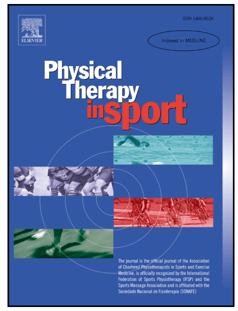

Can the Functional Movement Screen™ be used to capture changes in spine and knee motion control following 12 weeks of training?

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ABSTRACT

Objective: To examine whether objective measures of spine and frontal plane knee motion exhibited during Functional Movement Screen™ (FMS) task performance changed following a movement-guided fitness (MOV) and conventional fitness (FIT) exercise intervention.

Design: Secondary analysis of a randomized controlled experiment. Before and after 12 weeks of exercise, participants' kinematics were quantified while performing the FMS and a series of general whole-body movement tasks.

Setting: Biomechanics laboratory.

Participants: Fifty-two firefighters were assigned to MOV, FIT, or a control (CON) group.

Outcome measures: Peak lumbar spine flexion/extension, lateral bend and axial twist, and frontal plane knee motion.

Results: The post-training kinematic changes exhibited by trainees while performing the FMS tasks were similar in magnitude (effect size < 0.8) to those exhibited by CON. However, when performing the battery of general whole-body movement tasks, only MOV showed significant improvements in spine and frontal plane knee motion control (effect size > 0.5).

Conclusions: Whether graded qualitatively, or quantitatively via kinematic analyses, the FMS may not be a viable tool to detect movement-based exercise adaptations. Amendments to the FMS tasks and/or scoring method are needed before it can be used for reasons beyond appraising the ability to move freely, symmetrically, and without pain.

KEY WORDS

Exercise, firefighter, injury, knee, low back, prevention

INTRODUCTION

The Functional Movement Screen™ (FMS) was designed to screen for the general inability to move freely, symmetrically and without pain (5, 6). However, its utility could be extended if the movement patterns exhibited while performing FMS tasks reflect those employed in other settings. For example, if an individual's deep squat and in-lunge performance are able to capture specific movement tendencies (e.g. uncontrolled spine motion) also employed in a sport or workplace environment, the FMS may offer a viable means to assess injury risk and inform the design of personalized exercise programs.

In 2012, our research group published a paper that investigated whether the FMS could be used to evaluate the outcomes of two 12-week exercise interventions (12). One exercise program was designed specifically to make the participants as physically "fit" as possible (i.e. increase aerobic capacity, muscular strength and endurance, power, and flexibility), using principles of exercise science; the program mimicked many popular high intensity exercise approaches being used to improve fitness. The other program was designed and administered using similar principles of exercise science, but also relied on the theory and application of motor learning and biomechanics to guide the coach's observations and interpretations of participants' movement behaviors (9). While the global objective of both training programs was to improve strength, endurance and aerobic capacity, the coach who administered the movement-oriented program also used demonstration, instruction and feedback to instil "desired" postural and motion habits while participants performed all exercises (e.g. maintenance of neutral frontal plane knee alignment while squatting, lunging and running). The FMS was administered by a certified instructor using the verbal instructions outlined by Cook et al. (7) and qualitatively graded via video observation. Between the pre- and post-training tests, no changes were found in the average composite FMS scores of either intervention group. However, it was concluded that FMS scores could not be used for our intended purpose because scores on individual FMS tasks were extremely variable amongst control group participants (e.g. 15 of 20 participants received a different score on the shoulder mobility screen).

In a follow-up to the above investigation, numerous exercise adaptations were documented (9). Both exercise interventions elicited significant improvements (effect sizes between 0.5 and 1.2) in aerobic capacity, strength and muscular endurance, but the trainees also exhibited a number of changes in kinematic injury risk indicators when performing a battery of unrehearsed *transfer* tasks (i.e. tasks not performed during the exercise interventions) that were used to judge the extent to which motor learning had occurred. The movement-trained participants employed less spine and frontal plane knee motion post-training (i.e. a desirable outcome), measured via quantitative motion analysis, whereas those completing the fitness-only intervention displayed the opposite response (i.e. an undesirable outcome). Although the FMS is purported to be a movement screening tool that can assist in personalizing recommendations for training (18), its qualitative grading criteria did not uncover these kinematic adaptations to exercise (12). However, had participants' movement patterns been objectively measured while performing each of the FMS tasks, it is possible that changes in spine and frontal plane knee motion control during FMS task performance may have gone undetected when grading task performance based on visual inspection.

