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The Effects of Strength and Conditioning on Functional Movement Screen™ Scores in Secondary School Basketball.

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Purpose: Injury prevention and mitigation are among the primary responsibilities of Athletic Trainers. Research has indicated that basketball players at the secondary school level suffer up to 2.1 time loss injuries (TLI) per 1,000 athletic exposures (AE). It has been suggested that Functional Movement Screen (FMS™) composite and individual task scores may help determine injury risk. Researchers have suggested that a variety of strength and conditioning strategies may positively alter both composite and individual FMS™ task scores and reduce movement asymmetry. ***Methods:*** During a retrospective analysis of the records of all junior varsity and varsity basketball players at one secondary school over one season, no TLI was recorded over 1900 AE following the implementation of team-specific strength and conditioning programming. ***Results:*** Significant increases in pre-season and post-season composite FMS™ scores (pre-season mean = 14.33 ± 1.84; post-season mean = 16.44 ± 1.72; $p < 0.001$), and FMS™ individual task scores; deep squat (DS) ($p < 0.001$), hurdle step (HS) ($p = 0.002$), in-line lunge (ILL) ($p = .011$), active straight leg raise (ASLR) ($p = .02$), and rotary stability (RS) ($p = .005$) were noted across 27 male and female participants. Among females, composite FMS™ scores changed significantly (pre-season mean = 14.92 ± 1.38; post-season mean = 17.00 ± 1.04; $p < 0.001$), as did HS ($p < 0.001$) and ILL ($p = .025$). Among males, significant changes were noted in composite FMS™ scores (pre-season mean = 13.87 ± 2.07; post-season mean = 16.00 ± 2.04; $p < 0.001$), as well as DS ($p = 0.007$), and RS ($p = .025$). Reductions in the number of scores of one and movement asymmetries were also evident during post-season FMS™ screening. ***Conclusions:*** Emphasizing movement competency and strength and conditioning training has positive effects on injury risk reduction in secondary school basketball players.
Keywords: *Injury Risk Reduction, Functional Testing, Secondary Schools Patient Population*

INTRODUCTION:

The prevention, evaluation, diagnosis, and management of orthopedic injury are paramount among the professional responsibilities of Athletic Trainers (AT).[1] Hoffman et al. defined these roles as stages of prevention based on a public health disease model where primary prevention represents targeted measures aimed at preventing injury (e.g. strength and conditioning programming targeted at anterior cruciate ligament (ACL) injury prevention).[2] In secondary school environments, ATs may function as both clinician and strength and conditioning coach depending on staffing models and the specific needs of a given patient population.[3,4] As ATs continue to serve as both sports medicine professional and strength and conditioning coach, roles that both include injury prevention, it is important to consider how injury risk may be reduced through screening and intervention in a dual role athletic training clinical practice.

In the 2014/2015 school year, 4,563,236 boys and 3,400,297 girls participated in high school sports in the United States.[5] Among this population, approximately 550,305 boys and 430,368 girls participated in basketball at the high school level.[5] Steadily growing participation rates amount to ever increasing athlete exposures (AE), a measure of practice and competition time often utilized to evaluate relative injury risk.[6-8] Based on common guidelines, an AE consists of one athlete participating in one organized practice or competition.[7-9] Athletic injury is often defined by having met three criteria; 1) the event must have occurred during AE, 2) the event must have required medical attention, and 3) the event must have resulted in time loss from practice or competition for one or more days beyond onset.[7,9] This definition is commonly referred to as time loss injury (TLI).

Injury surveillance data from ATs at 100 secondary schools across the United States between 2005 and 2007 indicated that the overall rate of TLI for secondary school basketball was 2.08 per 1,000 AE (3.66 in competition and 1.43 in practice) and 1.83 per 1,000 AE (2.93 in competition and 1.38 in practice) for girls and boys respectively.[7] As participation rates continue to grow, so too does the importance of understanding the epidemiology, care, and prevention of athletic injury in secondary school student-athletes.[6] Given the relative risk of injury during training or competition in secondary school basketball, it is crucial that ATs continue to develop their understanding of measurable injury risk, prevalence, and injury prevention.

