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RELATIONSHIP BETWEEN DYNAMIC BALANCE, FUNCTIONAL MOVEMENT AND MUSCLE LENGTH IN YOUNG ADULTS

ODNOS MED DINAMIČNIM RAVNOTEŽJEM, FUNKCIONALNIM GIBANJEM IN DOLŽINO MIŠIC PRI MLADIH ODRASLIH

ABSTRACT

The functional movement screen is an easily administered and noninvasive tool for identifying weaknesses and asymmetry during exercises and daily activity. Also the bilateral asymmetries in flexibility and in Y Balance Test have been associated with injuries. However, relationships among these attributes are unclear especially in young adults. The aim of this study was to determine the association between dynamic balance using the Y-Balance Test (YBT), functional movement using the functional movement screen (FMS) and muscle lengths using a standard goniometer in a young adults. Secondary aims were to investigate whether this parameters differed between male and female. One hundred twenty-three healthy people (male: n=68, age=21.49±1.47 years; female: n=55, age=20.98±1.67 years) participated in the study. Spearman correlation analysis was used to determine the relationship between muscle lengths and FMS, and the YBT. There were positive correlations between the muscle lenghts and the YBT(.197<r<.352). There were significant relationships between FMS and muscle lengths (hamstring and iliopsoas). Functional movement scores were not significantly different between male and females (p>.05) when considered as total scores. However, females performed significantly better than male on the shoulder mobility (p = .004) and straight leg raise (p=.000) but poorer than male on the trunk stability push-up (p = .001) and deep squat (p =.000). We conclude that muscle length in young, male and female can effect in FMS and dynamic balance.

Keywords: Adult, balance, joint flexibility, movement

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IZVLEČEK

Funkcionalni pregled gibov je enostavno in neinvazivno orodje za odkrivanje pomanjkljivosti in asimetrije med vadbo in vsakodnevno aktivnostjo. Dvostranske asimetrije v prožnosti in v Y-testu ravnotežja povezujemo s poškodbami. Vendar pa so odnosi med navedenimi atributi nejasni, zlasti pri mladih odraslih. Glavni namen te raziskave je bil ugotoviti povezavo med dinamičnim ravnotežjem z uporabo Y-testa ravnotežja (YBT), funkcionalnim gibanjem z uporabo funkcionalnega pregleda gibov (FMS) in dolžine mišic z uporabo standardnega goniometra pri mladih odraslih. Drugoten cilj je bil preučiti, ali se ti parametri razlikujejo med moškimi in ženskami. V raziskavi je sodelovalo 123 zdravih oseb (moški: n = 68, starost = 21,49 ± 1,47 let; ženske: n = 55, starost = 20,98 ± 1,67 let). Z analizo Spearmanove korelacije smo opredelili odnos med dolžinami mišic in FMS ter YBT. Med dolžinami mišic in YBT smo opazili pozitivne korelacije (.197 < r < .352). Značilni odnosi so bili tudi med FMS in dolžinami mišic (zadnja stegenska mišica in mišica iliopsoas). Vrednosti funkcionalnih gibov se med moškimi in ženskami niso značilno razlikovali (p > .05), ko smo jih upoštevali kot končne rezultate. Vendar pa so se ženske odrezale značilno bolje od moških pri mobilnosti ramena (p = .004) in dvigu iztegnjene noge (p = ,000) ter slabše pri sklecah s stabilnim trupom (p = .001) in globokih počepih (p = .000). Zaključili smo, da dolžina mišic pri mladih moških in ženskah lahko vpliva na FMS in dinamično ravnotežje.

Ključne besede: odrasel, ravnotežje, prožnost sklepov, gibanje

INTRODUCTION

Involvement in any sport or activity requiring physical exertion has within it an inherent danger of physical injury (Tracey, 2003). Recently, sport participation and training intensities have dramatically increased: resulting in a greater potential for, and incidence of, physical injury. Therefore, researchers (O'Connor, Deuster, Davis, Pappas & Knapik, 2011; Peate, Bates, Lunda, Francis & Bellamy, 2007) have suggested that risk factors for noncontact injuries are modifiable when identified through movement patterns, right-to-left asymmetry, or balance abnormalities. The Functional Movement Screen (FMS) and the lower quarter Y Balance Test (YBT) are examples of screening tools that are being used clinically to assess injury risk based on abnormal movement patterns, asymmetry, and dynamic balance.