The objective of the current study was to re-examine the abovementioned dataset to determine whether objectively measured kinematic injury risk indicators were captured during participants' FMS task performance. If the constituent FMS tasks were able to capture the noted changes in participants' movement patterns, then perhaps it could also be used as a simple and cost-effective transfer test. It was hypothesized that trainees would exhibit similar changes in spine and frontal plane knee motion to those reported by Frost et al. (9) for the battery of unrehearsed transfer tasks. Specifically, trainees participating in the movement-guided and fitness-only interventions were expected to exhibit less and more joint motion, respectively, while performing the FMS following training.

METHODS

Participants

A convenience sample of 60 men from the Pensacola Fire Department were recruited to participate in a randomized controlled experiment. All men were free of musculoskeletal injury or pain at the time of testing and on full active duty. Because of the time commitment required, 4 withdrew before completing the 12-week training intervention. An additional 4 data sets were lost to due to equipment malfunction, leaving 52 participants who completed pre- and post-testing. All men were free of musculoskeletal injury or pain at the time of testing and were on full active duty. Their mean (SD) age, height, body mass and Functional Movement Screen™ (FMS) score are included in Table 1. The University's Office of Research Ethics, the Baptist Hospital Institutional Review Board and the City of Pensacola each approved the investigation and all participants gave their informed consent before the data collection began.

Insert Table 1 approximately here

Functional Movement Screen™ (FMS)

The FMS is a seven task test (5, 6) comprising the following whole-body movements: 1) Deep squat (SQT) – individuals place a dowel overhead outstretched arms and squat as low as possible, first with the heels on the floor and then with the heels raised by approximately 4 cm; 2) Hurdle step (HRD) – individuals place a dowel across their shoulders and step over a hurdle placed in front of them; 3) In-line lunge (LNG) – individuals perform a split squat with their feet aligned and a dowel contacting their head, back and sacrum; 4) Shoulder mobility (SHR) – individuals attempt to touch their fists together behind their back (internal and external shoulder rotation); 5) Active straight leg raise (SLR) – individuals actively raise one leg as high as possible while lying supine with their head on the ground; 6) Trunk stability push-up (PSH) – individuals perform a push-up with their hands shoulder width apart, first with their thumbs at the level of the forehead and then at the level of the chin; 7) Rotary stability (ROT) – individuals assume a quadruped position and attempt to touch their knee and elbow, first on the same side of the body and then on the opposite. "Clearing" tests are also included with the SHR, PSH and ROT to identify other painful movements that may not be provoked while performing the primary FMS tasks. The inter-rater reliability of FMS scores is considered acceptable (20).

Experimental Protocol

Participants were instrumented with reflective markers for whole-body kinematic tracking and familiarized with the tasks they would be asked to perform. Because the FMS was performed as part of a larger investigation comprising a variety of movements performed in a randomized fashion (8), including those reported in Frost et al. (9), the seven FMS tasks were not performed in sequence. Each FMS task was administered by an FMS certified instructor using the standardized verbal instructions outlined by Cook et al. (7). Three repetitions of each task were performed and approximately 15s and 60s of rest were given between each repetition and task, respectively. Beyond the standardized task instructions, no feedback was given regarding task performance at any time (13).

Training

Following baseline testing, participants were assigned (stratified randomization) to one of three groups: 1) movement-guided fitness training; 2) conventional fitness training; or 3) control. Each group was matched for age, height, body mass and pre-intervention composite

FMS score (graded via qualitative observation). The FMS was graded by an FMS certified instructor using frontal and sagittal plane videos and the 21-point scale described by Cook et al. (7). The two interventions comprised 12-week, periodized exercise programs designed to improve general fitness characteristics (e.g. aerobic capacity) and performance outcomes (e.g. treadmill time), but differed most notably with regards to the instructions and feedback provided by the coaches regarding *how* (kinematically) each exercise should be performed. Participants in both groups attended three 1.5-hour sessions each week at a local training facility and were coached by strength and conditioning professionals accredited by the National Strength and Conditioning Association. Each training intervention included multiple phases with varying frequencies, intensities, durations and types of activities. Additional details of the 12-week training exercise programs can be found in Frost et al. (9).

At no time were the objectives of the FMS, the differences between each training group or the study hypotheses discussed with the participants. Each individual was required to attend 30 of the 36 scheduled training sessions to be included in the analyses. Within one week of completing training (week 13), participants were screened with the FMS a second time. The CON participants were asked to maintain their current fitness regimen for 12 weeks before completing their post-intervention testing session.

