ recently calculated a pooled ICC statistic of 0.81 across the FMS™ literature.

Results of the current study also suggest that a change in Overall ME Test score of 12.68 points is required for this change in overall functional movement quality to be considered “real” ($MDC_{95\%} = 12.68$). This MDC value is associated with the error of the measure itself^{11,13} and is based upon the SEM calculated

between the Day 1 and Day 2 ME Test scores ($SEM = 4.57$). Thus, a 12.68 increase in Overall ME Test score may represent a practically significant change in functional movement quality when the ME Test is being utilized among practitioners and clinicians to assess changes in the functional movement quality of an individual as a result of an intervention. Unlike the FMS™,^{6,7} the ME Test utilizes a 0 – 100 scoring scale for both the Overall ME Test score and each the sub-test score of the ME Test. As a result, even though

Table 4. Intra-rater test-retest agreement of movement compensations observed during 1-Leg Squat sub-test of the ME Test.

Compensation	Observed Agreement	κ_{PABA}	κ_{PABA} Interpretation*
Right Leg – Foot Flattens	78%	0.57	Moderate
Left Leg – Foot Flattens	78%	0.57	Moderate
Right Leg – Knee Moves In	87%	0.74	Substantial
Left Leg – Knee Moves In	100%	1.00	Almost Perfect
Right Leg – Knee Moves Out	100%	1.00	Almost Perfect
Left Leg – Knee Moves Out	100%	1.00	Almost Perfect
Right Leg – Uncontrolled Trunk	91%	0.83	Almost Perfect
Left Leg – Uncontrolled Trunk	83%	0.65	Substantial
Right Leg – Loss of Balance	83%	0.65	Substantial
Left Leg – Loss of Balance	96%	0.91	Almost Perfect
ME Test = Movement Efficiency Test; κ_{PABA} = prevalence-adjusted bias-adjusted kappa statistic. * κ_{PABA} interpretation based on guidelines provided by Landis and Koch ¹⁹			

Table 5. Intra-rater test-retest agreement of movement compensations observed during Push-Up sub-test of the ME Test.

Compensation	Observed Agreement	κ_{PABA}	κ_{PABA} Interpretation*
Head Moves Forward	91%	0.83	Almost Perfect
Scapular Dyskinesis	83%	0.65	Substantial
Low Back Arches / Stomach Protrudes	87%	0.74	Substantial
Knees Bend	70%	0.39	Fair
ME Test = Movement Efficiency Test; κ_{PABA} = prevalence-adjusted bias-adjusted kappa statistic. * κ_{PABA} interpretation based on guidelines provided by Landis and Koch ¹⁹			

Table 6. Intra-rater test-retest agreement of movement compensations observed during Shoulder Movements sub-test of the ME Test.

Compensation	Observed Agreement	κ_{PABA}	κ_{PABA} Interpretation*
Right Shoulder – Flexion: Compensation during movement / Unable to bring hand to wall	74%	0.48	Moderate
Left Shoulder – Flexion: Compensation during movement / Unable to bring hand to wall	78%	0.57	Moderate
Right Shoulder – Internal Rotation: Compensation during movement / Unable to bring hand to mid-line of trunk	78%	0.57	Moderate
Left Shoulder – Internal Rotation: Compensation during movement / Unable to bring hand to mid-line of trunk	78%	0.57	Moderate
Right Shoulder – External Rotation: Compensation during movement / Unable to bring hand to wall	83%	0.65	Substantial
Left Shoulder – External Rotation: Compensation during movement / Unable to bring hand to wall	78%	0.57	Moderate
Right Shoulder – Horizontal Abduction: Compensation during movement / Unable to bring hand to wall	78%	0.57	Moderate
Left Shoulder – Horizontal Abduction: Compensation during movement / Unable to bring hand to wall	78%	0.57	Moderate
ME Test = Movement Efficiency Test; κ_{PABA} = prevalence-adjusted bias-adjusted kappa statistic. * κ_{PABA} interpretation based on guidelines provided by Landis and Koch ¹⁹			

previous research by Teyhen et al.²¹ has examined the MDC of the FMS™, it is not possible to compare the MDC_{95%} of the ME Test identified in the current study to the MDC_{95%} of the FMS (12.68 vs. 2.07, respectively).