As a practice model, the inclusion of ATs at the primary prevention level, either in the combined role of AT and strength and conditioning coach, or directly engaged with the strength and conditioning process, may represent a significant factor in the prevention of TLI. Screening tools such as the Functional Movement Screen™ (FMS™) allow for the quick and efficient evaluation of fundamental human movement patterns.[10,11] Utilizing the FMS™ may also uncover pain during screening, indicating the need to refer to a healthcare professional, such as an AT, for further assessment.[10,11] As a screen for movement associated pain, the FMS™ holds value in the realm of injury prevention through the early detection of painful movement or pain provoking patterns that may indicate an underlying condition. Such screening processes represent a first step in primary injury prevention.

Regarding the utility of the FMS™ as a screen for potential injury risk, however, the literature is inconclusive. While some researchers' interpretations contradict the value of the FMS™ as a predictive measure of injury, other researchers have suggested that the FMS™ has value in assessing injury risk via composite score values.[12-23] Across a variety of athletic populations, researchers have demonstrated injury risk increases with a composite score of ≤ 14.[15-23] For example, professional football players scoring ≤ 14 represents an 11 fold increase in injury risk.[21] In female collegiate basketball, soccer, and volleyball players, a score of ≤ 14 correlates with up to a fourfold increase in lower extremity injury risk.[17] When compared with populations who have a history of injury, collegiate athlete composite scores ≤ 14 have been suggested to have a 15 fold increased risk of injury when compared to scores ≥ 15.[19] It has also been suggested that injury risk increases with individual task scores of 1, signifying dysfunctional movement patterns, or asymmetry in paired movements during FMS™ screening.[22] Kiesel, Butler, and Plisky proposed that there may be a specific correlation between risk of injury and a score of 1 on the deep squat (DS), an individual task scored in the FMS™, noting that participants with a DS score of 1 appear to be up to 5 times more likely to have a composite score < 14.[22] It is important to note that when evaluating FMS™ results, composite scores have a maximum of twenty one and a pain free minimum of seven while individual task scores have a maximum of three and a pain free minimum score of one.

Training that utilizes strength and conditioning tactics and corrective exercise programs are often employed for the purposes of performance enhancement and are commonly believed to assist in the prevention of injury. However, mixed evidence and diverse training programs leave changes in FMS™ scores based on intervention programs a topic of debate. Researchers in the area of primary injury prevention have reported positive changes in FMS™ composite and individual task scores, as well as the resolution of asymmetries, with application of interventions including training and strength and conditioning.[22,24-26] Kiesel et al. applied corrective exercise training interventions on an individualized basis according to the participants task specific FMS™ scores.[22] Though the authors conclude that the FMS™ cannot independently predict how or when an injury will happen, Kiesel and colleagues suggest that the FMS™ may be clinically significant for the sports medicine team when surveying large groups of people, such as athletic teams, to extrapolate data regarding injury risk.[22] Bodden, Needham, and Chockalingham found that FMS™ scores increased significantly in mixed martial artists when specific corrective exercise interventions were applied to participants compared to controls who made no specific changes to their training.[24] Linek et al. applied specific core based intervention programming with adolescent male volleyball players finding that alterations in training to include such an intervention significantly changed FMS™ composite and individual task scores when compared to 'normal' training and practice activities at 8 week intervals.[25] In contrast, Sprague et al. investigated changes in composite and individual task scores comparing NCAA Division II teams with and without strength and conditioning programming discovering no significant differences in score changes between teams with and without strength and conditioning programs during their competitive seasons.[26] However, with little included regarding the details of the strength and conditioning programming, it is difficult to make meaningful conclusions regarding the influence of programming on functional movement outcomes in the study.[26] The results of our study suggest that meaningful change in individual task and composite scores can be accomplished with efficient, in season, performance-based strength and conditioning training without specific programming aimed at an individual's FMS® scores.[22,24-26] Considering the current body of evidence, the FMS™ may provide a reliable and valid tool to assess alterations in injury risk when considering the three primary factors: composite score, individual task scores of one, and paired movement asymmetries. The purpose of this retrospective study is to examine and highlight the utility of the FMS™ as a measure of the efficacy of a newly implemented strength and conditioning program with regard to injury risk reduction in secondary school student-athletes over the course of a competitive basketball season.

