ANGULAR KINEMATICS OF THE DEEP SQUAT TEST IN FUNCTIONAL MOVEMENT SCREEN™ ACCORDING TO THE SCORING SYSTEM

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ABSTRACT

The aim of this study was to determine to angular kinematic differences of the Functional Movement Screen (FMS)TM deep squat test according to the classifications. 23 university students (age 22.43±1.53yrs; height 177.26±6.09cm and weight 70.21±12.40kg) participated to this study voluntarily. Participants performed a deep squat test three times according to Cook's guidelines for Functional Movement Screening. They get scored by a clinician as 1, 2 or 3. During the test performance, 3D angular kinematic data was collected by 8 high speed Oqus 7+ cameras which were connected directly to the computer. Left and right knee, hip and shoulder angles; trunk flexion angle; hip, calf segmental angles, dowel angle in frontal axis; and also thigh segmental angle in horizontal axis were assessed to examine differences between the three scoring groups by using Qualisys Track Manager (QTM) Version 2.12.

SPSS 18.0 (SPSS Inc., Chicago, IL, USA) program was used for the differences by Kruskal Wallis test. As a result of the study, the significant difference were found at right and left knee angle between groups ($p<0.05$). Also in horizontal plane, right and left thigh were significantly difference between groups ($p<0.05$) too. There were no significant differences found in other parameters. ($p>0.05$). As a conclusion, in squat movement, as the limitation of motion increases, the hip and knee angles were getting higher and because there was a knee excursion in the horizantal plane, the mechanics of movement distorted.

***Keywords**: Angular Kinematics, Deep Squat, FMS, Screening.*

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Introduction

Functional movement is the ability to produce and maintain a balance between mobility and stability along the kinetic chain while performing fundamental patterns with accuracy and efficiency[25, 27]. Muscular flexibility, strength, coordination, balance, endurance, and movement efficiency are components necessary to achieve functional movement, which is integral to performance and sport-related skills[18] and also in health promotion environments, like gyms for general population[26]. Physically active people may face the risk of long or short term injuries and these injuries are commonly as lower extremity especially in sportive activities/ games and may occur after an intensive exercises or/and neuromuscular fatigue[4, 8].

Preventing injuries, it should be determined whether the athletes are in the risk group[4]. One of the popular screening tool for this, is the Functional Movement Screen™ (FMS)[12]. FMS™ has demonstrated some efficacy in the prediction of injuries and is thus used by many practitioners to make recommendations for exercise[3, 10, 22]. As the fundamental of functional training system and the classic test of body functional movement, FMS™ is widely applied in physical therapy and strength and conditioning area, and has good reliability and validity[28]. It consists of 7 fundamental movements which are scored on a 0-3 ordinal scale; involving locomotor, manipulative, and stabilizing actions that assess balance, mobility, and stability[12, 17, 20, 21].

It also has developed a series of corrective exercises that are prescribed based on the level and type of faulty movement patterns achieved. So together with these corrective exercises, the FMS™ is promoted to reduce the risk of sport-related musculoskeletal injury[20]. Chorba et al 2010 indicated that the risk of injury in female collegiate athletes could be identified by using a functional movement screening tool[29]. However McCunn et al 2016 mentioned that in their review, none of the movement screens that appear within the scientific literature currently had enough evidence to justify the tag of 'injury prediction tool'[30].

The scoring of the screening is made according to the criteria given by the guidelines provided by Cook et al., (2010). However, within this criterion, no angular evaluation of the subjects were found and the angular differences of the individuals who score 1- 2 and 3 are not specified. One of the potential confounders is the issue of whether a knowledge of a task's scoring criteria can change how individuals perform. If someone can influence their score based on their knowledge or understanding of the test, the outcomes of any strategy to prevent injury and improve performance, be it coaching or exercise related, could be compromised[10]. The main purpose of this study was to determine to the angular differences of related joints according to the FMS™ scoring criteria and its classifications. It was hypothesized that segmental angles would change as individuals adapted their movement in an attempt to meet the scoring criteria.