However, since several recent studies have failed to identify improvements in FMS™ scores as a result of targeted corrective or functional training programming,²²⁻²⁴ the clinical utility of the FMS™ for use

Table 7. Intra-rater test-retest agreement of movement compensations observed during Trunk Movements sub-test of the ME Test.

Compensation	Observed Agreement	κ_{PABA}	κ_{PABA} Interpretation*
Right Trunk Lateral Flexion: Compensation during movement / Unable to touch lateral joint line of knee	83%	0.65	<i>Substantial</i>
Left Trunk Lateral Flexion: Compensation during movement / Unable to touch lateral joint line of knee	87%	0.74	<i>Substantial</i>
Right Trunk Rotation: Compensation during movement / Unable to rotate shoulder to midline	96%	0.91	<i>Almost Perfect</i>
Left Trunk Rotation: Compensation during movement / Unable to rotate shoulder to midline	91%	0.82	<i>Almost Perfect</i>
ME Test = Movement Efficiency Test; κ_{PABA} = prevalence-adjusted bias-adjusted kappa statistic. * κ_{PABA} interpretation based on guidelines provided by Landis and Koch ¹⁹			

Table 8. Intra-rater test-retest agreement of movement compensations observed during Cervical Movements sub-test of the ME Test.

Compensation	Observed Agreement	κ_{PABA}	κ_{PABA} Interpretation*
Right Cervical Lateral Flexion: Compensation during movement / Unable to side-bend half the distance to the shoulder	74%	0.48	<i>Moderate</i>
Left Cervical Lateral Flexion: Compensation during movement / Unable to side-bend half the distance to the shoulder	83%	0.65	<i>Substantial</i>
Right Cervical Rotation: Compensation during movement / Unable to rotate chin to shoulder	87%	0.74	<i>Substantial</i>
Left Cervical Rotation: Compensation during movement / Unable to rotate chin to shoulder	70%	0.39	<i>Fair</i>
ME Test = Movement Efficiency Test; κ_{PABA} = prevalence-adjusted bias-adjusted kappa statistic. * κ_{PABA} interpretation based on guidelines provided by Landis and Koch ¹⁹			

among practitioners and clinicians has been questioned.^{8,9} It has been previously suggested that a lack of responsiveness of the FMS™ scoring system may be a result of the 0 – 3 ordinal scoring scale of the FMS™ sub-tests may contribute to the equivocal clinical utility noted in the literature.²⁵⁻²⁹ Although a 0 – 100 scale has been introduced by developers of the FMS™,^{30,31} there is currently a lack of research utilizing this scoring scale. It is possible that the 0 – 100 scoring scale of the ME Test may prove to be more sensitive to changes in functional movement quality as a result of a targeted corrective exercise intervention, but further research to confirm this hypothesis is warranted.

In addition, the minimal clinically important difference (MCID), or the smallest change in which a patient/individual would consider to be beneficial,³² of the Overall ME Test score remains unidentified. Therefore, future research should explore the

relationships between changes in ME Test scores as the result of an intervention with these individual's perceived benefits in functional movement quality.³³ Such research would assist with determining the MCID associated with the ME Test and will help further elucidate the level of change in ME Test scores that are required to be clinically meaningful.

That said, systematic bias was potentially identified within the 2-Leg Squat with Heel Lift and Cervical Movements sub-tests, as significant differences ME Test scores were identified between Day 1 and Day 2, suggesting that systematic bias may be apparent within these specific sub-tests. It is possible that the differences between Day 1 and Day 2 are related to the number of movement compensations being assessed, differences in precise implementation of testing instructions for these sub-tests, and/or an expected amount of variability in movement quality across days. However, these potential mechanisms

could only be considered speculative at this point and future research examining the potential variability in sub-tests scores across longer durations of time is required to further elucidate the potential, if any, influence of these factors. Furthermore, large ranges in the SEM and MDC statistics were identified within the individual sub-tests of the ME Test (Table 1). Taken together, these results indicate that the response stability varies among the individual sub-tests. Therefore, although the intra-rater test-retest reliability of the individual sub-tests ranged from *fair-to-excellent*, caution should be taken if utilizing a single sub-test of the ME Test to assess changes in functional movement quality and utilizing the Overall ME Test score may be more appropriate.