METHODS

Under approval by the University Institutional Review Board and with signed informed consent, or parental consent and participant ascent in the case of minors, the de-identified records of 30 secondary school basketball players were analyzed for this study. A retrospective analysis of pre-season and post-season FMS™ scores was performed for both boys and girls grade 9-12 basketball seasons in one secondary school after the implementation of an in-season strength and conditioning program. The primary investigator, a Certified Athletic Trainer and Strength and Conditioning Coach also certified and trained in the use of the FMS™, collected pre-season and post-season FMS™ scores prior to the first competition of the basketball season for all student athletes as part of pre-participation examinations (PPE). Post-season FMS™ scores were collected within 14 days of the end of competitive season. Of the 30 participants involved in this study, 3 were excluded during analysis of FMS™ scores with pain scores of 0 during pre-season testing leaving 27 active participants in the study (female n=12, male n =15).

Intervention

In-season strength and conditioning programming was designed by a certified and state licensed AT and a Master of Science level athletic training student, both of whom were Certified Strength and Conditioning Specialists (CSCS). The programming was designed as a team-based approach with in-session training alterations made individually dependent upon each participant's needs and ability and implemented over the course of one basketball season. Sessions were conducted over the course of the 15-week competitive season with approximately 2-3 sessions per team, per week, depending on the competitive schedule of each team, with no programming scheduled on game days. During regularly scheduled practice, each team would divide into two groups with one group reporting to the weight room for approximately 20 minutes to conduct strength and conditioning training while the other team would continue with regular practice activities. After the first group completed the strength and conditioning session, participants would rotate back to the basketball court and the second group would begin strength and conditioning training. Strength and conditioning exercise selection was not based on the individual FMS™ scores of each participant, and therefore was selected and progressed based on individual competency in a given movement pattern or exercise per the observation of the AT and strength and conditioning coaches during training.

Outlined in Table 1 are the strength and conditioning progressions by movement pattern utilized in training during the intervention period. The first phase of each days strength and conditioning sessions began with a three-part warm-up. The first exercise was a core stability centered drill (i.e. rolling patterns, planks, crawling).[27,28] The second and third drills included hip (e.g. half kneeling hip hinge) and shoulder (e.g. kettlebell halos) dominant exercises designed to influence new active range of motion through increased stability and motor control.[29] Phase two of the strength and conditioning sessions was comprised of progressions through five major movement patterns of hip hinge, squat, push, pull, and carry utilizing body weight training, barbells, dumbbells, and kettlebells in regressions and progressions that built complexity and load into each drill. The third phase consisted of a progression of low amplitude plyometrics. Levels of difficulty during progression were assigned based on the development of intrinsic core stability over the use of artificial stability via an implement (e.g. strict overhead press before bench press), compressive loading of the spine before shear force loading (e.g. goblet squat before barbell back squat), bilateral load before unilateral load in the extremities (e.g. deadlift before single leg deadlift or barbell strict overhead press before single arm strict overhead press), concentric force production before eccentric force absorption (e.g. single leg jump before single leg landing), and level of complexity during multi joint ballistic lifts (e.g. barbell push press before barbell jerk). (Table 1)

Statistical Analysis

Data analysis was performed using the Statistical Package SPSS version 21 (IBM Corp. Armonk, NY, USA). Paired samples T-tests were used to compare mean changes in FMS™ composite while Wilcoxon signed rank tests were used for analysis of individual task scores pre to post-intervention with a predetermined α level of $p \leq .05$. Between-group comparisons of FMS™ composite scores were compared using a Bonferroni adjustment with an α level of $p \leq .025$. Effect size calculations for composite scores were completed using Cohen's d. Cohen's d values for effect size were considered as follows; ≤ .2 = small, ≥ .5 = medium, and ≥ .80 = large.[29] Effect size (*r*) calculations for individual task scores were completed using the *Z*-scores calculated during Wilcoxon signed rank tests with; ≤ .3 = small, ≥ .3 = medium, and ≥ .50 = large.