The YBT challenges single limb stance while simultaneously moving the non-stance limb in an anterior, posterolateral and posteromedial direction (Plisky et al., 2009). The FMS is a means of identifying weak links and asymmetry in one's basic functional movements (Cook, Burton & Hoogenboom, 2006). The screen consists of 7 different functional movements that assess the following: trunk and core strength and stability, neuromuscular coordination, asymmetry in movement, flexibility, acceleration, deceleration, and dynamic flexibility (Peate, Bates, Lunda, Francis & Bellamy 2007). The YBT and the FMS are specific tests proposed for use in screening injury risk in defined populations such as athletic populations (Lockie et al., 2015) and officer candidates (O'Connor et al.,2011). Lower extremity muscle length (flexibility) is measured indirectly by measuring adjacent joint range of motion (Corkery et al., 2007). Lower-extremity flexibility, specifically, has been shown to be important for successful performance of sport movements and activities of daily life. Beyond flexibility for function, flexibility is an essential factor for reducing injury risk (Overmoyer & Reiser 2015).

Within the knowledge of the authors, there are three studies in the literature that examined the relationship between these parameters; Lehr et al. (2013) university athletes and Teyhen et al. (2014a, 2014b) have examined the military population. Although initial evidence suggests that muscle length tests, YBT and FMS tools may be beneficial in predicting injury risk, there is insufficient evidence to show that they relate to each other (Teyhen et al., 2014a). Understanding the relationship between clinical measure (lower-extremity muscle length) that contribute to performance on the YBT and FMS in healthy individuals may assist in the design of preventive neuromuscular training programs for the lower extremity that target impairments associated with decreased muscle length, dynamic balance and functional movement. However, there is no study examining the relationship between muscle length, FMS, and Y balance in young adults. Against this background, the aim of this study was to determine the association between dynamic balance using the Y-Balance Test (YBT), functional movement using the functional movement screen (FMS) and muscle lengths using a standard goniometer in a young adults. Secondary aims were to investigate whether this parameters differed between male and female.

METHODS

Participants

A convenience sample of 123 healthy people (male:68, female:55) were tested. Participants had not suffered a head, musculoskeletal, or spine injury within the last 6 months; and reported no vestibular, visual, or balance disorders. Before testing, all participants signed assent forms and provided signed parental consent forms. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki. Additionally, the approval of experimental procedures were provided by Pamukkale University Ethics Committee (60116787-020/39277) and also written consent forms were obtained from all subjects, who were completely informed about the procedures.

Procedures

Age, activity level, and past medical history were recorded. The subjects also had height and weight recorded using a standardized medical scale.

Muscle Length Measurements

Bilateral muscle length measurements of the gastrocnemius, hamstring, rectus femoris and iliopsoas muscles were obtained using a standard goniometer. The four muscles were measured from distal to proximal and the right lower extremity was tested before the left. The muscles were separated into two groups, gastrocnemius/hamstring and iliopsoas/rectus femoris, according to the protocol described by Corkery et al.(2007). Gastrocnemius length was measured by having the subject lie prone in a figure four position, with the measuring foot hanging over the edge of the table (Fig. 1). Hamstring muscle length was assessed using the active knee extension. The subject was placed supine on a table with contralateral hip and thigh strapped down for stability. A crossbar was utilized to maintain the patient in 900 of hip (Fig. 2). Rectus femoris length was assessed using the modified Thomas test (Fig. 3). Iliopsoas length was determined using the Thomas test (Fig. 4). The average of 2 consecutive measurements was used for analysis. All muscle length measurements were performed by the same researcher.