Data Collection and Signal Processing

Three-dimensional motion data were measured using a passive optoelectronic motion capture system (Vicon, Centennial, CO, U.S.A.). Reflective markers were placed on 23 anatomical landmarks to assist in defining the endpoints of the trunk, pelvis, thighs, shanks and feet. The hip joint centers and knee joint axes were also determined "functionally" using similar methods to those described by Begon et al. (1) and Schwartz and Rozumalski (22). This method has been shown to improve the day-to-day reliability of the linked-segment model (15). Sets of 5 markers, fixed to rigid pieces of plastic, were secured to each body segment with

Velcro® straps and used to track its position and orientation in 3D space. One standing calibration trial was collected such that the orientation of each segment's local axis system could be determined via a transformation from an axis system embedded within each rigid body. The anatomical markers were removed once the calibration procedures were completed. The marker data were collected at 160 Hz and smoothed with a low-pass filter (4^{th} order, dual pass Butterworth) with an effective cut-off frequency of 6 Hz.

Data Analyses

The movement patterns of the SQT, HRD, LNG, PSH and ROT tasks were characterized with five variables, each chosen to reflect a visually observable feature that has been previously cited as a possible mechanism for low back (2, 19) or knee (3, 16, 17) injury. Spine flexion/extension (FLX), lateral bend (BND) and axial twist (TST) were computed by expressing the relative orientation of the rib cage with respect to the pelvis. The corresponding direction cosine matrix was decomposed with a Cardan rotation sequence of flexion/extension, abduction/adduction and axial rotation to compute the spine angle about each axis. The orientation of the lumbar spine in standing was defined as zero degrees. The position of the left (LFT) and right (RGT) knee joint center in the medial/lateral direction was described relative to a body-fixed plane created using the corresponding hip joint, ankle joint and distal foot (10). LFT and RGT were only computed for the SQT, HRD and LNG. Given constraints associated with the SHR (i.e. hands placed behind back) and SLR (i.e. lying down), it was not possible to analyze spine motion during these tasks.

To objectively define the start and end of each trial, event detection algorithms were created in Visual 3D™ by tracking the motion of the trunk, pelvis, right forearm and whole-body center of mass. Only the contralateral ROT variation was analyzed, as 31 of the 52 participants could not perform at least one balanced ipsilateral repetition. To verify that events were defined as intended, model animations of all trials were inspected visually.

Maximums and minimums of the five dependent variables were computed. The "peak" of each variable was described as the deviation (maximum, minimum or range) hypothesized to be most relevant to the types of injuries sustained by firefighters (i.e. FLX – flexion, BND and TST – range, LFT and RGT – medial displacement).

Statistical Analyses

Kinematic adaptations to each task were evaluated on a task-by-task basis using the movement variability seen between- and within-participants. Two measurements were used to describe the magnitude of each pre-post change. An effect size (ES) was computed to describe the pre-post differences in FLX, BND, TST, LFT and RGT relative to the pooled between-subject variation. An ES equal to one indicated that the pre-post difference was equal to the variation observed between participants. A positive effect implied that less motion was observed post-training. A within-subject normalized difference (WND) was computed to express the pre-post differences relative to the maximum variation observed within participants (± 1SD of the group mean) across all metrics (i.e. maximum, minimum or range) for that particular variable (11). This same approach was also used to examine the subject-specific responses for each dependent measure. A score greater than one or less than negative one indicated that the individual's post-training change was greater than the average variability observed within participants (± 1SD). A change of this magnitude was defined herein as a practically significant change (11). The strength of either variable was interpreted using the general guidelines offered by Cohen (4), whereby values of 0.2, 0.5 and 0.8 corresponded to small, moderate and large differences, respectively.

RESULTS

Group Adaptations

Deep Squat

The movement group exhibited 3 changes (TST heels down, and FLX and LFT heels up) with a WND greater than 0.5, although only that seen for TST reflected a decrease in motion (Figure 1). The fitness group also showed changes in FLX and LFT for the two conditions with a WND greater than 0.5, and similarly, each reflected a negative adaptation. Few changes were shown by the control group, the largest of which was a negative change in LFT when the heels were raised (ES=0.3; WND=0.3).

Insert Figure 1 approximately here

Hurdle Step

Post training, more FLX was used by the movement group when performing the left and right HRD (ES>0.2; WND> 0.2) (Figure 1). An increase in LFT (ES=0.3; WND=0.7) was also noted during the right HRD when the leg was in single support. As was found for the SQT, the fitness group exhibited comparable adaptations to those of the movement group; participants increased FLX during the left screen (ES=0.4; WND=0.44), and FLX (ES=0.6; WND=0.5) and LFT (ES=0.4; WND=0.8) while performing the right HRD. The control group exhibited 5 changes during the left and right side screens with an ES and WND greater than 0.2, but each was also negative.