Materials and methods

Participants

23 students (6 women, mean age 22,66±1,96yrs; mean height 172,50±1,97cm and mean weight 56,83±3,71kg; 17 men, mean age 22,25±1,41yrs; mean height 178,94±6,18cm and mean weight 56,83±3,71kg) from Halic University, School of Physical Education and Sport Department participated in this study as voluntarily. The students have not experienced any lower extremity injuries before. The study was conducted consistent with the recommendations of the Declaration of Helsinki. Before participating to the study, the subjects were informed about the research, including potential the risks and benefits of the study. Written consent was obtained from all the students.

Procedures

The data collection was done in Halic University, Department of Physical Education and Sport's Laboratory, Istanbul and asked all participants to refrain from alcohol, caffeine and ergogenic aids the day before the test. According to the procedure, there was no given warming time for the participants. Since there is no additional weight added to the athlete and the screens are designed to uncover limitations to movement, extensive warm-up is not required[5].

The reflector markers which 3 cm diameter were attached to their selected joints of right and left acromion, olecranon, medial styloid, great trochanter, proximal patella, lateral malleolus and the dowel. These markers were applied to the participants with double-sided tape (Figure 1).

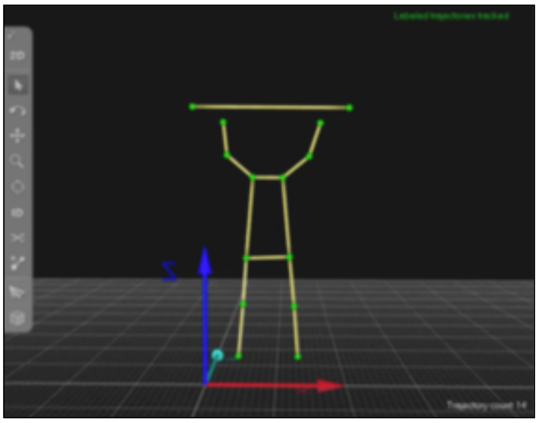

Figure 1: Marker Positions.

Kinematic data were collected by using 8 high speed (120 Hz) Oqus 7+ cameras (Dimensions: 18.7×11×12.5cm; Weight: 1.9-2.1kg) which were connected directly to the computer. The cameras were placed to each other about 3-4 meters distance and 4-6meters to the participants. For analyses of the 3D angular kinematics, Qualisys Track Manager (QTM) Version 2.12, which is proprietary tracking software, designed to work seamlessly with any model of Qualisys camera, ensuring fast and precise data collection (Qualisys AB, 2011), were used. A dynamic calibration method which was a wand calibration was used. T stick was simply moved around in the volume while a stationary reference object in the volume defines the coordinate system for the motion capture. Calibration time was set for 45sec (Figure 2). Marker trajectories were low pass filtered at 5Hz using Butterworth filter.

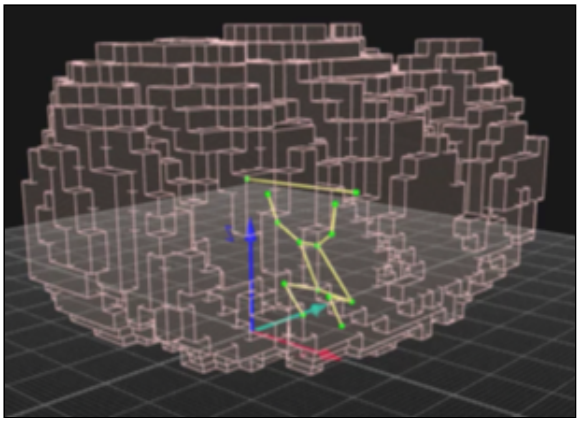

Figure 2: Calibration Cube.

All participants performed a deep squat three times, permitting the observer to vary their view of the athlete's movement through different planes of motion (i.e., sagittal and frontal), respectively. It was scored according to Cook's guidelines. The best trial was used for kinematic data analysis. 3D data for the lower extremity during the deep squat trials were analyzed to examine differences between the three scores of the FMS™. Left and right joint angles (knee, hip and shoulder); trunk flexion angles; hip, calf segmental angle, dowel angle in frontal axis; and also thigh segmental angle in horizontal axis were assessed to examine differences between the three groups.

