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Research Article

Use of a Case Series to Determine which Sub-scores Best Correlate with the Total Dynamic Movement Assessment Score

Kellie R Stickler[1]*, Trent R Nessler[2], Paul Kang[3] and Linda M Denney[4]

[1]*Physical Therapist, Cerner Corporation, USA*

[2]*Department of Sports Medicine, Select Medical, USA*

[3]*Department of Epidemiology and Biostatistics, University of Arizona College of Medicine-Phoenix and College of Public Health-Phoenix,USA*

[4]*Physical Therapy & Athletic Training program, Northern Arizona University, USA*

Abstract

Risk factors contributing to lower extremity injury include improper biomechanics, decreased or imbalanced lower extremity strength, and poor neuromuscular control. Fatigue or repeated poor mechanics could be causation for the frequency of reported lower extremity injuries. The Dynamic Movement Assessment (DMA) was developed to assess athletes using a fatigue protocol. The purpose of this retrospective case series is to evaluate which DMA sub-scores best correlate with the total DMA score. Fifteen female collegiate soccer players performed a fatigue protocol followed by the DMA. Six performance tests and algorithm determined an aggregate risk score. Analysis determined independent associations between each DMA test and the aggregate risk rating score. All predictors were entered into one model and stepwise variable selection ascertained which DMA tests best predict the aggregate risk rating score. There were statistically significant differences in risk rating scores between the adduction statuses within the Step Up Test (Past Midline = 1.33 ± 0.78 vs To Midline = 2.67 ± 0.57; p = 0.02), Single Leg Squat Test (Past Midline = 1.00 ± 0.60 vs To Midline = 2.00 ± 0.0; p = 0.02) and the Single Leg Hop Test (Past Midline = 1.25 ± 0.86 vs To Midline = 2.67 ± 0.57; p = 0.02). The DMA assessment tests that best predict the aggregate assessment scores were the Full Squat Test, Single Leg Squat Test, Single Leg Hop Test and Side Plank Right Test. Four of the 6 tests utilized in the DMA protocol best determine higher aggregate DMA score; however, the performance of all 6 tests strategically promotes fatigue to therefore identify faulty movement patterns. The inability to maintain proper knee alignment with single leg activities and the presence of corkscrewing were two indicators of high aggregate risk scores.

Keywords: Biomechanics; Female Athlete; Injury Prevention

***Corresponding author:** Kellie R Stickler, Physical Therapist, Cerner Corporation, 5344 Nall Ave, Roeland Park, KS 66202, USA, Tel: +1 8165893001, E-mail: kelliersticklerr@gmail.com

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Introduction

Lower extremity injuries are prevalent (60-80%) in female soccer players [1,2] and incidence of injury varies per level of competition [3]. Knee injuries account for over 86% of soccer injuries and result in delayed return to play and a risk of lower performance [4].The rate of injury is higher in matches and tournaments compared to practice and training [5]. Considering ACL injury is primarily non-contact, suggests overuse and fatigue as a factor predisposing the athlete to injury. Although the definition of overuse injury varies, [6] fatigue or repeated poor mechanics could be the common root cause for the frequency of reported lower extremity injuries in women's soccer. Knee injuries were the largest reported overuse injury (47%) associated with increased valgus [7]. The risk of re-injury was three-fold per 1000 athletic exposure hours [8] consistent with the findings of increased injury to younger, less skilled female soccer players [9,10]. Faude, et al., [11] found high risk of overuse injury in elite female soccer athletes related to previous injury and body composition. Identifying risk factors for this cohort are collectively biomechanical, [7,10,12] prior injury, [13] and most recently high BMI, [14] increased age, weight and body composition [11].

Risk factors for knee injury, both intrinsic and extrinsic, include altered biomechanics [8,12] decreased lower extremity strength [7], poor neuromuscular control [15] and hormonal differences [16,17]. Biomechanically, if an athlete has an aberrant movement pattern, such as landing with knee abduction moment [10] and less knee flexion, then his or her peak ground reaction force could be increased greater than 3-6 times body weight [12]. Also, neuromuscular fatigue has been shown to change landing mechanics in both men and women [18].