In-Line Lunge

The largest changes displayed by the movement group were increases FLX (ES=0.3; WND=0.5) and LFT (ES=0.3; WND = 0.5) while performing the left LNG (Figure 2). The fitness group also performed the left LNG with more FLX (ES=0.4; WND=1.1) and LFTES=0.5; WND=0.7), but also exhibited an increase in RGT during the right side screen (ES=0.4; WND=0.6). Control group members also performed the left LNG with more FLX and LFT;

however, in either case the changes observed were of a smaller magnitude than those of either intervention group.

Insert Figure 2 approximately here

Stability Push-up

The movement group exhibited small increases (WND>0.2) in FLX while performing both PSH variations (Figure 2). Positive adaptations (ES and WND >0.2) were noted in BND and TST during the forehead and chin conditions, respectively. The fitness group displayed less FLX, BND and TST post-training, with larger improvements seen during the chin variation (ES>0.2; WND>0.4). The control group exhibited positive adaptations for FLX (ES>0.3; WND>0.4) and BND (ES and WND >0.2) during both PSH variations. The FLX improvement during the chin condition was larger than any adaptation seen amongst the intervention groups (ES=0.8; WND=1.4).

Rotary Stability

The movement group demonstrated a small negative change in FLX and a small positive change in BND (Figure 2). No post-training differences were noted in the FLX and TST for participants in the fitness group, although they did exhibit substantially less BND (ES=0.4; WND=0.9). No changes were displayed by the control group.

<u>Subject-Specific Adaptations</u>

The number of firefighters who exhibited significant changes (i.e. WND>1.0) in FLX, BND, TST, LFT and RGT for each FMS task was comparable for each group (Figure 3). Expressed as a percentage of the number of participants in the group, averaged across variables and tasks, 15% of all movement group participants (n=21) exhibited positive significant changes post-training. This is in comparison to 14% and 19% for the fitness (n=16) and control (n=15) groups, respectively. Similarly, no differences were seen in the number of participants displaying negative significant changes post-training. Expressed as a percentage, 18%, 19% and 15% of participants in the movement, fitness, and control groups, respectively, exhibited post-training movement patterns comprising substantially more (i.e. WND>1.0) spine and frontal plane motion than was seen during their baseline test.

Insert Figure 3 approximately here

DISCUSSION

The post-training changes in spine and frontal plane knee motion exhibited during the FMS tasks were not different between the MOV, FIT and CON groups. Averaged across the five FMS tasks investigated, 14% to 19% of the changes displayed by all three groups were described as practically significant. This finding supports our previous conclusions made based on the qualitative grading of the FMS (12); within-subject FMS task scores were highly variable across all three groups. Therefore, had the effectiveness of both exercise programs been evaluated exclusively using post-training changes in FMS task performance (qualitative or quantitative), it could have been concluded that neither intervention was able to elicit consistent changes in kinematic injury risk indicators. However, inherent to this statement are two assumptions: FMS scores are a valid measure of such indicators; and FMS task demands are sufficient to expose – with adequate sensitivity and specificity – personal factors that influence movement behaviors. Data reported previously (12, 14) and in the current study show that individuals who are pain- and injury-free can use a range of movement patterns to meet the low-demand FMS task objectives (i.e. movement varies considerably within and between "healthy" individuals). This flexibility makes it challenging to use the FMS to gauge the transfer of training or to isolate causes/effects of movement impairments or dysfunction, as a changing score may reflect naturally occurring variability in a performer's movement patterns. As such, caution should be exhibited when using the FMS to assess the extent to which a performer's movement behaviors have been changed via training (i.e. transfer) or to make personalized exercise recommendations.

To claim that either exercise program was ineffective because participants failed to improve their performance on the FMS (qualitatively or quantitatively) would also be inappropriate given that neither intervention was designed specifically for this purpose (i.e. participants were not training to improve their FMS scores). The FMS was used strictly to evaluate the transfer of training based on the original assumption that composite scores would yield insight into the presence of personal factors hypothesized to influence movement behavior (e.g. pain, left versus right side asymmetries). That said, the results of would have been equally challenging to interpret had participants improved their composite scores, given that two very different interventions have yielded 3-point improvements on the FMS (13, 18). Kiesel et al. (18) provided participants with personalized 7-week exercise programs, while Frost et al. (13) simply provided their participants with knowledge of the specific criteria used to grade FMS task performance (e.g. "…to achieve a perfect score on the deep squat, your thighs must reach below parallel,…"). It could be argued that many more adaptations would be experienced as a result of training, though such an assertion also implies that the FMS or its constituent tasks should not be the only instrument used to evaluate the effects of an exercise intervention. Additional work is needed to establish criteria with which the utility of a particular task could be evaluated for the purpose of assessing transfer of training.