Presented in Table 2 are FMS™ intra-rater reliability, standard error measurement, and minimal detectible change (MDC) values for the primary investigator. Prior to the start of the study, intra-rater reliability of the investigating AT's FMS™ application was

Movement Pattern	Hip Hinge	Squat	Push	Pull	Carry	Plyometric Sagittal	Plyometric Frontal	Plyometric Transverse 90 Degree Rotation
	Deadlift	Kettlebell Goblet Squat	Barbell Strict Row	Barbell Strict Row	Farmers Carry	Double Leg Jump to Double Leg Receive	Double Jump to Double Leg Receive	Double Leg Jump to Double Leg Receive
	Kettlebell Swing	Barbell Front Squat	Barbell Push Press	Barbell Pendlay Row	Suitcase Carry	Single Leg Jump to Double Leg Receive	Single Leg Jump to Double Receive	Single Leg Jump to Double Leg Receive
	Single Leg Deadlift	Single Arm Kettlebell Front Squat	Barbell Bench Press	Kettlebell Renegade Row	Double Front Rack Carry	Double Leg to Single Leg Receive	Double leg Jump to Single Leg Receive	Double Jump to Single Leg Receive
	Single Arm Kettlebell Swing	Double Kettlebell Front Squat	Single Arm Overhead Kettlebell Strict Press	Kettlebell Turkish Get-up	Single Arm Front Rack Carry	Single Leg Jump to Sing Leg Receive	Single Leg jump to Single leg Receive	Single Leg Jump to Single Leg Receive
	Double Kettlebell Swing	Kettlebell Step Up Double Kettlebell	Double Kettlebell Overhead Strict Press	Strict Chin-up	Single Arm Overhead Carry			
	Single Arm Kettlebell Clean	Rear Foot Elevated Single Leg Squat with Double Kettlebell	Double Kettlebell Push Press	Kettlebell Windmill	Mixed One Suitcase One Front Rack Carry			
	Double Kettlebell Clean	Zercher Squat	Barbell Power Jerk	Strict Pull-up	Mixed One Suitcase One Overhead Carry			
	Single Arm Kettlebell Snatch	Barbell Back Squat	Double Kettlebell Jerk		Mixed One Front Rack One Overhead Carry			
	Double Kettlebell Snatch							

Table 1. Strength and Conditioning Progressions by Movement Pattern

determined by collecting FMS™ scores on 10 participants and repeating the measurement five days later.

A two-way mixed effects model Intraclass Correlation (ICC) with absolute agreement was used to assess intra-rater reliability for the FMS™.[30] Standard error of the mean (SEm) values were calculated for FMS™ using the formula ($SEm = SD\sqrt{1- ICC}$) where SD represents the standard deviation calculated during ICC analysis.[31] Minimal Detectable Change was calculated using the formula ($MDC = SEm \times 1.96 \times \sqrt{2}$).[31] (Table 2)

FMS™	Intraclass Coefficient (ICC) 3,1	Standard Error Measurement Value (SEM)	Minimal Detectable Change Value (MDC)
Composite Score	0.984	0.772	2.14

Table 2. Intra-rater Reliability for Functional Movement Screen™ (FMS™) (N=10)

RESULTS

Descriptive Statistics

Baseline descriptive analysis noted no statistically significant difference between groups in mean age (female = 16.1 ± 1.0, male = 16.4 ± 1.2, p = .579). However, there were statistically significant differences between mean height (female = 164.8 ± 6.7cm, male = 181.7 ± 8.2cm, p < 0.001) and weight (female = 59.5.6 ± 6.8kg, male = 79.3 ± 15.8kg, p < 0.001).

Descriptive Change in FMS ™ Scores

Table 3 highlights the raw changes in both FMS™ composite and individual task scores over the intervention period. Of all the participants in this study, none reached the composite minimum or maximum, however, ceiling and floor effects were accounted for on individual task scores. Accounting for minimum and maximum possible scores, raw analysis of changes in composite and individual task FMS™ scores indicate improvement in all areas with the exception of the trunk stability push up. Only 1 of 27 participants did not see a post-season increase in composite FMS™, however this participant's score of 15 would not be of concern as it falls above the proposed injury risk cut off score of 14 suggested in some literature.[21,22] Of note, 78.5% of participants increased their scores to a post-season value

above 14, resulting in 88% of the population finishing the season above the proposed lower threshold for injury probability.[21,22] (Table 3)

Scores of 1 and Asymmetry

Presented in Table 4 are the overall changes in scores of 1 on the FMS™, corresponding to the raw data presented in Table 3, experienced by participants. Overall, participants saw a 46% reduction in scores of 1 from pre-season to post-season screening including an 83% decrease in scores of 1 on the DS. (Table 4) Male participants saw the highest overall reduction in scores of 1 with 60%, while female participants reduced scores of 1 by 20%. (Table 4)