Functional Movement ScreenTM

The full system of the FMS™ included 7 tests; deep squat, hurdle step (right then left), inline lunge (right then left), shoulder mobility (right then left), active straight leg raise (right then left), trunk stability push-up, and rotary stability (right then left)[21, 13, 23]. The equipment consisted of a 121.9*5.1*15.3 cm PVC measurement board with removable dowel (76.2 cm) inserts, a 121.9cm PVC dowel, and elastic band for the hurdle step movement[21]. Clinicians certified to perform FMS™ are taught to demonstrate and evaluate each of the 7 movements. Evaluators assign 0 if there is any pain during the movement, 1 if the movement cannot be performed, 2 if there is any compensation, and 3 if the movement is performed without pain or compensation. For 3 of the movements, there is also an additional clearing test that the client performs. If there is pain on the clearing test, 0 is scored for that movement. A sum composite score for the 7 components ranges from 0 to 21[13, 17, 12].

The Deep Squat Test

The deep squat is a test that challenges total body mechanics when performed properly. It is used to assess bilateral, symmetrical, functional mobility of the hips, knees, and ankles. The dowel held overhead assesses bilateral, symmetrical mobility of the shoulders, as well as the thoracic spine[5].

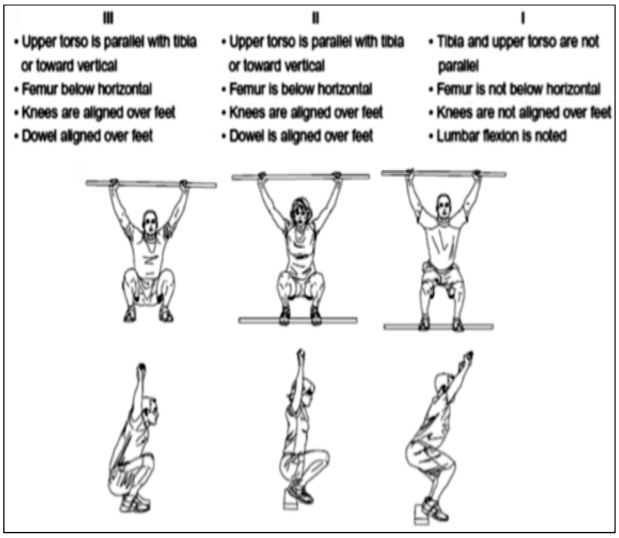

Figure 3: The Deep Squat Scoring System according to Groups 1, 2 and 3[3, 24].

The individual assumes the starting position by placing his/her feet approximately shoulder width apart with the feet aligned in the sagittal plane. Then adjusts their hands on the dowel to assume a 90degree angle of the elbows with the dowel overhead. Next, the dowel is pressed overhead with the shoulders flexed and abducted, and the elbows extended. The individual is then instructed to descend slowly into a squat position. The squat position should be assumed with the heels on the floor, head and chest facing forward and the dowel maximally pressed overhead. The individual may repeat the movement up to three times. If the criteria for a score of III is not achieved, the athlete is then asked to perform the test with a 2 x 6 board under their heels (Figure 3)[5, 12]. Scoring criteria has shown in Figure 3 according to the classifications[5, 10, 12].

Statistical Analysis

The data of angular kinematic variables from FMS™ deep squat trials were statistically analysed using SPSS 18.0 (SPSS Inc., Chicago, IL, USA) program. The results were presented as Means± SD. Kruskal-Wallis test were utilized to identify any differences between specific groups (group 1, 2 and 3) and MannWhitney-U test was used as a Post Hoc. The statistical significance level was set at 0.05.