Performance programs have been developed to decrease the risk of injury in sports such as soccer [19-21], however, results are inherently variable and the risk of re-injury persists. Tools have been utilized to assess quality of movement and patterns of movement of athletes. The Functional Movement Screen (FMS), a commonly used musculoskeletal screen, is used to determine risk of injury based on seven functional movements [5]. The FMS has been utilized for athlete screening and return to sport testing, however, it is recommended to be cautious when applying it to injury prevention [22]. The lack of predictive accuracy for decreasing the risk of athletic injury generated the development of the Dynamic Movement Assessment (DMA). The DMA boasts a multi-planar movement analysis with built-in fatigue model. The DMA is a sequence of 6 physical performance tests with video analysis to assess biomechanics and potential risk for injury. The 6 physical performance tests include full squat, step up, single leg squat, single leg hop, plank test, and side plank. This case series is used to evaluate which DMA sub-scores best correlate with the total DMA score.

Methods

Experimental Approach to the Problem

This is a retrospective cohort of Divison1 female soccer players over a period of one year. A convenience sample of soccer players from 1 collegiate soccer team was used for the study. Participation was voluntary. Exclusion criteria included diagnosis of sickle cell or current injury preventing participation.

Subjects

The subjects include 15 female soccer players with a mean age 19.8-years-old (19-21) from one university who participated in the 2012 soccer season and DMA protocol. IRB approval was waived for this study by the Institutional Review Board. Project number 1133862-1.

Procedures

The athletes participated in a functional agility short-term fatigue protocol followed by the DMA in pre-season. The protocol and assessment was conducted by a Physical Therapist (PT). The athlete performed six tests: full squat, step up, single leg squat, single leg hop, plank test, and side plank and scored on a 0-3 scale (3 represents best performance), for a total of 21 points. All tests were scored based on video review of performance of each test. Scoring was based on the worst repetition. Further scoring is described below the description of each test. Individual and overall scores on the battery of tests determined a risk rating for each athlete. A total score was calculated and a percentage of the overall total score was calculated. The DMA algorithm determined a 'risk' for injury (min, mild, moderate, high) and the athlete was provided visual feedback via video of poor movement patterns. Injuries sustained during the season were recorded per body part and categorized as 'contact injury' or 'non-contact injury'.

The DMA was conducted by a PT on 15 female soccer players pre-season. Testing was standardized using a line of reference (12 inches) for positioning the athlete to ensure image capture by HD camera (Logitech, 90 FPS) and to avoid individual variation. The athlete was within a three-foot circumference of the reference line at all times. The camera was positioned 25 feet from the reference line (Figure 1). Body position was determined for trunk, hip, knee, and ankle/foot position with reference to a plumb line. Common body position faults noted were adduction past midline (Figure 2) and corkscrewing (Figure 3). Tests were conducted in the following order to ensure a graduated level of fatigue: Full squat test, Step-up test, Single leg squat test, Single leg hop test, Plank test, Side plank test. No rest periods were allowed in between tests. If pain was reported during a test, testing was stopped and the athlete was scored a zero.

Full Squat Test

The athlete performed 10 squats facing the examiner and 10 squats facing away from the examiner. The squat was performed with feet shoulder width apart. Full squat test was scored based on peak lateral displacement during the squatting motion. A plumb line from the athlete's cervical spine to sacrum was used to measure displacement. Scoring was as follows: 3 = no lateral shift, 2 = lateral shift > 1", 1= lateral shift > 2", 0 = Pain or unable to perform squat.

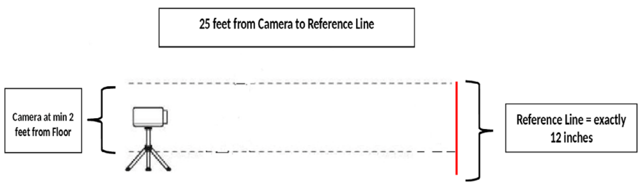

Figure 1: Camera Set-Up.

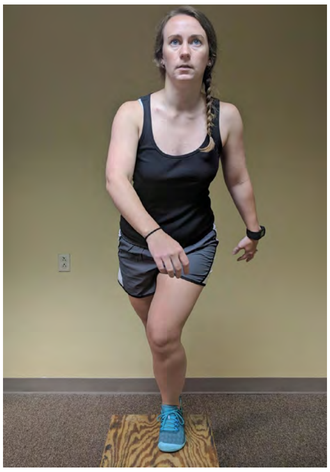

Figure 2: Knee Adduction Fault.

