Y-BALANCE TEST BUT NOT FUNCTIONAL MOVEMENT SCREEN SCORES ARE ASSOCIATED WITH PEAK KNEE VALGUS MOMENTS DURING UNPLANNED SIDESTEPPING: IMPLICATIONS FOR ASSESSING ANTERIOR CRUCIATE LIGAMENT INJURY RISK

Marcus Lee[1], Sophia Sim[2], Yeo Jiemin[2]

Sports Science Centre, Singapore Sports Institute, Sport Singapore, Singapore, Singapore[1]
Sports Science and Management, Nanyang Technological University, Singapore, Singapore[2]

This study explores if scores on the y-balance test (YBT) and functional movement screen (FMS) correlate with peak knee valgus moments during unplanned sidestepping. Fifteen female netballers performed the YBT, FMS and unplanned bilateral sidestepping. Their movements were recorded using a three-dimensional motion capture system. Scores on the YBT and FMS were correlated with peak knee valgus moments; a predictor of injury risk to the anterior cruciate ligament (ACL); of the left leg using Pearson's R. A moderate-to-strong negative correlation was found between posterolateral reach composite (r = -0.60) and absolute (r = -0.61) scores with peak knee valgus moments. The posterolateral reach component of the YBT could be a simple test to infer peak knee valgus moments during sidestepping and potentially ACL injury risk.

KEY WORDS: biomechanics, cutting, 3D motion analysis, injury prevention, knee, netball

INTRODUCTION: Non-contact anterior cruciate ligament (ACL) injuries are devastating and account for 70% of all ACL injuries (Griffin et al., 2000). Landing and sidestepping are the main movements that result in non-contact ACL injuries (Hewett, 2005). Poor neuromuscular control of the upper and lower body when performing these high risk movements may result in high knee valgus and knee internal rotation moments which could strain the ACL (Hewett, 2005). High knee valgus moments have been independently reported to rupture the ACL (Hewett, 2005). Females have been reported to be 4-6 times more susceptible to ACL injury compared with males due to poor landing and sidestepping biomechanics (Hewett, 2005). This is a concern in the sport of Netball as it has a high participation rate from females, demands frequent performances of landing and sidestepping, and also has one of the highest incidences of non-contact ACL injuries (Gianotti, Marshall, Hume & Bunt, 2009). An effective simple-to-administer screening tool to assess ACL injury risk would be useful in safeguarding the well-being of netballers.

The Functional Movement Screen (FMS) evaluates postures during seven fundamental movements that require mobility and stability to identify potential injury risk. Each movement is rated from 0 to 3. A score of 14 and below out of a maximum of 21 for the seven movements has been associated with higher injury risk (Sullivan, Hörman, Davidsson & Schneiders, 2011). Removing the shoulder mobility movement from the seven movements has been reported to yield stronger correlations between the scores of the other six movements and lower extremity injury, such as ACL injury. This results in a new total score of 18 for the six movements which are the deep squat, hurdle step, in-line lunge, active straight leg raise and rotary stability (Chorba, Chorba, Bouillon, Overmyer & Landis, 2010).

The Y-Balance Test (YBT) is another screening tool that has been reported to predict injury risk (Plisky, Rauh, Kaminski & Underwood, 2006). It requires pushing a reach indicator as far as possible in three directions (anterior, posteromedial and posterolateral) for each leg. The score is read in half a centimetre for each direction. The composite score is the sum of the three reach directions, divided by three times the limb length, multiplied by 100. A composite score lower than the risk cut point for an individual's age, gender, sports or activity level has been associated with higher injury risk. A bilateral reach difference of more than 4 cm has also been associated with higher injury risk.

Poor scores on the FMS and YBT have been reported to associate with a higher risk of lower limb injuries (Kiesel, Plisky & Voight, 2007; Shojaedin, Letafakar, Hadadnezhad & Dehkhoda, 2013). The association between scores on these tests with, specifically, non-contact ACL

injuries, is however unclear. The aim of this study is to explore if scores on the YBT and FMS correlate with peak knee valgus moments during unplanned sidestepping. Any associations found between these movement-based tests with knee valgus moments would potentially allow sports practitioners to more easily screen their athletes prior to physical activity to get an indication of the athletes' risk of non-contact ACL injuries without the need for elaborate 3D biomechanical analyses.

METHODS: Fifteen female netballers (Age=24.6±2.5 yrs; Height=1.75±0.06 m; Weight=63.2±7.4 kg) participated in this study. All participants were injury free at the point of testing and were competent in performing sidestepping. All procedures were approved by the institutional review boards of the Singapore Sports Institute and Nanyang Technological University.