Similar to the results in the current study, previous research has also identified large, and sometimes conflicting, ranges in intra-rater test-retest reliability among the various FMS™ sub-tests in the FMS™ literature as well.³⁴ Since it is possible that these ranges in FMS™ sub-test reliability may be contributing to the questionable construct of the FMS™ composite score,²⁵⁻²⁹ future research should also examine the factorial validity of the Overall ME Test score. Moreover, although both the ME Test and the FMS™ quantify functional movement quality, the variance shared between these two assessments remains unexplored. Therefore, future research should also examine the criterion-reference validity of the ME Test in relation to the already established FMS™ assessment.

Finally, since the Fusionetics™ Human Performance System utilizes movement compensations identified during each sub-test to calculate each ME Test score, it is also important to examine the consistency associated with identifying these specific movement compensations. As such, the intra-rater test-retest reliability of the binomial movement compensation data of each individual sub-test of the ME Test was examined as well. The results of the current study suggest that the intra-rater test-retest reliability of the individual movement compensations ranged from *fair-to-almost perfect*. Although a large range in κ_{PABA} statistics were observed (κ_{PABA} range = 0.30 – 1.00), it should be noted that the vast majority (92%) of the individual movement compensations held *moderate-to-almost perfect* intra-rater test-retest reliability and an average observed agreement of 85.7%

was found between the movement compensations identified on Day 1 and Day 2. These results suggest that the individual movement compensations associated with the scoring of each sub-test of the ME Test hold adequate intra-rater test-retest reliability as well. Collectively, these results provide further support for the response stability in the scoring of the Overall ME Test score, as consistency in the identification of these movement compensations would theoretically be required to create consistency in this scoring process.

Beyond the support regarding the reliability of the ME Test scoring methods, the current study introduces to the literature preliminary insight into the level of change in ME Test scores that is required to hold practical relevance. To date, this information is unknown and these results provide clinicians and practitioners with initial scientific evidence to guide the use of the ME Test as a functional outcome measure within their practice. Specifically, there is a growing trend among clinicians and practitioners to prescribe specific corrective exercises in an attempt to improve many of the same movement compensations observed during the ME Test.^{35,36} For example, the targeted strengthening of the gluteus medius and other proximal musculature in an effort to mitigate dynamic knee valgus observed during movement.^{37,38} Based on this growing trend and the results of the current study, improvements in ME Test scores may indicate successful mitigation of the observed movement compensations as a result of the targeted corrective exercise programming. Such outcomes would provide additional rationale for the sensitivity of the ME Test and support for its use as a useful assessment tool. However, further research examining both the responsiveness of the ME Test and the efficacy of such corrective exercise programming is required.

Limitations

There are limitations to consider with the current study. Similar to other commercially available products that rely on a proprietary algorithm to generate an outcome, the proprietary nature of the ME Test scoring does not allow for practitioners and researchers to identify how various movement compensations are weighted within the scoring calculations. Due to this, the reproducibility of this study is not

generalizable without utilizing the Fusionetics™ Human Performance System. The current study did, however, examine the intra-rater test-retest reliability of the 60 total movement compensations for each individual sub-test as well. Since the vast majority (92%) of the individual movement compensations held *moderate-to-almost perfect* intra-rater test-retest reliability, it is likely that the response stability of these scoring criteria resulted in the *fair-to-excellent* intra-rater test-retest reliability identified within the ME Test scores.