Scores of 1	Pre-season	Post-Season	Percent Change
Deep Squat (DS)	11	3	-83%
Female	15	12	-20%
Male	27	11	-60%
Total	42	23	-46%

Table 4. Percent Change in FMS™ Scores of 1

Table 5 highlights the raw changes in asymmetrical scores over the intervention period. The pre- and post-season raw data presented in Table 5 suggests significant reductions in movement asymmetries among both male and female participants. Across all participants, movement asymmetries were reduced by 65% at post-season screening. (Table 5)

Participant	**Sex F-1 M-2**	**Pre/Post Aggregate Scores**	**Pre/Post DS Scores**	**Pre/Post HS Scores**	**Pre/Post ILL Scores**	**Pre/Post SM Scores**	**Pre/Post ASLR Scores**	**Pre/Post TSP Scores**	**Pre/Post RS Scores**
1	1	**12/16**	**1/2**	2/2	**2/3**	3/3	**2/3**	1/1	**1/2**
2	1	**15/16**	2/2	**2/3**	3/3	3/3	2/2	1/1	2/2
3	1	**15/17**	**2/3**	2/2	3/3	3/3	**2/3**	1/1	2/2
4	1	**15/18**	**2/3**	**2/3**	3/3	**2/3**	3/3	1/1	2/2
5	1	**16/18**	*3/2*	**2/3**	**2/3**	3/3	3/3	1/1	**2/3**
6	1	**17/19**	3/3	**2/3**	3/3	**2/3**	3/3	1/1	3/3
7	1	**14/17**	**1/2**	**2/3**	**2/3**	3/3	3/3	1/1	2/2
8	1	**14/16**	2/2	**2/3**	**2/3**	3/3	2/2	*2/1*	**1/2**
9	1	**17/18**	**2/3**	3/3	**2/3**	3/3	3/3	*2/1*	2/2
10	1	**14/17**	**2/3**	**1/2**	3/3	**2/3**	3/3	1/1	2/2
11	1	**15/16**	2/2	**2/3**	3/3	3/3	2/2	1/1	2/2
12	1	**15/16**	3/3	**2/3**	2/2	2/2	3/3	1/1	2/2
13	2	**11/13**	1/1	**1/2**	1/1	*3/2*	**1/2**	2/2	**2/3**
14	2	**14/15**	1/1	**2/3**	2/2	3/3	2/2	2/2	2/2
15	2	15/15	2/2	*3/2*	**2/3**	3/3	2/2	*2/1*	**1/2**
16	2	**17/19**	2/2	**2/3**	3/3	3/3	**2/3**	3/3	2/2
17	2	**14/18**	**1/3**	*3/2*	**2/3**	3/3	3/3	**1/2**	**1/2**
18	2	**16/17**	**1/2**	3/3	2/2	3/3	*3/2*	**2/3**	2/2
19	2	**17/19**	**2/3**	3/3	3/3	**2/3**	3/3	2/2	2/2
20	2	**13/16**	2/2	2/2	**2/3**	**2/3**	**2/3**	1/1	2/2
21	2	**16/19**	**2/3**	**2/3**	3/3	3/3	**2/3**	2/2	2/2
22	2	**12/15**	**1/2**	**1/2**	3/3	3/3	**1/2**	1/1	2/2
23	2	**10/13**	1/1	**1/2**	*2/1*	2/2	2/2	**1/3**	**1/2**
24	2	**13/14**	2/2	1/1	3/3	3/3	1/1	1/1	**2/3**
25	2	**13/15**	**1/2**	2/2	2/2	2/2	3/3	**1/2**	2/2
26	2	**14/16**	**1/2**	2/2	2/2	3/3	3/3	2/2	**1/2**
27	2	**13/16**	**1/2**	2/2	**1/2**	2/2	**2/3**	3/3	2/2
% Increase Excluding Ceiling Effect		**96.30%**	**56%**	**62.50%**	**52.94%**	**50%**	**50%**	**15.38%**	**34.61%**
% Decrease Excluding Floor Effect		*0%*	*4.16%*	*7.69%*	*3.84%*	*1%*	*3.84%*	*21.42%*	*0%*
Pre/Post % > 14		Pre 51.85% **Post 88.88%**							

Table 3. Changes in FMS™ Composite and Individual Task Scores
Bold=Increase *Italic=Decrease* Plain Text=No