Participants performed the YBT, FMS and unplanned sidestepping in a randomized manner. The YBT for lower limb was performed by pushing the reach indicator as far as possible anteriorly, posteromedially and posterolaterally for each leg. Participants performed four practice sets for familiarization prior to three sets for testing. The maximal reach distance in each direction was recorded from the apparatus. Individual reach distance was normalized to limb length and multiplied by 100 and expressed as a percentage. The composite score; the sum of the three reach directions, divided by three times the limb length, multiplied by 100; was also calculated. The mean maximal reach scores in three directions as a percentage of limb lengths for each leg was calculated. The sequence of legs tested and reach directions were counterbalanced to prevent sequence effects.

The deep squat, hurdle step, in-line lunge, active straight leg raises, trunk push up and rotary stability exercise were performed as part of the modified FMS. Two familiarization sets of the exercises were performed prior to one test set. Each set required participants to perform three trials of each exercise bilaterally where applicable. Participants were videoed from the front, back, left and right when performing the FMS. The footage of the six movements were individually scored according to a standardised scoring system from 0-3. The sequence of movements performed by participants within a test set was counterbalanced to prevent sequence effects.

Participants performed unplanned bilateral sidestepping by changing directions from a straight run at $4.5±0.5$ ms^{-1} in response to an arrow that appeared on a screen indicating the direction of travel. For clarity, an arrow pointing to the left would require participants to sidestep to the left by pushing off their right leg, and vice versa. All sidesteps were performed at 45 degrees to the straight line. A total of 12 sidesteps, six in each direction, were performed. The sequences of the unplanned bilateral sidestep cuts toward the left or right were randomised to minimise anticipation. Participants' three-dimensional motion data were recorded at 250 Hz using a 12-camera Vicon MX motion analysis system (ViconPeak Ltd, Oxford, UK). Thirty-two retroreflective markers were affixed to participants according to the UWA Lower Body and Torso marker set and model (Besier, Cochrane, Lloyd & Ackland., 2001) to facilitate three dimensional motion analysis. Ground reaction forces were synchronously collected at 2kHz using a 900 mm x 600 mm AMT force plate (Advanced Mechanical Technology Inc., Watertown, MA). Knee valgus moments from three successful sidesteps to the right using the left leg to push-off were calculated using inverse dynamics during weight-acceptance phase, normalized to bodyweight and height, and analysed (Lee, Lloyd, Lay, Bourke, & Alderson, 2013).

SPSS (Version 22.0, IBM, Singapore) was used to assess the normality of all data before the performance of two-tailed, Pearson's product-moment correlation coefficient to assess correlations between average normalized peak knee valgus moments and 1) average normalized YBT composite scores, 2) average normalized YBT maximal reach scores in each direction, 3) FMS total scores and 4) FMS scores of each movement component. Significant correlations were defined as $p < 0.05$.

RESULTS: A moderate-to-strong negative correlation was found between YBT composite (r = -0.60, p=0.020) and normalized posterolateral reach (r = -0.61, p=0.016) scores with peak knee valgus moments. The lower the YBT scores were, the higher the peak knee valgus moments during unplanned sidestepping. None of the other YBT and FMS component or composite scores correlated with peak knee valgus moments.

Table 1

Correlations of FMS Composite and Component Scores with Average Normalized Peak Knee Valgus Moments

	Mean±SD	r	p
Average Peak Knee Valgus Moments from left leg (Nkg^{-1})	0.61±0.24	-	-
Composite Score	13.2±1.3	0.009	0.974
Deep Squat Score	2.1±0.7	0.034	0.904
Hurdle Step Score	2.1±0.4	-0.311	0.260
In-line Lunge Score	2.2±0.4	-0.061	0.830
Active Straight Leg Raise Score	2.3±0.6	0.177	0.529
Trunk Pushup Score	2.2±0.7	0.021	0.941
Rotary Stability Score	2.1±0.7	0.009	0.974

Table 2
Correlations of Average Normalized YBT Composite and Component Scores with Average Normalized Peak Knee Valgus Moments. * represents $p < 0.05$.

	Mean±SD	r	p
Average Peak Knee Valgus Moments (Nkg^{-1})	0.61±0.24	-	-
Composite Left (%)	93.83±3.84	-0.59	0.02*
Composite Right (%)	93.59±5.00	-0.11	0.69
Left Anterior Reach (%)	68.33±5.28	-0.26	0.35
Left Posterolateral Reach (%)	105.65±4.89	-0.61	0.02*
Left Posteromedial Reach (%)	107.51±5.08	-0.49	0.07
Right Anterior Reach (%)	67.51±3.90	-0.004	0.99
Right Posterolateral Reach (%)	105.58±5.95	-0.005	0.99
Right Posteromedial Reach (%)	107.66±6.77	-0.19	0.49

DISCUSSION: The FMS and YBT are two simple-to-administer tests that assess the movement proficiencies and dynamic balance of individuals. Scores from the FMS and YBT have been reported to predict injuries (Kiesel et al., 2007). Nonetheless, it was previously unknown whether there were any relationships between the scores on the FMS and YBT, and non-contact ACL injury risk via unplanned sidestepping, respectively. The aim of this study was to explore if scores on the FMS and YBT correlate with peak knee valgus moments; a predictor of non-contact ACL injury risk; during unplanned sidestepping.