	Group 1 (n=4)	Group 2 (n=6)	Group 3 (n=13)
	Mean±Std.D	Mean±Std. D	Mean±Std. D
Hip Flexion Angle (Right) (º)	83,46±16,63	62,42±10,10	60,29±8,62
Knee Extension Angle (Right) (º)	*81,75±20,51*	*49,32±12,53*	***49,38±8,81****
Shoulder Angle (Right) (º)	111,26±3,09	112,14±6,88	112,29±6,64
Hip Flexion Angle (Left) (º)	73,59±20,35	60,69±10,06	60,05±9,14
Knee Extension Angle (Left) (º)	*80,71±21,78*	*50,52±12,49*	***48,85±9,30****
Shoulder Angle (Left) (º)	117,07±1,61	115,13±8,65	112,94±8,22
Trunk Flexion Angle (º)	32,35±9,98	25,74±7,67	24,54±5,43
Right Calf Angle (Frontal Plane) (º)	30,28±13,31	32,77±7,96	30,14±6,82
Left Calf Angle (Frontal Plane) (º)	29,54±10,79	29,66±6,04	31,25±5,42
Right Thigh Angle (Horizantal Plane) (º)	*-23,25±11,95*	*6,02±11,93*	***8,75±7,97****
Left Thigh Angle (Horizantal Plane) (º)	*-20,74±14,19*	*7,56±12,08*	***9,44±8,29****
Hip Segment Angle (Frontal Plane) (º)	0,73±2,27	1,36±1,37	-0,22±2,99
Dowel Angle (Frontal Plane) (º)	-1,34±2,72	-1,07±1,46	-0,70±2,48

Table1: The Mean and Std.Deviation of Angular Parameters for Deep Squat Test according to Classifications.
**p<0.05*

Results

Deep squat angular kinematics for some selected joints and segments differed between the classifications. The angles for all evaluated parameters were shown in Table 1. Hip and knee angle were greater in score 1 compared to score 2 and 3 for both right and left side (Table 1). According to the results the significant difference were found at right and left knee angle between group 1 and 2 (p<0,03; p<0,05 respectively); between group 1 and 3 (p<0,06). Also in horizontal plane, right and left thigh were significantly difference between group 1 and 2 (p<0,01); 1 and 3 (p<0,001). There were no significant differences found in other parameters. (p>0,05).

Discussion

This study examined the differences of angular kinematics of FMS™ deep squat test according to the scoring classifications. Similar to present study there were some researches done for deep squat testing[3, 16], although most researchers have investigated to determine either reliability of the FMS™ testing system[13, 19, 20, 21] or relationships between other performance and health parameters[1, 2, 4, 6, 9, 15].

The ability to perform the deep squat requires closed-kinetic chain dorsiflexion of the ankles, flexion of the knees and hips, and extension of the thoracic spine, as well as flexion and abduction of the shoulders[5]. Results showed that squat performances were differed. The significance differences were found between group 1 and 2, 3, especially in knee angles and thigh segments (p<0.05). Findings suggest that the knee angles create different positions during examination. The knee joint is the primary modulator of lower extremity motion during the deep squat and has to resolve large joint moments proximally from the hip and distally from the ankle[3]. Since the FMS™ deep squat test is commonly used to identify mobility or stability impairments of the entire kinetic chain[12], the participants who have a lower scores, cannot completed proper movements. In present study, right knee extension angle was 81,75±20,51° for 1; 49,32±12,53° for group 2; 49,38±8,81° for group 3 and left knee extension angle was 80,71±21,78° for group 1; 50,52±12,49° for group 2; 48,85±9,30° for group 3. These extension angles were similar with literature[3, 14]. Butler et al., 2010, found peak knee flexion as 84.7±4.3° for group 1; 111.0±4.9° for group 2 and 130.7±3.8°. Krause et al., (2015) was found knee flexion angle as 109,9° after a 3d motion analysis. There were no any differences found between group 2 and 3 angular kinematics for all parameters (p>0.05). It is thought that this was caused by the fact that a platform was placed under the feet of the participants. The platform may have affected the squat mechanism because it would change the dorsiflexion angle of the participants. Butler at al., (2010), found significant difference of the three variables of interest at the ankle joint was that the peak dorsiflexion excursion was greater in group 3 compared to group 1 (p<0.03) and they emphasized that there was a large effect size difference (p<0.04) between group 1 and group 3 along with a moderate effect size difference (p<0.27) between group 2 and group 3 for peak dorsiflexion (p<0.10) (3). In this study dorsiflexion angle was not examined.