Figure 1: Goniometric measurement of Gastrocnemius

Figure 2: Goniometric measurement of Hamstring muscle

Figure 3: Goniometric measurement of Rectus femoris

Figure 4: Goniometric measurement of Iliopsoas

Balance Measurements

Balance was assessed using the YBT. The YBT is a screen of dynamic balance requiring stance leg balance while the contralateral leg reaches in anterior (YBTANT), posteromedial (YBTPM) and posterolateral (YBTPL) directions (Smith, Chimera & Warren 2015). The protocol used instructions from the Move2Perform Web site (Web1). The YBT composite score (YBTCS) was calculated by summing the maximal distance from each direction. Consistent with the existing literature, the reach distance was normalized to the lower-extremity length (sum of the % limb length reached in all 3 directions) (Plisky et al., 2009, Plisky, Rauh, Kaminski & Underwood,2006). Lower extremity length was measured from the ASIS to the most distal portion of the medial malleolus (Teyhen et al., 2014a). Initial evidence also suggests that high school athletes with anterior reach asymmetries >4 cm and females with total excursion in all 3 directions <94% of their limb length were 2.5 and 6.5 times more likely to sustain a future lower-extremity injury. (Plisky et al. 2006; Teyhen et al., 2014).

Functional Movement Screen (FMS)

The FMS consists of 7 movement tasks and 3 clearance screens. Movement tasks include the deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability. Participants were allowed 3 attempts for each task. Each movement task was scored using standard composite scoring. Any task that produced pain was scored 0. The FMS composite scores (FMSCS) could range from 0 to 21 points, and individual task scores could range from 0 to 3 points (Cook, Burton & Hoogenboom 2006). One rater, whom had 2 years of experience using the FMS in clinical practice, scored participant performance on the movement tasks.

Statistical Analyses

All data were analysed using the IBM® SPSS® Statistics (Version 23.0) software. Continuous variables were expressed as mean±standard deviation. Normality and homogeneity of variables were checked with Kolmogorov-Simirnow test. In independent group comparisons, the Independent Samples t-tests was used for the data of which parametric test assumptions were provided; the Mann Whitney U test was employed for the data for which parametric test assumptions were rejected. Correlation coefficients (Pearson or Spearman coefficient, depending on normality) were calculated in order to determine the relationship between FMS, YBT scores and limb length. Effect size was calculated for Spearman correlation analyzes, considering small (r=.10), medium (r=.30) and large (r=.50) effects (Cohen, 1988). In all analyzes p <0.05 was considered statistically significant.

RESULTS

The Independent Samples t-tests showed significant differences in height, weight, body mass index (BMI), limb length and YBT scores according to the gender (p<0.05). Table 1 shows the

Table 1. Subject characteristics for the combined group (N=123), females (n=55) and males (n=68) and gender differences

Variable	Combined Mean +SD	Female Mean +SD	Male Mean +SD	P
Age (y)	21.26±1.58	20.98±1.67	21.49±1.47	0.078
Height (cm)	170.91±9.92	162.95±6.46	177.35±7.17	0.000*
Weight (kg)	66.46±13.67	56.07±7.57	74.87±11.56	0.000*
BMI** (kg/m^2)	22.55±2.91	21.06±2.08	23.74±2.95	0.000*
Limb length (R) (cm)	94.17±6.83	89.84±4.9	97.68±6.15	0.000*
Limb length (L) (cm)	94.14±6.79	89.84±4.87	97.63±6.1	0.000*
Flexibility (˚)				
Hamstring (R) (˚)	66.93±13.89	66.09±15.27	67.6±12.74	0.551
Hamstring (L) (˚)	67.53±17.1	66.89±17.7	68.04±16.69	0.712
Gastrocnemius (R) (˚)	16.17±2.41	16.02±2.41	16.3 ±2.42	0.530
Gastrocnemius (L) (˚)	16.49±2.54	16.27±2.49	16.66±2.59	0.401
Rectus femoris (R) (˚)	56.41±5.26	55.98±4.33	56.75±6.0	0.422
Rectus femoris (L) (˚)	56.68±7.34	56.50±5.0	56.83±8.82	0.799
Iliopsoas (R) (˚)	3.20±0.98	3.30±1.03	3.13±0.94	0.325
Iliopsoas (L) (˚)	3.10±0.98	3.22±1.05	3.00±0.92	0.222
FMS (points)	11.03±1.87	10 85±1.74	11.17±1.96	0.345
YBT (R) (cm)	87.04±8.53	84.97±7.29	88.71±9.11	0.005*
YBT (L) (cm)	87.90±8.71	85.75±7.59	89.62±9.21	0.004*

*p<0.05 **BMI = Body mass index. R: Right extremity, L: Left extremity, SD: Standart Deviation statistics for age, physical characteristics, muscle length, FMS, and the YBT and gender differences. Subject characteristics and all performance measures except for limb lenghts, YBT and BMI parameters were not significant difference for gender.