The results of the current study can also only be generalized to college-aged university students, as reliability must be established within each sample population of interest.¹⁰ Therefore, future research examining the intra-rater test-retest reliability and MDC characteristics should be conducted among other various clinical populations of interest (e.g., collegiate & professional athletes, tactical athletes, etc.). In addition, the current study utilized live assessment methods during each testing session, which meets the intended utility of the movement screen. It is possible that the assessment of movement compensations, and thus, the scoring of each sub-test, will differ between live and *post hoc* video analysis methods. Although use of video to make the assessments could become a practical limitation a movement screen for a clinician, future research should examine if differences in assessment methods exist within the scoring of the ME Test.

Finally, the researcher who performed all ME Test assessments in the current study (K.T.E.), was an ATC with greater than two years of previous experience with conducting the ME Test on numerous individuals. As a result, future research should be conducted to examine the intra-rater test-retest reliability of practitioners and clinicians of other professional backgrounds (e.g., strength and conditioning [S&C] professionals, physical therapists [PTs], etc.), as well as the effect of training and familiarity with the ME Test on the intra-rater test-retest reliability among various practitioners and clinicians. Similarly, although preliminary data has been presented regarding the inter-rater reliability of the ME Test,^{4,5} further research investigating the consistency in ME Test scoring between raters, and the potential scoring biases between raters of differing professional

backgrounds (e.g., S&C professionals vs. PTs vs. ATCs, etc.), should be explored as well.

CONCLUSIONS

In conclusion, results of the current study indicate that the Fusionetics™ ME Test holds adequate intra-rater test-retest reliability for use among practitioners and clinicians. Results of the current study also suggest that a 12.68 point change in Overall ME Test score may represent a practically significant change in functional movement quality when utilizing the ME Test to assess changes in the functional movement quality of an individual as a result of an intervention. However, caution should be taken by practitioners and clinicians if deciding to utilize an individual sub-test of the ME Test to quantify and/or monitor changes in functional movement quality.

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Appendix A. Movement Efficiency (ME) Test Instructions Checklist.

Sub-Tests	Participant Positioning	Tester Instructions / Participant Actions
2-Leg Squat	<ul style="list-style-type: none"> - Feet shoulder-width apart - Toes pointing straight ahead - Arms extended overhead 	<ul style="list-style-type: none"> - Perform 5 squats as if sitting into chair - <u>Observe</u>: front, side, & back views
2-Leg Squat with Heel Lift	<ul style="list-style-type: none"> - Elevate heels approximately 2" - Feet shoulder-width apart - Toes pointing straight ahead - Arms extending overhead 	<ul style="list-style-type: none"> - Perform 5 squats as if sitting into chair - <u>Observe</u>: front, side, & back views
1-Leg Squat (completed bilaterally)	<ul style="list-style-type: none"> - Balancing on 1-leg, with hands on hips - Toes pointing straight ahead - Non-involved foot & leg are neutral 	<ul style="list-style-type: none"> - Perform 5 squats as if sitting into chair - <u>Observe</u>: front, side, & back views
Push-Up	<ul style="list-style-type: none"> - Assume a push-up position - Hands outside shoulders, even with chest - Head looking at ground, cervical spine at neutral 	<ul style="list-style-type: none"> - Perform 5-10 push-ups - <u>Observe</u>: Side view
Shoulder Movements (4 total movements completed bilaterally)	<ul style="list-style-type: none"> - Standing with back to wall - Feet hip-width apart, arms by sides - Heels, buttocks, shoulders & back of head touching wall 	<ol style="list-style-type: none"> 1. Flexion: Raise arm straight overhead, touch thumb to wall 2. Internal Rotation: Elbows at 90°, rotate shoulder taking wrists forward toward mid-line of body 3. External Rotation: Elbows at 90°, rotate shoulder taking back of wrist to wall 4. Horizontal Abduction: Hands together in front of body, reach back of wrist to wall <p><u>All of the above</u>: Observe front & side views; perform one arm at a time</p>
Trunk Movements (2 total movements completed bilaterally)	<ul style="list-style-type: none"> - Standing with back to wall - Feet shoulder-width apart, arms by sides - Heels, buttocks, shoulders, & back of head touching wall - Rotation: Individual steps away from wall, places hands across shoulders 	<ol style="list-style-type: none"> 1. Lateral Flexion: Side bend and slide hand down outside of leg to lateral knee joint line 2. Rotation: Rotate upper body (maintaining a neutral pelvis/hips) each direction as far as possible <p><u>All of the above</u>: Observe front & side views; perform movement in each direction</p>
Cervical Movements (2 total movements completed bilaterally)	<ul style="list-style-type: none"> - Feet shoulder-width apart, arms by sides - Head in neutral position 	<ol style="list-style-type: none"> 1. Lateral Flexion: Tip head, taking ear to shoulder 2. Rotation: Rotate head and look over shoulder <p><u>All of the above</u>: Observe front & side views; perform movement in each direction</p>