In an attempt to capture the post-training adaptations to each exercise program investigated in the current study, a battery of physical fitness tests and general whole-body movement tasks (i.e. squatting, lunging, lifting, pushing and pulling) were performed alongside the FMS (9). Interestingly, a combination of five general tasks performed at multiple loads and speeds was able to expose exercise-induced changes in kinematic injury risk indicators (i.e.

transfer) that went undetected by the FMS. The movement-trained group employed less spine and frontal plane knee motion while performing each of the five general tasks, whereas the fitness-trained group exhibited more spine and frontal plane knee motion while squatting, lunging and pushing. On average, 23% of the control participants exhibited positive changes of a magnitude that were practically significant, which is similar to the 19% reported here for the FMS. But in comparison, 43% and 30% of the movement- and fitness-trained firefighters, respectively, also showed positive post-training adaptations. It could be argued that superior transfer would be expected for the battery of general tasks given some similarity to the exercises performed while training; however, this assertion highlights the importance of choosing a transfer test that reflects the movement behaviors being targeted with training. If the movement patterns adopted to perform the FMS tasks do not reflect those that would be deemed critical for a performer (e.g. movement patterns relevant to sport or occupational demands), there may be little merit in trying to improve FMS task scores via exercise.

The battery of general squatting, lunging, lifting, pushing and pulling tasks investigated alongside the FMS (9) was previously shown to capture the extent to which firefighters control their spine and frontal plane knee motion while performing essential duties specific to their occupation (e.g. magnitude of spine flexion was similar) (10). But perhaps more relevant to the current study was the finding that the strength of the relationship between the general and occupation-specific tasks increased when the demands (i.e. external load and movement speed) were elevated. This may be the reason that many of the movement-related changes were not detected by the FMS; its physical demands may not be sufficient to expose the movement behaviors that contribute to an elevated risk of injury. For example, the post-training changes in spine and frontal plane knee motion documented in the FMS deep squat with the heels down were near identical in both magnitude and direction to those observed while participants performed the least demanding (i.e. low load, low speed) squat pattern reported by Frost et al. (9). Both training groups displayed an increase in spine flexion (ES >

0.5) and modest changes in right side knee motion (ES > 0.3), albeit positive and negative for the MOV and FIT groups, respectively. As shown by Frost et al. (9), it was only when participants were challenged with the higher demand conditions that their spine and knee motion were found to discriminate between the training-induced kinematic adaptations. A similar finding was noted for the in-line lunge and the low-demand lunge pattern. While performing both tasks, the movement-trained individuals exhibited no change in their tendency to control spine flexion or frontal plane knee motion, though a positive response (i.e. less spine flexion) was seen when they were asked to perform at a higher speed. Without investigating the higher demand conditions, the post-training changes observed during the battery of general tasks may have appeared quite similar to those reported here for the FMS, which may imply that training had little impact on the performance of low demand activities. For this reason, to fully appreciate the effectiveness of either intervention, there may be value in contrasting the pre-post changes of the transfer tests to the changes observed for a series of specific exercises that were performed during training.

Because the FMS deep squat and in-line lunge were shown to capture the spine and knee motions observed while performing the general patterns, there may be merit in modifying the FMS to include more physically demanding exposures when screening a specific population or for a particular type of injury. Many scientists seeking to investigate ACL injury risk factors only investigate high-demand activities (e.g. drop landing (16, 21)) given the possibility that the hypothesized injury-generating motions may not surface when performing less challenging tasks. For the purpose of investigating injury risk, it is also important that the tasks chosen to capture a particular movement behavior (e.g. uncontrolled frontal plane knee motion) do in fact provide a suitable exposure. Performing push-ups with the hands placed symmetrically, for example, would be inappropriate to evaluate frontal or transverse plane lumbar spine control since there is no net external demand frontal or transverse plane moments to be balanced by the trunk musculature. This notion supports the dissimilar post-training adaptations between the unilateral push patterns presented by Frost et al. (9) and the FMS push-up task, and highlights one of the reasons why the FMS may not serve as a viable transfer test to assess pre-post training changes in control of spine rotation. Further work is needed to establish a framework that would assist with the selection of tasks that can be used to identify the impact of a particular intervention beyond the exercise environment and the specific activities rehearsed while training.