The analysis results showed that YBT scores was a non-parametric variable. In order to determine whether there are statistically significant differences in the YBT scores between the gender, Mann Whitney u test was applied. Their YBT composite scores were not significant differences (p>0.05) (Table 2). But, female YBTPM and YBTPL normalized reach distance were significantly lower than male (p<0.05).

However, female and male had different percentages of asymmetry; YBTANT ([female] versus %25.45, %27.94 [male]) and YBTPM ([female] versus %47.27, %60.29 [male]), YBTPL ([female] versus %50.91, %48.53 [male]). Total subjects had 26.83% anterior, 54.47% posteromedial, and 49.59% posterolateral YBT asymmetry.

Table 2. Mean reach distance of YBT and limb length of subjects (values expressed as Mean±SD) and gender differences.

	Combined	Female	Male	Z	p
			Reach distance** (cm)		
Anterior (cm)	73.89± 9.12	70.32± 7.53	76.78± 9.33	-3.851	0.000*
Posteromedial (cm)	88.17± 12.33	80.58± 9.19	94.33± 11.09	-6.069	0.000*
Posterolateral (cm)	85.53± 14.28	78.70± 11.04	91.06± 14.26	-4.739	0.000*
Compositeɫ	247.60± 26.83	229.59± 17.23	262.16± 24.29	-6.641	0.000*
Limb length** (cm)	94.16± 6.81	89.84 ± 4.88	97.65 ± 6.12	-6.540	0.000*
			Normalized reach distanceɫ (%)		
Anterior (%)	78.52± 8.34	78.31± 7.68	78.69± 8.88	-.122	0.805
Posteromedial (%)	93.80± 12.52	89.95± 11.53	96.91± 12.50	-3.133	0.002*
Posterolateral (%)	90.94± 14.51	87.84± 13.28	93.45 ± 15.06	-2.152	0.032*
Composite§ (%)	93.78 ± 12.02	95.50± 11.62	92.39 ± 12.25	-1.333	0.155
			Asymmetry(cm)		
Anterior (cm)	3.44 ±2.86	3.2 ±2.47	3.63±3.14	-.611	0.541
Posteromedial (cm)	5.59±4.61	4.79±3.85	6.24±5.07	-1.587	0.112
Posterolateral (cm)	5.14±4.12	5.33±4.22	4.98±4.07	-.505	0.614

*pɫ 0.05 Mann Whitney u test

**Average of right and left limb in cenimeters.

ɫ Sum of the 3 reach distances (anterior, posterolateral, posteromedial) in centimeters.

ɫ Reach distance divided bu limb length multiplied by 100.

§ Sum of the 3 normalized reach distances (anterior, posterolateral, posteromedial) divided by 3 times limb length multiplied by 100.

Kolmogorov-Simirnow test results showed that FMS scores was parametric variable. Significant interaction was further investigated using the Independent Samples t-test. FMSCS was 11.03±1.87 points. We found no significantly differences between female and male in FMSCS (p>0.05) (Table 3). But, when the scores of FMS movements are compared female FMS scores significantly lower than male in deep squat and trunk stability push up; however, sigficantly higher than male on shoulder mobility and straight-leg raise (p<0.05).