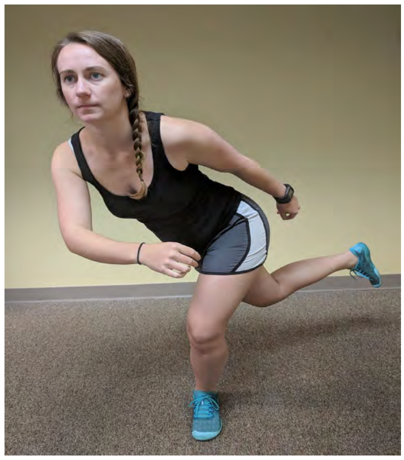

Figure 3: Corkscrew Fault.

Step-Up Test

The athlete stepped up on a 12-inch step with one leg to full knee extension, followed by a tap of the opposite foot then returning to starting position with a step down of the opposite leg. Once full contact was made with both feet (to starting position) the step up was repeated with the same leg as previous for a total of 10 repetitions.

Once completed, the same technique was performed starting with the opposite leg stepping up. Ten repetitions were performed for the opposite leg. For the Step-Up Test, the plumb line was placed at medial aspect of the first metatarsal and measurement was taken of knee position relative to the plumb line. Scoring was as follows: 3 = no to minimal adduction, 2 = adduction to midline, 1= adduction past midline, 0 = pain or unable to perform test.

Single Leg Squat Test

The athlete performed a 30-45 degree single leg squat for 10 repetitions without touching the opposite foot to the ground. The technique was repeated 10 times on the opposite leg. For the Single Leg Squat Test, the plumb line was placed at medial aspect of the first metatarsal and measurement was taken of knee position relative to the plumb line. Scoring was as follows: 3 = no to minimal adduction, 2 = adduction to midline, 1= adduction past midline, 0 = pain or unable to perform test. If the player demonstrated corkscrewing, a note was made but their test sub-score was not changed.

Single Leg Hop Test

The athlete stood on one leg and performed a hop in place as high as they could for 10 repetitions without touching the opposite foot to the ground. This technique was repeated 10 times on the opposite leg. For the Single Leg Hop Test, the plumb line was placed at medial aspect of the first metatarsal and measurement was taken of knee position relative to the plumb line. Scoring was as follows: 3 = no to minimal adduction, 2 = adduction to midline, 1= adduction past midline, 0 = pain or unable to perform test. If the player demonstrated corkscrewing, a note was made but their test sub-score was not changed.

Plank Test

The athlete assumed the position of plank with elbows on the ground, feet together, neutral pelvic position and neutral cervical spine (looking at the floor). The position was held for one minute. A lower score was recorded if the hips lowered toward the floor. For the Plank Test, scoring was based on ability to maintain the position for 1 minute. A reference line was placed at the buttocks and score was based on how long the player could hold within 1" of reference line. Scoring was as follows: 3 = no drop or rise, 2 = held for 45 seconds or greater, 1 = held for 30 seconds to 44 seconds, 0 = less than 30 seconds, pain, or unable to perform.

Side Plank Test

The athlete assumed a side plank position on their elbow with feet together, neutral pelvic position, neutral cervical spine and opposite hand on their hip. The position was held for one minute and then performed on the other side. Each side was scored separately. For the Side Plank Tests, scoring was based on ability to maintain the position for 1 minute. A reference line was placed at the top hip and score was based on how long the player could hold within 1" of reference line. Scoring was as follows: 3 = no drop or rise, 2 = held for 45 seconds or greater, 1 = held for 30 seconds to 44 seconds, 0 = less than 30 seconds, pain, or unable to perform.

A complete fatigue assessment protocol includes 80 repetitions and 3 minutes of plank exercises. Athletes were instructed they might feel soreness following the test. Pre-season data was collected by the PT via DMA scoring system and recorded on computer using de-identifying coding ID for each athlete. Injury data was collected by the team athletic trainer and provided to the PT for the corresponding athlete. A spreadsheet was developed utilizing the de-identified information for all details including DMA scores, risk profile and recorded injury.

Statistical Analysis

Participant characteristics were assessed as means, standard deviations for continuous variables and frequencies, proportions for categorical variables. The Wilcoxon Rank Sum was utilized to compare continuous variables for 2- sample comparisons; while the Fisher's Exact Test was utilized to compare categorical variables. Coefficients and 95% confidence intervals were calculated using univariate linear regression to ascertain independent associations between each DMA assessment tool and the aggregate risk rating score. Furthermore, all of the predictors were entered into one model where the stepwise variable selection ascertained which DMA tests best predict the aggregate risk rating score. The aggregate risk rating score approximated a normal distribution following a log transformation. All p-values were 2-sided and $p < 0.05$ were considered statistically significant. All data analyses were conducted using STATA version 14 (STATA Corp; College Station, TX).