CONCLUSIONS

Although the FMS was originally intended to serve as a way to screen for the general inability to move freely, symmetrically, and without pain during low demand activities, it is also being used to design personalized exercise programs and evaluate the extent to which training transfers beyond the exercise environment. The findings of this investigation highlight the need for further amendments to the FMS tasks and/or scoring method before it can be used for these purposes. Post-training changes in participants' spine frontal plane knee motion that were captured via a battery of general whole-body movement tests were not reflected in FMS task performance. This implies that the FMS, whether graded qualitatively using composite or task scores, or quantitatively via kinematic analyses, may not be a viable tool to assess performers' movement behaviors. Additional research is needed to examine the validity of the FMS, and the extent to which its constituent tasks are able to capture specific personal characteristics or movement patterns that would be targeted while training.

HIGHLIGHTS

Findings

- Post-training changes in spine and knee motion control were similar across groups
- Substantial variation in spine and knee motion was seen amongst the control group
- The FMS did not capture kinematic changes that occurred in response to training

Practical Implications

- Low demand movement screens may not challenge control of relevant motions
- The FMS may not be an effective tool to assess the transfer of training

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TABLE CAPTIONS

Table 1. The mean (SD) age, height, body mass and composite Functional Movement Screen™ (FMS) score for each intervention group prior to training.

FIGURE CAPTIONS

Figure 1. Training adaptations in the peak spine and frontal plane knee motion for the deep squat (heels up and down) and hurdle step (left and right side). Changes are presented as a function of the maximum within-subject variation + 1SD observed for each task. The (ES) effect size of each difference is also described by the inclusion of one (ES=0.2-0.5), two (0.5-0.8) or three (>0.8) asterisks. A positive change implies that less motion was employed post-training.

Figure 2. Training adaptations in the peak spine and frontal plane knee motion for the trunk stability push-up (hands at forehead and at chin) and in-line lunge (left and right side). Changes are presented as a function of the maximum within-subject variation + 1SD observed for each task. The (ES) effect size of each difference is also described by the inclusion of one (ES=0.2-0.5), two (0.5-0.8) or three (>0.8) asterisks. A positive change implies that less motion was employed post-training.

Figure 3. The number of participants exhibiting post-training changes greater than the maximum within-subject variation +1SD observed for each variable (i.e. a practically significant change). The differences presented reflect changes to the peak spine flexion (FLX), lateral bend (BND) and twist (TST), and the right (RGT) and left (LFT) frontal plane knee displacement. A positive change implies that less motion was employed post-training.