Table 3. Mean FMS scores of subjects (values expressed as Mean±SD) and gender differences

Variable (points)	Combined Mean +SD	Female Mean +SD	Male Mean +SD	t	P*
Deep squat	1.74±0.64	1.53±0.60	1.91±0.62	-3.470	0.001*
Hurdle step	1.34±0.48	1.35±0.50	1.34±0.48	.082	0.935
Inline lunge	1.41±0.53	1.48±0.55	1.35±0.50	1.436	0.154
Shoulder mobility	2.70±0.48	2.84±0.36	2.59±0.54	2.924	0.004*
Active straight leg raise	1.82±0.61	2.06±0.62	1.63±0.53	4.222	0.000*
Trunk stability push up	1.41±0.69	1.02±0.23	1.74±0.77	-6.695	0.000*
Rotator stability	1.30±0.41	1.28±0.43	1.32±0.40	-.555	0.580
Total composite scores	11.03±1.87	10.85±1.75	11.18±1.97	-8.382	0.345

*pł 0.05 (Independent-sampels t-test)

Spearman correlation analysis was used to determine the relationship between muscle length and FMS, and the YBT (Table 4). The YBT were significantly associated with muscle length especially ankle dorsiflexion, knee flexion and knee extension. Between BMI and FMS scores has been found negative correlation (p=0.01;r=-0.238).

Table 4. Relation of muscle length, BMI and function with Y-Balance Test normalized composite scores and FMS composite score.

Variable	Mean ± SD	Correlation with FMS	Correlation with YBT(R)	Correlation with YBT(L)
Muscle length				
Gastrocnemius(R)	16.17±2.41	0.90	0.205*	0.124
Gastrocnemius(L)	16.49±2.54	0.157	0.157	0.197*
Hamstring (R)	66.93±13.89	0.201*	0.169	0.193*
Hamstring (L)	67.53±17.1	0.122	0.246**	0.271**
Iliopsoas(R)	3.20±0.98	-0.211*	-0.038	-0.037
Iliopsoas(L)	3.10±0.98	-0.140	-0.112	-0.125
Rectus femoris (R)	56.41±5.26	-0.140	0.352**	0.283**
Rectus femoris (L)	56.68±7.34	-0.026	0.228*	0.171
BMI (kg/m2)	22.55±2.91	-0.238**	0.059	0.032
FMS				
Total score (0-21)	11.03±1.87	NA	0.012	0.028
Hurdle step R (0-3)	1.42±0.59	NA	0.059	0.054
Hurdle step L (0-3)	1.26±0.51	NA	0.082	0.067
In-line lunge R(0-3)	1.41±0.60	NA	-0.032	-0.069
In-line lunge L (0-3)	1.40±0.58	NA	0.096	0.065
Shoulder mobility R(0-3)	2.76±0.48	NA	0.088	0.054
Shoulder mobility L(0-3)	2.63±0.60	NA	0.011	0.001
Deep squat (0-3)	1.74±0.64	NA	0.130	0.162
Active straight leg raise R(0-3)	1.80±0.66	NA	-0.137	-0.121
Active straight leg raise L(0-3)	1.84±0.62	NA	-0.155	-0.100
Trunk stability push (0-3)	1.41±0.69	NA	0.106	0.164
Rotary stability R(0-3)	1.35±0.50	NA	0.047	0.058
Rotary stability L(0-3)	1.26±0.46	NA	-0.053	0.007

Variable	Mean ± SD	Correlation with FMS	Correlation with YBT(R)	Correlation with YBT(L)
YBT				
Anterior R (cm)	73.37±9.41	0.112	NA	NA
Anterior L (cm)	74.40±9.35	0.148	NA	NA
Posterior medial R(cm)	86.57±13.05	0.027	NA	NA
Posterior medial L(cm)	89.79±12.46	0.024	NA	NA
Posterior lateral R(cm)	86.47±14.27	0.040	NA	NA
Posterior lateral L(cm)	84.59±14.96	0.046	NA	NA
Composite R(cm)	87.33±8.53	0.012	NA	NA
Composite L(cm)	88.18±8.42	0.028	NA	NA

BMI = Body mass index. R: Right extremity, L: Left extremity

Effect size was calculated for Spearman correlation analyzes, considering small (r=.10), medium (r=.30) and large (r=.50) effects (Cohen, 1988).

DISCUSSION

This study adds to the literature in the area by providing data examining the association between dynamic balance, functional movement and muscle lengths in young adults 18-25 years of age. These performance tests have been linked to musculo-skeletal injury risk in both athletic and military settings (Teyhen et al., 2014a, 2014b). On the other hand, to the authors' knowledge, this is the first study to investigate relationships between these performance tests in young adults 18-25 years of age. This study demonstrated that was a low level relationship between dynamic balance-muscle lengths and functional movement-muscle lengths. In addition, when these performance tests compared between male and female, females performed significantly better than male on the shoulder mobility test and straight leg raise test but poorer than male on the trunk stability push-up test, deep squat test and the YBT.