Participant	Sex F-1 M-2	Pre/Post L HS	Pre/Post R HS	Pre/Post L ILL	Pre/Post R ILL	Pre/Post L SM	Pre/Post R SM	Pre/Post L ASLR	Pre/Post R ASLR	Pre/Post L RS	Pre/Post R RS
1	1	2/2	2/2	2/3	2/3	3/3	3/3	2/3	2/3	1/2	1/2
2	1	2/3	2/3	3/3	3/3	3/3	3/3	2/2	3/2	2/2	2/2
3	1	2/2	2/2	3/3	3/3	3/3	3/3	2/3	3/3	2/2	2/2
4	1	3/3	2/3	3/3	3/3	2/3	2/3	3/3	3/3	2/2	2/2
5	1	2/3	2/3	2/3	2/3	3/3	3/3	3/3	3/3	2/3	2/3
6	1	2/3	2/3	3/3	3/3	2/3	2/3	3/3	3/3	3/3	3/3
7	1	2/3	2/3	2/3	2/3	3/3	3/3	3/3	3/3	2/2	2/2
8	1	2/3	2/3	2/3	2/3	3/3	3/3	2/2	2/2	1/2	1/2
9	1	3/3	3/3	2/3	2/3	3/3	3/3	3/3	3/3	2/2	2/2
10	1	1/2	1/2	3/3	3/3	2/3	3/3	3/3	3/3	2/2	2/2
11	1	2/3	2/3	3/3	3/3	3/3	3/3	2/2	2/2	2/2	2/2
12	1	2/3	2/3	2/2	2/2	2/2	3/3	3/3	3/3	2/2	2/2
13	2	1/2	1/3	1/1	1/1	3/2	3/2	2/2	1/2	2/3	2/3
14	2	2/3	2/3	2/2	2/2	3/3	3/3	2/2	2/2	2/2	2/2
15	2	3/2	3/2	2/3	2/3	3/3	3/3	2/3	3/2	1/2	2/2
16	2	2/3	2/3	3/3	3/3	3/3	3/3	2/3	2/3	2/2	2/2
17	2	3/2	3/2	2/3	2/3	3/3	3/3	3/3	3/3	1/2	1/2
18	2	3/3	3/3	2/2	2/2	3/3	3/3	3/2	3/2	2/2	2/2
19	2	3/3	3/3	3/3	3/3	2/3	2/3	3/3	3/3	2/2	2/2
20	2	2/2	2/2	2/3	2/3	2/3	2/3	2/3	2/3	2/2	2/2
21	2	2/3	2/3	3/3	3/3	3/3	3/3	2/3	2/3	2/3	2/2
22	2	1/3	1/2	3/3	3/3	3/3	3/3	2/2	1/2	2/2	2/2
23	2	1/2	1/2	2/1	2/1	2/2	3/2	2/2	2/2	1/2	1/2
24	2	1/1	1/1	3/3	3/3	3/3	3/3	1/1	1/1	2/3	2/3
25	2	2/2	2/2	2/2	2/2	2/2	2/2	3/3	3/3	2/2	2/2
26	2	2/2	2/2	2/2	2/2	3/3	3/3	3/3	3/3	1/2	1/2
27	2	2/2	2/2	2/2	1/2	2/2	2/2	2/3	2/3	2/2	2/2

Table 5. FMS™ Asymmetries

Table 6, corresponding with Table 5, presents the combined and grouped percent change in asymmetry as measured by the FMS™. Male participants reduced asymmetries on the FMS™ by 56% while female participants reduced asymmetrical scores by 80%. (Table 6)

Asymmetry	Pre-Season	Post-Season	Percent Change
Female	5	1	-80%
Male	9	4	-56%
Total	14	5	-65%