Appendix B. Movement Efficiency (ME) Test Grading Form.			
2-LEG SQUAT			
Checkpoint	Compensation	Right	Left
View: Front			
Foot/Ankle	Foot Turns Out		
	Foot Flattens		
Knee	Knee Moves In (Valgus)		
	Knee Moves Out (Varus)		
View: Side			
L-P-H-C	Excessive Forward Lean		
	Low Back Arches		
	Low Back Rounds		
Shoulder	Arms Fall Forward		
View: Back			
Foot/Ankle	Heel of Foot Lifts		
L-P-H-C	Asymmetrical Weight Shift		
2-LEG SQUAT WITH HEEL LIFT			
Checkpoint	Compensation	Right	Left
View: Front			
Foot/Ankle	Foot Turns Out		
	Foot Flattens		
Knee	Knee Moves In (Valgus)		
	Knee Moves Out (Varus)		
View: Side			
L-P-H-C	Excessive Forward Lean		
	Low Back Arches		
	Low Back Rounds		
Shoulder	Arms Fall Forward		
View: Back			
L-P-H-C	Asymmetrical Weight Shift		
1-LEG SQUAT			
Checkpoint	Compensation	Right	Left
View: Front			
Foot/Ankle	Foot Flattens		
Knee	Knee Moves In (Valgus)		
	Knee Moves Out (Varus)		
L-P-H-C	Uncontrolled Trunk: Flexion, Rotation, and/or Hip Shift		
	Loss of Balance		
L-P-H-C = Lumbo-Pelvic-Hip-Complex. Note: if not specifically indicated, a compensation is defined as any accessory motion utilized by the individual that is not required to complete the desired movement.			

Appendix B. Movement Efficiency (ME) Test Grading Form. (continued)			
PUSH-UP			
Checkpoint	Compensation	Right	Left
View: Side			
Spine	Head Moves Forward		
	Scapular Dyskinesis		
L-P-H-C	Low Back Arches / Stomach Protrudes		
Knees	Knees Bend		
SHOULDER MOVEMENTS			
Checkpoint	Compensation	Right	Left
View: Side			
Shoulder	Flexion: Compensation during movement / Unable to bring hand to wall		
	Internal Rotation: Compensation during movement / Unable to bring hand to mid-line of trunk		
	External Rotation: Compensation during movement / Unable to bring hand to wall		
	Horizontal Abduction: Compensation during movement / Unable to bring hand to wall		
TRUNK MOVEMENTS			
Checkpoint	Compensation	Right	Left
View: Front			
Spine	Trunk Lateral Flexion: Compensation during movement / Unable to touch lateral joint line of knee with fingers		
	Trunk Rotation: Compensation during movement / Unable to rotate lateral aspect of shoulder to mid-line of sternum		
CERVICAL MOVEMENTS			
Checkpoint	Compensation	Right	Left
View: Front			
Spine	Cervical Lateral Flexion: Compensation during movement / Unable to side-bend neck so that ear is approximately half the distance to shoulder		
	Cervical Rotation: Compensation during movement / Unable to rotate chin to acromion of shoulder		
L-P-H-C = Lumbo-Pelvic-Hip-Complex. Note: if not specifically indicated, a compensation is defined as any accessory motion utilized by the individual that is not required to complete the desired movement.			