A review of the literature indicates that performance on the YBT varies by physical activity level, sport, occupation, gender, and age (Teyhen et al., 2014a, Plisky et al., 2009, Plisky et al., 2006, Teyhen et al., 2016, Gribble & Hertel, 2003). The results from the current study support the findings that composite scores vary by physical activity level. Previously published research reveals that the mean YBTCS for soccer players ranged between 97 and 101% (American adolescent: 97.8% ± 6.2, high school: 98.4% ± 1.1, college: 100.9% ± 0.9, professional: 101.8% ± 1.2), basketball athletes scored 98-103% (females: 98.4% ± 8.2, males: 103.0% ± 8.0), and baseball players scored 95.8% ± 6.1 when normalized to leg length (Butler et al., 2012; Butler, Queen, et al., 2013; Garrison et al., 2013; Plisky et al., 2006). The normalized YBTCS reported in the current study was 93.78% ± 12.02 ([female] versus 95.50% ± 11.62, 92.39% ± 12.25 [male]). The average values reported in the current study were above the reported cutoff values demonstrating increased risk for injury. Specifically, the YBTCS score that predicted injury risk was 94% for female high school basketball players (Plisky et al., 2006) and 89% for collegiate football players (Lehr et al., 2013). In our opinion, although these cutt off values are for athletes, the current study suggests that young individuals have lower risk of injury as a result of the YBT.

Plisky et al. (2006) reported that anterior asymmetry greater than 4 cm, with the modified Star Excursion Balance Test (SEBT), was associated with lower extremity injury in high school–age basketball players. The current study, total subjects had 26.83% anterior YBT asymmetry. Although protocol, administration, and population were different, the findings of this current investigation are similar to those previously reported by Plisky et al. (2006). In addition, research on participants performing SEBT and YBT found decreased anterior reach for YBT (Coughlan 2012). This indicates that SEBT and YBT anterior asymmetry may be valuable in injury prediction; however, the motor control strategies may be different (Coughlan 2012, Smith 2015).

The mean FMSCS reported in in the current study was 11.03±1.87 ([female versus 10.85±1.74, 11.17±1.96 [male]). Previously published research reveals that the mean FMSCS ranged between 11.8 ± 2.8 and 17.4±3.1 ([military members 15.7±2, 16.2 ±2.2 (Teyhen 2014a, Teyhen 2014b), professional male football players 17.4±3.1 (Kiesel K, Plisky PJ, Voight ML 2007), healthy adults 14.8 ±2.8-15.4±2.4 (Perry & Koehle, 2013,), older active adult 11.8 ± 2.8 (Mitcell et al.2016) and physically active individuals 15.7±0.2 (Schneiders, Davidsson, Hörman & Sullivan, 2011])

Previously, Schneiders et al. (2011) established a FMSCS for a young (age: 18–40 years), active, general population of 15.7±0.2. Perry and Koehle (2013) established 14.8 ±2.8 as FMSCS among male and 15.4±2.4 in female in the general population. Our FMSCS for young adults are 11.03±1.87. A higher level of exercise participation was associated with a higher FMSCS. This deduction overlaps with the current study results. Because our participants did not participate in any regular physical activity, the FMSCS were quite low compared to the literature.

We found no difference between female and male subjects in FMSCS. However, we have realized a significant difference in the deep squat, trunk stability push up, shoulder mobility and straight-leg raise between gender. Also female showed better performance in flexibility related shoulder mobility and active straight-leg raise, while male were better at trunk stability push-up and deep squat movements, which required more strength and stability (Table 3). Our results are similar, Chimera et al. (2015) found no difference between female and male athletes in FMSCS; however, female and male athletes performed differently in all movement patterns of the FMS except for the deep squat and hurdle step. In our study, the deep squat score was better than the male while there was no difference in the hurdle step.