The null correlations between scores on the FMS and peak knee valgus moments suggest that while the FMS may be a useful tool to predict general lower limb injuries, it may not be relevant in assessing an individual's risk of non-contact ACL injury via unplanned sidestepping. Sports practitioners who are specifically interested in the assessment and subsequent prevention of ACL injuries may need to utilize alternative movement-based tests. The moderate-to-strong negative correlations between the peak knee valgus moments and the composite YBT scores, and normalized posterolateral reach scores, indicate that low scores on the YBT may associate with higher knee valgus moments during unplanned sidestepping. Consequently, practitioners can use the YBT as a time- and cost-effective tool to assess athletes' potential risk of ACL injury during sidestepping compared with performing three-dimensional motion analyses to assess the biomechanics of athletes' sidesteps; a costly process that also requires significant time commitment from the athletes to undergo.

Performing well on the YBT, especially the posterolateral reach component, requires good eccentric strength and control of the hip extensors, knee flexors, hamstrings and gluteals. Future research could develop a neuromuscular training program that is targeted at improving athletes' abilities to perform the posterolateral reach on the YBT and thereby, hopefully reduce non-contact ACL injury risk during game situations by way of a reduction in peak knee valgus moments during sidestepping. Prospective studies could also be performed to monitor how YBT scores may be related to non-contact ACL injury occurrences during game situations.

CONCLUSION: This exploratory study found no correlations between peak knee valgus moments during unplanned sidestepping and scores on the FMS. Conversely, there was a moderate-to-strong negative correlation between the peak knee valgus moments and the composite YBT scores, and normalized posterolateral reach scores. The posterolateral reach component of the YBT presents a simple-to-administer test to periodically monitor an athlete's risk of non-contact ACL injury risk when sidestepping.

REFERENCES:

Besier, T., Lloyd, D., Cochrane, J., & Ackland, T. (2001). External loading of the knee joint during running and cutting maneuvers. *Medicine and Science In Sports And Exercise*, 1168-1175.

Chorba, R., Chorba, D., Bouillon, L., Overmyer, C., & Landis, J. (2010). Use of a Functional Movement Screening Tool to Determine Injury Risk in Female Collegiate Athletes. *North American Journal of Sports Physical Therapy*, 5(2), 47-54.

Gianotti, S., Marshall, S., Hume, P., & Bunt, L. (2009). Incidence of anterior cruciate ligament injury and other knee ligament injuries: A national population-based study. *Journal of Science and Medicine in Sport*, 12(6), 622-627.

Griffin, L. Y., Agel, J., Albohm, M. J., Arendt, E. A., Dick, R. W., Garrett, W. E., ... & Wojtys, E. M. (2000). Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. *Journal of the American Academy of Orthopaedic Surgeons*, 8(3), 141-150.

Hewett, T. (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: A prospective study. *American Journal of Sports Medicine*, 33(4), 492-501.

Kiesel, K., Plisky, P., & Voight, M. (2007). Can serious injury in professional Football be predicted by a preseason Functional Movement Screen? *North American Journal of Sports Physical Therapy*, 2(3), 147-158.

Lee, M., Lloyd, D., Lay, B., Bourke, P., & Alderson, J. (2013). Effects of Different Visual Stimuli on Postures and Knee Moments during Sidestepping. *Medicine & Science in Sports & Exercise*, 45(9), 1740-1748.

Plisky, P. J., Rauh, M. J., Kaminski, T. W., & Underwood, F. B. (2006). Star Excursion Balance Test as a Predictor of Lower Extremity Injury in High School Basketball Players. *Journal of Orthopaedic & Sports Physical Therapy*, 36(12), 911-919.

Shojaedin, S., Letafatkar, A., Hadadnezhad, M., & Dehkhoda, M. (2013). Relationship between functional movement screening score and history of injury and identifying the predictive value of the FMS for injury. *International Journal of Injury Control and Safety Promotion*, 21(4), 355-360.

Sullivan, S., Hörman, E., Davidsson, Å., & Schneiders, A. (2011). Functional Movement Screen Normative Values in a Young, Active Population. *The International Journal of Sports Physical Therapy*, 6(2), 75-82.

Moore, C. & Info, E.Z. (1997). A survey of authors of rejected conference papers. *Journal of Useful Information*, 50, 105-11.

Order, I.N. (1996). *An editor's guide to successful publishing.* Perth: ECU Press.

Structure, S.P., Syntax, I. & Flow, W.L. (1994). Writing clearly. In U.R. Fastidius & N.O.T. Hasty (Eds.), *Lectures in Queen's English* (pp 61-64). Perth: Sorrento Press.

Thorough, U.B. & Concise, B. (1997). Reasons for rejecting conference papers. *Journal of Better Scientific Writing*, 24(Suppl. 1), 41-49.