Table 6. Percent Change in FMS™ Asymmetries

Statistical Changes – Combined Basketball

Table 7 presents statistically significant changes in both composite and individual FMS™ task scores combined among male and female participants. No significant differences were indicated regarding pre-season composite FMS™ scores (female = 14.92 ± 1.4, male = 13.87 ± 2.1, p = .144). A paired samples T-test with a Bonferroni α adjustment noted that significant post-intervention mean changes in composite FMS™ scores existed across male and female participants combined (pre-season = 14.33 ± 1.84; post-season = 16.44 ± 1.72; p < 0.001, *d*=2.08). Wilcoxon signed rank tests suggested significant changes in individual task scores including; DS (pre-season = 1.70 ± 0.67; post-season = 2.22 ± 0.64; p < 0.001, *r*=.64), HS (pre-season = 2.00 ± 0.62; post-season = 2.48 ± 0.58; p = 0.002, *r*=.61), ILL (pre-season = 2.33 ± 0.62; post-season = 2.63 ± 0.62; p = .011, *d*=.47), ASLR (pre-season = 2.33 ± 0.68; post-season = 2.59 ± 0.57; p = .02, *r*=.45), and RS (pre-season = 1.85 ± 0.46; post-season = 2.15 ± 0.36; p = .005, *r*=.54). No statistically significant change was noted in SM or TSP, yet the SM screen had modest effect size (*r*=.31) while the TSP had a low effect size (*r*=.12). (Table 7)

Pre-Season Post-Season	Combined Participants	*p-Value*	Effect Size Cohen's D
Composite	14.33 ± 1.84 16.44 ± 1.72	*p* < 0.001	*d* = 2.08
Deep Squat (DS)	1.70 ± 0.67 2.22 ± 0.64	*p* = 0.001	*r* = .64
Hurdle Step (HS)	2.00 ± 0.62 2.48 ± 0.58	*p* = 0.001	*r* =.61
Inline Lunge (ILL)	2.33 ± 0.62 2.63 ± 0.62	*p* = .009	*r* = .47
Active Straight Leg Raise (ASLR)	2.33 ± 0.68 2.59 ± 0.57	*p* = .017	*r* = .49
Rotatory Stability (RS)	1.85 ± 0.46 2.15 ± 0.36	*p* = .003	*r* = .64

Table 7. Combined Participant Changes in FMS™ Composite and Individual Task Scores Pre to Post-Intervention

Statistical Changes – Male Participants

Shown in Table 8 are the statistical changes in both composite and individual FMS™ task scores among male participants. Paired samples T-test results indicated significant post-intervention mean changes in composite FMS™ scores (pre-season = 13.87 ± 2.07; post-season = 16.00 ± 2.04; p < 0.001, *d*=2.01), DS (pre-season = 1.40 ± 0.51; post-season = 2.00 ± 0.66; p = 0.007, *r*=.7), and RS (pre-season = 1.80 ± 0.41; post-season = 2.13 ± 0.35; p = .025, *r*=.58). No statistically significant change was noted in HS, ILL, SM, ASLR, or TSP, however, the HS (*r*=.37), ILL (*r*=.35), ASLR (*r*=.49), and TSP (*r*=.37) had modest effect sizes suggesting an inadequate participant number to identify statistical significance. (Table 8)

Pre-Season Post-Season	Male Participants	*p-Value*	Effect Size Cohen's D
Composite	13.87 ± 2.07 16.00 ± 2.04	*p* < 0.001	*d* = 2.01
Deep Squat (DS)	1.40 ± 0.51 2.00 ± 0.66	*p* = 0.003	*r* = .70
Hurdle Step (HS)	2.00 ± 0.76 2.27 ± 0.59	*p* = 0.164	*r* =.38
Inline Lunge (ILL)	2.20 ± 0.68 2.40 ± 0.74	*p* = .189	*r* = .36
Shoulder Mobility (SM)	2.67 ± 0.49 2.73 ± 0.46	*p* = .582	*r* = .15
Active Straight Leg Raise (ASLR)	2.13 ± 0.74 2.47 ± 0.64	*p* = .055	*r* = .54
Trunk Stability Push Up (TSP)	1.73 ± 0.71 2.00 ± 0.76	*p* = .164	*r* = .38
Rotatory Stability (RS)	1.80 ± 0.41 2.13 ± 0.35	*p* = .019	*r* = .58

Table 8. Changes in FMS™ Composite and Individual Task Scores in Male Participants Pre to Post-Intervention