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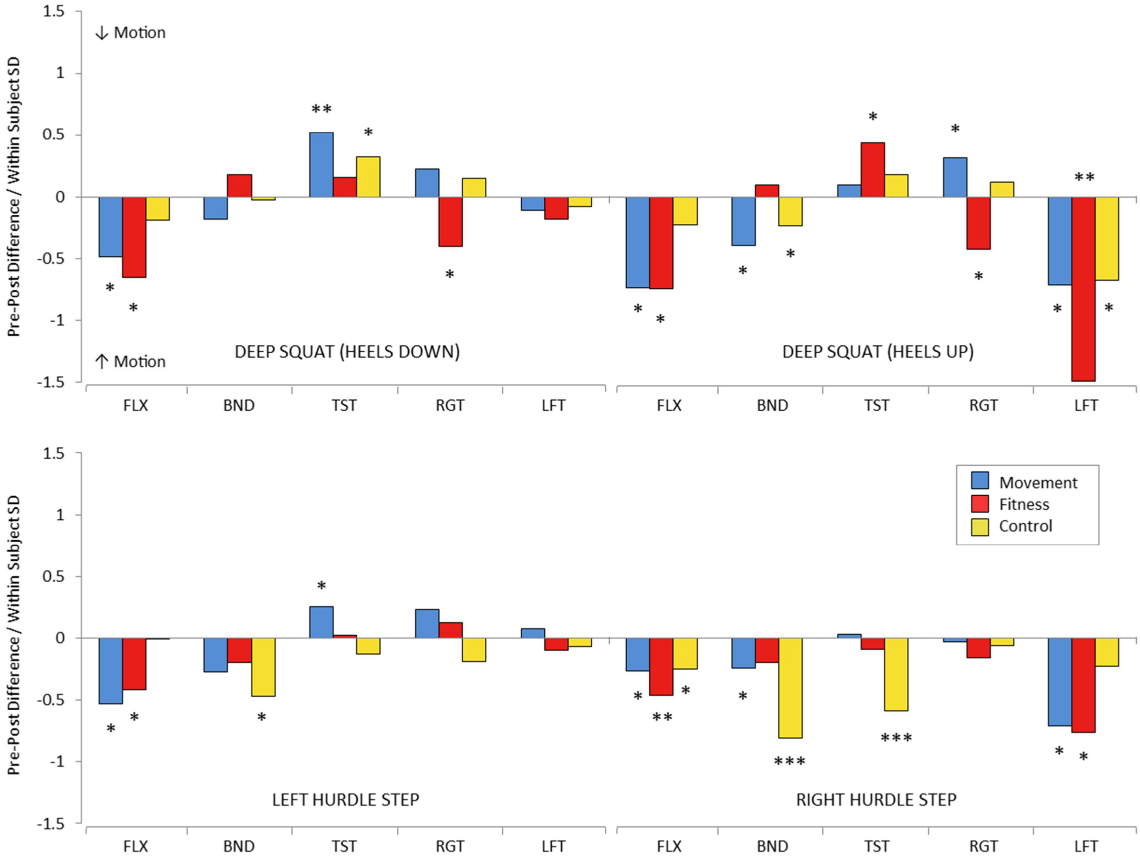
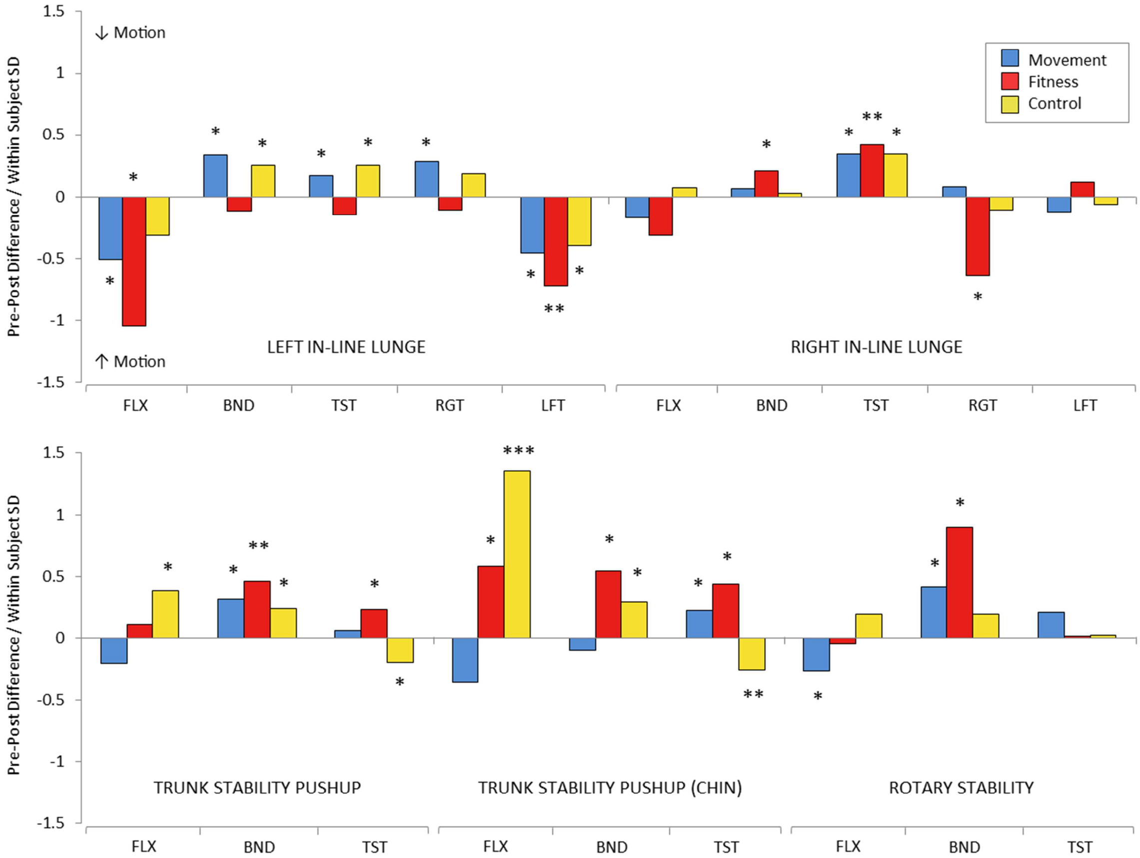
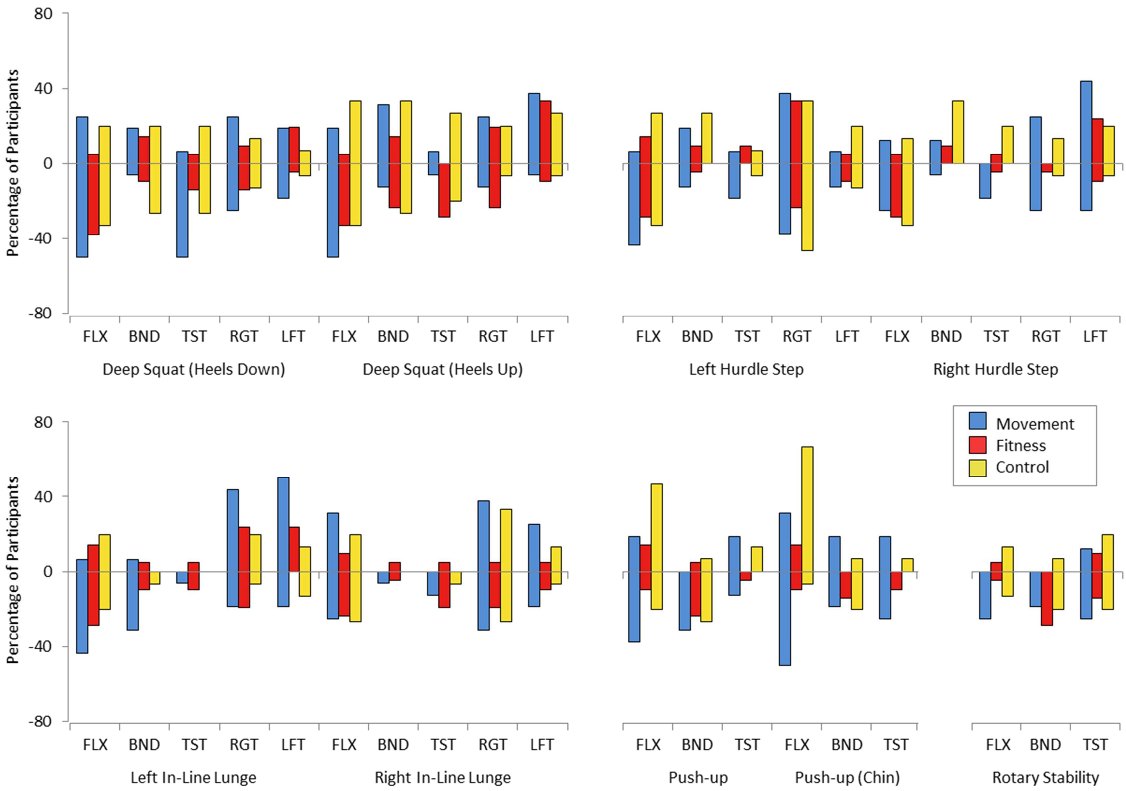
Table 1. The mean (SD) age, height, body mass and Functional Movement Screen™ (FMS) score to each intervention group before training.