Results

Data on 15 female Divison1 soccer players were included in this analysis. During the playing season, 5 (33.3%) reported injury. Sustained injuries were hamstring strain, quadriceps strain, patella tendonitis and ankle sprain. Nine (60.0%) athletes demonstrated a left lateral shift during testing and 6 (40.0%) were observed going past midline into adduction.

Individual DMA assessment scores are shown in Table 1. Athletes scored the highest on the Plank Test (2.20 ± 0.86) followed by Side Plank Test-Left (2.00 ± 0.92) and the Side Plank Test-Right (1.93 ± 0.88). After stratifying by adduction status, participants who were observed performing adduction past midline recorded lower scores (higher risk rating) compared to participants whose adduction status were properly limited to the midline. There were statistically significant differences in risk rating scores between the adduction statuses within the Step-up Test (Past Midline = 1.33 ± 0.78 vs To Midline = 2.67 ± 0.57; p = 0.02), Single Leg Squat Test (Past Midline = 1.00 ± 0.60 vs To Midline = 2.00 ± 0.0; p = 0.02) and the Single Leg Hop Test (Past Midline = 1.25 ± 0.86 vs To Midline = 2.67 ± 0.57; p = 0.02).

Similar to the Past midline adduction, participants who performed corkscrews during activity observed lower assessment scores (higher risk ratings) compared to others who did not perform corkscrews. The Step-up Test and the Single Leg Hop Test scores showed statistically significant differences in scores between the Corkscrew (No Corkscrew= 2.16 ± 0.98 vs Corkscrew = 1.22 ± 0.67; p = 0.04) and No Corkscrew (No Corkscrew = 2.50 ± 0.83 vs Corkscrew = 0.89 ± 0.33; p = 0.002) groups, respectively. With respect to aggregate DMA assessment scores, statistical significance was observed between the Adduction groups (Past Midline = 11.0 ± 3.24 vs To Midline = 16.0 ± 2.64; p = 0.03) and the Corkscrew groups (No Corkscrew = 15.0 ± 2.60 vs Corkscrew = 10.0 ± 2.87; p = 0.007), respectively.

Univariate linear regression reported that the Single Leg Squat Test observed the highest relationship to the aggregate assessment scores (Beta (95% CI) = 0.37 (0.13, 0.61); p = 0.005), followed by Side Plank Test-Right (Beta (95% CI) = 0.32 (0.15, 0.48); p = 0.001), and Side Plank Test-Left (Beta (95% CI) = 0.31 (0.16, 0.46); p = 0.001), respectively. However, the stepwise variable selection showed that the DMA assessment tools that best predict the aggregate assessment scores were Full Squat Test (Beta (95% CI) = 0.16 (0.06, 0.25); p = 0.004), Single Leg Squat Test (Beta (95% CI) = 0.17 (0.04, 0.31); p = 0.02), Single Leg Hop Test (Beta (95% CI) = 0.09 (0.002, 0.17); p = 0.04), and the right side of the Side Plank Test (Beta (95% CI) = 0.24 (0.14, 0.33); p < 0.001) (Table 2).

Discussion

Due to the risk and prevalence of injury in soccer players and the potential detrimental outcome of injuries, including lack of return to sport, there is need for the use of a screening tool to assess the risk in each individual athlete. This case series demonstrates that the DMA assessment tool could be a viable option to determine an aggregate risk score for athletes. The built in fatigue protocol for sequencing 6 tests identifies faulty movement patterns, yet 4 tests specifically correlate with higher aggregate DMA scores. The Full Squat Test, Single Leg Squat Test, Single Leg Hop Test and Side Plank Test-Right in the DMA protocol best correlate to aggregate DMA scores. Analysis of the FMS had similar results identifying 2 tests related to injury in male soccer players [5]. The trunk stability push-up and the rotary stability exercise were associated with injuries.

The inability to maintain proper knee alignment with single leg activities and the presence of corkscrewing were the two most significant indicators of high aggregate risk scores. Knee adduction or knee valgus past midline correlated with a high risk and represents poor mechanics associated with athletic movements such as cutting [23,24]. Improved biomechanical outcomes with external focus cueing have gained favor over using limb symmetry for double and single-leg testing [25]. The lack of knee stability and poor positioning can be identified in double limb activities such as the functional squat or single-limb squat tests. Use of 2-D motion analysis, as used in our study, identified knee valgus during a single-leg hop test over visual observation [26]. Thus the use of DMA to identify faulty biomechanics in both double and single-leg tests is enhanced with video capture compared to other assessment tools. Our study found that knee valgus with the Single Leg Squat Test, Step-up Test, and Single Leg Hop Test was all related to higher aggregate DMA scores. Both double and single leg tests require trunk control and any trunk displacement will alter lower extremity kinematics [27,28].