In the present study, there were no any significant differences in hip angular changes (p>0.05). Similar results found in different studies especially between group 2 and 3[3, 7, 11]. In group 1, a greater range of motions was observed in the lower limb movement. Because of the high center of mass, the hip range of motion was wider than the other groups. Although the study did not reveal any significant difference from the statistical point of view, the movement angles were found higher in group 1 than in the other groups. This might be due to the low number of subjects. A limitation of this study was that the sample size was small (Group 1 n=4; Group 2 n=6; Group 3 n=13), which could limit the generalizability of the investigation. Also, it was excluded subjects that had any present musculoskeletal injury, surgery, or neurological condition; therefore, findings can only be generalized to a population of healthy, young athletes from different sport branches and variable training experiences between the ages of 20-25. Cook et al., 2010 indicated that limited mobility in the lower extremity including poor closed-kinetic chain poor flexion of the hips may also cause poor test performance.

Another consequence of the study was the angular differences of the thigh segment in the horizontal plane. Participants in group 1 had some excursions in knee horizontal angles to get more range of motion from their joints (-23,25±11,95° for right knee; -20,74±14,19° for left knee). In some joints, some positions of the body were manipulated in order to increase the range of motion. It is important that such mistakes are taken into consideration when scoring of the deep squat performance in FMS™.

In conclusion, the squat is a movement needed in most athletic events and is required for most power movements involving the lower extremities. It is important to the creation of a chain movement from the lower limbs and to apply these movements during squat technique, students/athletes/clients should stay away from inconsistent angular movements and keep the body posture stable at proper angular positions. It is recommended that the corrective exercises should be applied, according to the motion of ranges obtained in this study.

References

1) Beach TA, Frost DM, Callaghan JP. FMS™ scores and low-back loading during lifting-Whole-body movement screening as an ergonomic tool?. Appl Ergon 2014; 45: 482-489.
2) Bushman TT, Grier TL, Canham-Chervak MC, Anderson MK, North WJ, Jones BH. Pain on functional movement screen tests and injury risk. J Strength Cond Res 2015; 29: 65-70.
3) Butler RJ, Plisky PJ, Southers C, Scoma C, Kiesel KB. Biomechanical analysis of the different classifications of the Functional Movement Screen deep squat test. Sports Biomech 2010; 9:270-279.
4) Clifton DR, Harrison BC, Hertel J, Hart JM. Relationship between functional assessments and exercise-related changes during static balance. J Strength Cond Res 2013; 27: 966-972.
5) Cook G, Burton L, Kiesel K, Rose G, Bryant MF. Movement: Functional Movement Systems: Screening, Assessment, and corrective strategies. Aptos, CA: On target publications, 2010.
6) Duncan MJ, Stanley M, Wright SL. The association between functional movement and overweight and obesity in British primary school children. BMC Sports Sci Med Rehabil, 2013; 5: 11.
7) Escamilla RF, Fleisig GS, Lowry TM, Barrentine SW, Andrews JR. A three-dimensional biomechanical analysis of the squat during varying stance widths. Med Sci Sports Exerc 2001; 33: 984-998.
8) Fernandez W, Yard E, Comstock R. Epidemiology of lower extremity injuries among US high school athletes. Acad Emerg Med 2007; 14: 641-645.
9) Fox D, O'Malley E, Blake C. Normative data for the Functional Movement Screen™ in male Gaelic field sports. Phys Ther Sport, 2014; 15: 194-199.
10) Frost DM, Beach TA, Callaghan JP, McGill SM. Using the Functional Movement Screen™ to evaluate the effectiveness of training. J Strength Cond Res 2012; 26: 1620-1630.
11) Hemmerich A, Brown H, Smith S, Marthandam SSK, Wyss UP. Hip, knee, and ankle kinematics of high range of motion activities of daily living. J Orthop Res 2006; 24: 770-781.
12) Kiesel K, Plisky P, Butler R. Functional movement test scores improve following a standardized off-season intervention program in professional football players. Scand J Med Sci Sports 2011; 21: 287-292.
13) Koehle MS, Saffer BY, Sinnen NM, MacInnis MJ. Factor structure and internal validity of the functional movement screen in adults. J Strength Cond Res 2016; 30: 540-546.
14) Krause DA, Boyd MS, Hager AN, Smoyer EC, Thompson AT, Hollman JH. Reliability and accuracy of a goniometer mobile device application for video measurement of the functional movement screen deep squat test. Int J Sports Phys Ther 2015; 10:37.
15) Lockie RG, Schultz AB, Callaghan SJ, Jordan CA, Luczo TM, Jeffriess MD. A preliminary investigation into the relationship between functional movement screen scores and athletic physical performance in female team sport athletes. Biol Sport 2015; 32:41-51.
16) McMillian DJ, Rynders ZG, Trudeau TR. Modifying the Functional Movement Screen deep squat test: The effect of foot and arm positional variations. J Strength Cond Res 2016; 30: 973-979.
17) Minick KI, Kiesel KB, Burton L, Taylor A, Plisky P, Butler RJ. Interrater reliability of the functional movement screen. J Strength Cond Res 2010; 24: 479-486.
18) Okada T, Huxel KC, Nesser TW. Relationship between core stability, functional movement, and performance. J Strength Cond Res 2011; 25: 252-261.
19) Parenteau-G E, Gaudreault N, Chambers S, Boisvert C, Grenier A, Gagné G, Balg F. Functional movement