In this study 95.12% of the 123 participants had a score of 14 or less which might indicate a potentially higher risk of injury. Kiesel et al. (2007) determined that athletes who scored 14 or less on the FMS possessed dysfunctional movement patterns that may correlate with greater risk of injury but because of the small sample size of 41 footballers and the fact that the target group didn't represent a general athletic population, the authors of this study suggest that this cutoff value should be used with caution. Unfortunately, we can not comment on this because our study has healthy individuals, no history of injuries in the past 6 months, but their FMSCSs were well below the cut-off value. Before setting a clear cut-off value, further studies can be done on different athletic populations, occupational groups and young adults. Future research should also target specific age groups.

In the current study, the gastrocnemius muscle length was measured using active dorsiflexion, rather than passive ankle dorsiflexion applied by the researcher. This method was chosen to eliminate researcher bias and standardize measurements (Corkery et al. 2007). In similar studies, no studies were performed on hamstring, iliopsoas and rectus femoris muscle lengths in addition to dorsiflexion. We have reached only one study investigating the these measurements. Overmoyer & RF (2015) found that bilateral average hip flexion was 62±11°, knee angle for hamstring (28.3°) and Iliopsoas muscle length (2.3°). Our rectus femoris lengths (56±6°) were lower that findings the hamstring mean value (67°) was quite higher, but the iliopsoas mean value (3.1°) was similar. The reason for this difference; may be that the flexibility varies with gender, age group and physical activity status.

There are very few studies in the literature investigating the relationship between muscle length, YBT and FMS. Teyhen et al. (2014a) found that healthy soldiers who performed better on the YBT demonstrated superior performance on the FMS in-line lunge test, greater mobility of the shoulder and upper thoracic spine on the FMS shoulder/upper trunk mobility test, fewer hops to complete the 6-m hop test, and greater ankle dorsiflexion range of motion (Teyhen et al. 2014a). In another study by Teyhen et al.(2016) FMS, YBT and ankle dorsiflexion relationships were significant but poorly correlated. In contrast to this works the results of the Lockie et al.'s (2015) study generally showed that there were no relationships between the FMS and the modified Star Excursion Balance Test(mSEBT) in team sport athletes. They found that only four correlations between the mSEBT and FMS tests were significant, and two of these significant relationships suggested that a poorer score in the screen (the trunk-stability push-up) related to a further anteromedial excursion (Kiesel, Plisky &Voight, 2007). But the samples of these studies were different from ours. In our study, YBT were significantly associated with muscle length especially ankle dorsiflexion, knee flexion and knee extension.

We think that the results of our study will provide some clinic benefits. Firstly, understanding the relationship between YBT, FMS, and muscle length in young adults may help in the design of neuromuscular training programs to prevent increased injuries by participation in sports and physical activity. In addition, the availability of reference values allows comparison with young adults and sports people. Many functional activities in daily life and sport require the trunk stabilizers to transfer force asymmetrically from the lower extremities to the upper extremities and vice versa. Poor performance during rotary stability and trunk stability push-up test movements can be attributed to poor stability of the trunk (core) stabilizers and kinetic energy will be dispersed (lost), leading to poor performance and increased potential for injury (Cornell, Gnacinski, Zamzow, Mims & Ebersole, 2016). For protection from injury and optimal performance, push ups and rotary stability tests should also be emphasized and the corrective exercises of these movements can be added to the exercise programs.

The primary limitation of the current study was limited external validity due to the specific population examined. The current study only assessed young adults 18-25 years of age and future researchers should determine if similar results exist in ifferent age groups. This limitation is lessened because of the need for baseline data specific to young adults. A second limitation to external validity was the small sample size. Another limitation is a lack of injury history on the subjects included in the study.

In conclusion

The results of this study provide normative YBT composite scores for healthy young adult. The descriptive information provided may serve as a guide for clinicians working with young population for both screening and rehabilitation. Additionally, the current study provide insight into the low relationship between specific measures of muscle length tests of dynamic balance using the YBT and functional movement using the FMS. Future research is recommended to further refine and validate the FMSTM as a screening tool that can be used in different ages group healthy population and activity level.

Conflict of interest

No conflict of interest was reported.

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