DMA Assessment	Overall (N=15)	Past Midline Adduction (N=12)	Midline Adduction (N=3)	p-value1	No Corkscrew (N=6)	Corkscrew (N=9)	p-value1
	Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Full Squat Test	1.53 (0.83)	1.41 (0.79)	2.00 (1.00)	0.22	1.67 (0.81)	1.44 (0.88)	0.43
Step-up Test	1.60 (0.91)	1.33 (0.78)	2.67 (0.57)	0.02	2.16 (0.98)	1.22 (0.67)	0.04
Single Leg Squat Test	1.20 (0.67)	1.00 (0.60)	2.00 (0.0)	0.02	1.50 (0.83)	1.00 (0.50)	0.12
Single Leg Hop Test	1.53 (0.99)	1.25 (0.86)	2.67 (0.57)	0.02	2.50 (0.83)	0.89 (0.33)	0.002
Plank Test	2.20 (0.86)	2.16 (0.83)	2.33 (1.15)	0.69	2.50 (0.83)	2.00 (0.87)	0.25
Side Plank Test-Right	1.93 (0.88)	1.91 (0.90)	2.00 (1.00)	0.93	2.33 (0.81)	1.67 (0.86)	0.15
Side Plank Test-Left	2.00 (0.92)	1.91 (0.90)	2.33 (1.15)	0.45	2.33 (0.81)	1.78 (0.97)	0.26

Table 1: Individual DMA Assessment Scores stratified by Adduction type and Corkscrew status, respectively.

Note: [1]Wilcoxon Rank Sum to compare DMA Assessment Scores between groups.

DMA Assessment	Model 1 Beta (95% CI)[1]		Model 2 Beta (95% CI)[1]	p-value	Adjusted R2
Full Squat Test	0.20 (- 0.04, 0.43)	0.09	0.16 (0.06, 0.25)	0.004	0.87
Step-up Test	0.16 (- 0.06, 0.38)	0.14			
Single Leg Squat Test	0.37 (0.13, 0.61)	0.005	0.17 (0.04, 0.31)	0.02	
Single Leg Hop Test	0.17 (- 0.03, 0.37)	0.09	0.09 (0.002, 0.17)	0.04	
Plank Test	0.26 (0.05, 0.46)	0.02			
Side Plank Test-Right	0.32 (0.15, 0.48)	0.001	0.24 (0.14, 0.33)	< 0.001	
Side Plank Test-Left	0.31 (0.16, 0.46)	0.001			

Table 2: Linear regression to assess the relationship between each DMA assessment tool to the Aggregate DMA score.

Note: Model 1 calculated using Univariate Linear Regression.
Model 2 calculated using Multiple Linear Regression adjusting for all other predictors in the model following a stepwise variable selection.
[1]Coefficients represent the percent change in the log aggregate score per 1 unit increase within the separate assessment scores.
The primary outcome of aggregate DMA score observes a normal distribution following a log transformation.

Core stability had a negative correlation with high aggregate risk score, as measured by side planks. In addition, core stability has been shown in the literature [24,28] to have an effect on lower extremity injuries. A lack of core stability would cause the pelvis to rotate or tilt [27] similar to the corkscrew compensation demonstrated by athletes in the current study. Trunk endurance testing, based on the McGill battery as described by Werner, et al., [29] would be beneficial to prevent lower extremity re-injury. Whyte [24] proposes a dynamic core stabilization program for 6 weeks to improve core stabilization and in effect decrease risk of lower extremity injury. Core stability and endurance play an important role in a soccer player maneuvering around an opponent while trunk position during a single limb stance during a kick requires postural control [30]. Trunk position predicts lower extremity kinematics, therefore intervention exercises that incorporate trunk strengthening may reduce the potential for athletic injury.

This case series does have multiple limitations. Primarily, the small sample size and inclusion of only female collegiate soccer athletes limits the generalize ability of the study results. Also, this manuscript only discusses the DMA as an assessment tool without a post-season assessment following intervention. Further research is necessary to investigate the effect of biomechanical training and strengthening on risk and injury and the relationship to aggregate scoring of assessment tools.

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