screen test: A reliable screening test for young elite ice hockey players. Phys Ther Sport 2014; 15: 169-175.
20) Shultz R, Anderson SC, Matheson GO, Marcello B, Besier T. Test-retest and interrater reliability of the functional movement screen. J Athl Train 2013; 48: 331-336.
21) Waldron M, Gray A, Worsfold P, Twist C. The reliability of functional movement screening and in-season changes in physical function and performance among elite rugby league players. J Strength Cond Res 2016; 30: 910-918.
22) Conlon JK. The relationship between the Functional Movement Screen™ and countermovement jump height (Doctoral dissertation, The University of Wisconsin-Milwaukee) 2013.
23) Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function e part 1. N Am J Sports Phys Ther 2006; 1: 62-72.
24) Cook G, Burton L, Fields K. The Functional Movement Screen and Exercise Progressions Manual. Available from: http://isd194.org/lakeville-south/download/communications_master/Athletics:Activities/Athletic%20Trainer/FMSManual(2).pdf
25) Mills JD, Taunton JE, Mills WA. The effect of a 10-week training regimen on lumbo-pelvic stability and athletic performance in female athletes: A randomized-controlled trial. Phys. Ther. Sport 2005; 6: 60-66.
26) Paoli A, Moro T, Bianco A. Lift weights to fight overweight. Clin Physiol Funct Imaging 2015; 35:1-6.
27) Sediek RH, El-Tohamy AM, Nassar I. Relation Between Core-Stability and Functional Abilities in Children with Spastic Cerebral Palsy. Trends Appl Sci Res 2016; 11: 19.
28) Liao T, Zheng W, Meng Y. Application of Functional Movement Screen to the Evaluation of Youth's Physical Health. In Advances in Human Factors in Sports and Outdoor Recreation. Springer International Publishing 2017; 189-198.
29) Chorba RS, Chorba DJ, Bouillon LE, Overmyer CA, Landis JA. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. N Am J Sports Phys Ther 2010; 5: 47.
30) McCunn R, Aus der Fünten K, Fullagar HH, McKeown I, Meyer T. (2016). Reliability and association with injury of movement screens: A critical review. Sports Med 2016; 46: 763-781.

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