Statistical Changes – Female Participants

Table 9 outlines the statistical changes to composite and individual task FMS™ scores specifically among female participants. Paired samples T-test results indicated significant post-intervention mean changes in composite FMS™ scores (pre-season = 14.92 ± 1.38; post-season = 17.00 ± 1.04; p < 0.001, *d*=2.60), HS (pre-season = 2.00 ± 0.43; post-season = 2.75 ± 0.45; p < 0.003, *r*=.87), and ILL (pre-season = 2.50 ± 0.52; post-season = 2.92 ± 0.29; p = .025, *r*=.65). No significant change was noted in DS, SM, ASLR, TSP, or RS, yet large effect sizes were identified in the DS (*r*=.55), SM (*r*=.50), and RS (*r*=.55) with a moderate effect size identified in ASLR (*r*=.41) suggesting inadequate participation numbers to identity statistical significance. (Table 9)

Pre-Season Post-Season	Female Participants	*p-Value*	Effect Size Cohen's D
Composite	14.92 ± 1.38 17.00 ± 1.04	*p* < 0.001	*d* = 2.06
Deep Squat (DS)	2.08 ± 0.67 2.50 ± 0.52	*p* = 0.54	*r* = .62
Hurdle Step (HS)	2.00 ± 0.43 2.75 ± 0.45	*p* < 0.001	*r* =.87
Inline Lunge (ILL)	2.50 ± 0.52 2.92 ± 0.29	*p* = .017	*r* = .81
Shoulder Mobility (SM)	2.67 ± 0.49 2.92 ± 0.29	*p* = .082	*r* = .55
Active Straight Leg Raise (ASLR)	2.58 ± 0.52 2.75 ± 0.45	*p* = .166	*r* = .58
Trunk Stability Push Up (TSP)	1.17 ± 0.39 1.00 ± 0.00	*p* = .166	*r* = .58
Rotatory Stability (RS)	1.92 ± 0.52 2.17 ± 0.39	*p* = .082	*r* = .55

Table 9. Changes in FMS™ Composite and Individual Task Scores Pre to Post-Intervention Among Female Participants

DISCUSSION

Utilizing a team-based approach to strength and conditioning, statistically significant increases in FMS™ composite scores, and significant reductions in movement asymmetries and scores of 1 on FMS™ individual task scores occurred among male and female participants over the course of a single secondary school basketball season. Furthermore, FMS™ composite scores were elevated to levels above a proposed injury risk cut point in 11 of 27 participants while 13 of the 27 participants maintained or improved upon pre-season composite scores already above 14.[21,22] The season finished with all 27 male and female varsity and junior varsity basketball players missing 0 days of competition or practice due to orthopedic injury with over 1900 combined AE.

The participants in this study were all from one rural secondary school and had little experience with strength and conditioning training outside of limited traditional power and olympic lifting techniques prior to the development of the programming presented in this study. The implementation of a training program outside of sport specific practices may, regardless of design, have influenced movement competency and FMS™ scores; however, it is difficult to draw definitive conclusions due to the small sample size and lack of control.

Without a control population, it is difficult to extrapolate information regarding the magnitude of the effects suggested by the results of this study, however previous research has suggested that FMS™ scores in collegiate athletes are subject to marginal and inconsistent change without consistent intervention over the course of a competitive season.[26] Specific intervention strategies utilizing corrective exercises focused on emphasizing particular movements from the FMS™ have been shown to positively alter scores, however these interventions were not generalized across a population and may prove difficult to implement consistently among larger groups.[22] Pilot data among a population of male adolescent volleyball players suggested that interventions based on specific core dominant exercises may positively alter FMS™ scores, however, radical changes in training style and the specificity of the program used may present further issues with generalization.[25] The results of this study suggest that it is possible to utilize a more generalized population based approach to training to improve movement competency, measured by the FMS™, in a traditional athletic training and strength and conditioning environment and may correlate with reductions in injury risk based on previous research regarding FMS™ scores and risk of injury.[21-22]

CONCLUSIONS

As a clinical practice model, the integrated use of preventative strength and conditioning, utilizing the FMS™ as a measure of program efficacy, appears to be valuable. In practice the FMS™ has a number of potential clinical applications and implications as a performance metric and some evidence suggesting that injury probability may be linked with lower FMS™ composite or individual task scores. In athletic training, the FMS™ may be utilized as part of PPE screening and return to play justification. As a result, data collection within this clinical practice model allowed for pre-season and post-season FMS™ scores to be collected as a measure of change after the implementation of a new strength and conditioning program. This study suggests that a team based quasi-individualized strength and conditioning program can lead to significant, efficient, and meaningful change in FMS™ composite and individual task scores in secondary school basketball players representing measurable change in primary injury risk reduction.

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