Group (N)	Age (years)	Height (m)	Body Mass (kg)	FMS Score
Movement (21)	38.7 (10.4)	1.81 (0.06)	89.6 (14.7)	13.0 (2.8)
Fitness (16)	35.9 (9.7)	1.80 (0.07)	91.6 (13.4)	12.4 (1.5)
Control (15)	38.3 (9.3)	1.80 (0.06)	96.0 (15.2)	12.9 (2.9)


Pre-Post Difference / Within Subject SD
↓ Motion
↑ Motion
DEEP SQUAT (HEELS DOWN)
DEEP SQUAT (HEELS UP)
LEFT HURDLE STEP
RIGHT HURDLE STEP
FLX
BND
TST
RGT
LFT
Movement
Fitness
Control



1.5
1
0.5
0
-0.5
-1
-1.5
↓ Motion
↑ Motion
Pre-Post Difference / Within Subject SD
Movement
Fitness
Control
LEFT IN-LINE LUNGE
RIGHT IN-LINE LUNGE
FLX
BND
TST
RGT
LFT
TRUNK STABILITY PUSHUP
TRUNK STABILITY PUSHUP (CHIN)
ROTARY STABILITY


80
40
0
-40
-80
Percentage of Participants
FLX
BND
TST
RGT
LFT
Deep Squat (Heels Down)
Deep Squat (Heels Up)
Left Hurdle Step
Right Hurdle Step
Movement
Fitness
Control
Left In-Line Lunge
Right In-Line Lunge
Push-up
Push-up (Chin)
Rotary Stability

HIGHLIGHTS

Findings

- Post-training changes in spine and knee motion control were similar across groups
- Substantial variation in spine and knee motion was seen amongst the control group
- The FMS did not capture kinematic changes that occurred in response to training

Practical Implications

- Low demand movement screens may not challenge control of relevant motions
- The FMS may not be an effective tool to assess the transfer of training

ETHICS STATEMENT

The University's Office of Research Ethics, the Baptist Hospital Institutional Review Board and the City of Pensacola each approved the investigation and all participants gave their informed consent.