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Effect of gender, leg dominancy and body mass index on Y-balance performance among young healthy adults

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ABSTRACT

This study investigated the influence of the sex, dominant leg and BMI on dynamic balance control of young adults (mean age; 20 ± 1.56) using the Y-balance test-lower quarter (YBT-LQ). This cross-sectional study included 218 participants (105 men and 103 women) who were recruited as a convenient sample of young, normal adults. The examination was implemented in one session, with three trials in each direction on each leg. The maximum reach distance of the three trials in each direction was used for statistical analysis. The reported reach distances were also normalized for each participant's leg length. Males' right leg values in the posteromedial (PM), posterolateral (PL), and composite directions were substantially longer than females' ($p<0.05$), and no significant difference between both sexes in anterior (AT) direction ($p>0.05$). In all directions, there were no significant differences between both sexes for the left leg ($p>0.05$), and no significant differences between the right values of the dominant and non-dominant legs ($p>0.05$). However, the left values of the non-dominant legs were longer than the dominant leg in directions ($p<0.05$). The right leg values of the AT, PM, and composite values of the average BMI subjects was greater than the over-weight and obese subjects ($p<0.05$), and the left leg values of the AT and composite values of the average BMI subjects was greater than over-weight and obese subjects ($p<0.05$). Males have a longer right leg reach distance in the PM, PL directions, and composite value compared to females. The right leg dominant participants have longer reach distance of the left leg in all directions. When compared to over-weight and obese participants, average body weight subjects have bilaterally larger reach distance in the AT and composite directions.

KEYWORDS

Body Balance; Body Mass Index; Dominant Side; Sex; Postural Control

1. INTRODUCTION

Dynamic balance refers to the capability to maintain postural stability and orientation with the center of pressure over the base of support while other body components are in motion (Wilson et al., 2018). In young adults, the ability to maintain a dynamic equilibrium is critical in their daily lives, and are significant to enhance their quality of life. It aids in day-to-day tasks (e.g. climbing stairs, walking or riding a bike), leisure activities and sports (Alshehre et al., 2021; Sikora et al., 2020). A lack of dynamic equilibrium is linked to an increased risk of injury. Thus, it is essential to categorize this population's dynamic balance capabilities in order to allow for interventions to prevent injuries (Wilson et al., 2018).

Fundamental tests of motor control, balance and power are now preferred over traditional flexibility and strength measures to prevent and predict musculoskeletal injuries. One of these tests is the Y-balance test-lower quarter (YBT-LQ), which is used to evaluate dynamic balance performance and predict injury risk. It was created to make the star excursion balance test (SEBT) more consistent which make it commercially available and more practical (Neves et al., 2017). It has not been very extensively researched and most assumptions regarding injury risk are extracted from the SEBT (Alshehre et al., 2021). The test involves the participant to stand in the unipedal stance while simultaneously stretching out in the anterior (AT), posteromedial (PM), and posterolateral (PL) directions, allowing unilateral strength, stability, and balance testing in multiple directions (Wilson et al., 2018).

The SEBT has been demonstrated to be reliable, valid, and responsive to dynamic neuromuscular control training (Gribble et al., 2012) and was used to evaluate the effectiveness of training programs for recreational athletes (Abdelraouf et al., 2020). As the SEBT does not use a standardized protocol for test administration, there are variations in administration and interpretation. Furthermore, because the SEBT has eight reach directions, a total of 112 reach excursions are required to pass the test (Coughlan et al., 2012; Plisky et al., 2021). Robinson & Gribble (2008) proposed that the SEBT's eight reach directions were redundant in populations with healthy and chronic ankle instability. To improve the administration and time efficiency of SEBT, the number of reach directions tested was reduced, resulting in modified SEBT, and the YBT-LQ was created based on the modified SEBT.

The modified (SEBT) and Y-balance test are simplified versions of the SEBT, both of which have demonstrated reliability and injury prediction capabilities (Jagger et al., 2020). Because the two tests use the same reach directions, including AT, PM, and PL, clinicians tend to use them interchangeably. However, studies have shown that performance scores on the YBT-LQ and modified SEBT are not equivalent, and thus the assessments should not be used interchangeably (Bulow et al., 2019a; Jagger et al., 2020). So, the YBT-LQ was chosen as a method of assessment of dynamic balance in young adults due to its feasibility, reliability and wide usage. Moreover, it mimics the functional activities of daily living (Alshehre et al., 2021; Bulow et al., 2019b; Gribble et al., 2012).

There are a few things that can be looked at to determine the likelihood of a lower extremity injury, such as maximal reach distance assessed in distinct reach orientations, a composite score generated, and side to side asymmetries in the anterior reach direction (Bulow et al., 2019b). The population's normative dynamic balance performance scores differ depending on age, dominant leg, body mass index (BMI), and physical activity (Alawna et al., 2019; Alnahdi et al., 2015). Moreover, the BMI should be considered during measurement of physiological parameters of healthy adults rather than body height or weight (Abdel-Aziem et al., 2007). As a result of the multidimensional aspects of the reaching tests, conflicting results have been reported when exploring the effect of anthropometric parameters, dominancy of the lower limb, muscular strength, sex, age, BMI on the reaching distances (Alnahdi et al., 2015; Gribble et al., 2012; Sikora et al., 2020; Teyhen et al., 2014).

The discrepancy in the results showed how intrinsic factors, lifestyle and cultures in different countries affect the postural control and dynamic balance of a population being tested on. The effect of leg dominance and sex on YBT-LQ in normal adults has been poorly studied. Furthermore, the best of our knowledge, the BMI categorization has not been studied yet. Accordingly, it is necessary to investigate the influence of these variables in order to offer trustworthy, valid, specific, and unbiased information on dynamic postural control. So, this study aims to investigate the influence of the sex, leg dominancy and BMI on dynamic balance control of young adults using the YBT-LQ test.

2. METHODS

2.1. Study Design and Participants

This cross-sectional study is based on a random sample of 208 young, normal adults (105 men and 103 women) between the ages of 18 and 25. They were recruited from the local community. They were excluded if they demonstrated any of the following; 1) surgery on the lower extremity or spine in the past, 2) visual or inner ear problems, 3) vestibular or other balance disorders, 4) lower extremity or spinal dysfunction. After being notified about the study procedures, benefits, and potential hazards, each participant was screened for a neurological examination (e.g., strength, sensation, and reflexes) which was performed by one investigator to determine their eligibility for the study. The participants signed a written informed consent and the study was conducted according to declaration of Helsinki and ethically approved by the ethical review committee of Faculty of Physical Therapy, XXXX University (P.T.REC/012/003198).

2.2. Procedure

The Y-balance test kit (Functional Movement Systems, Inc., Chatham, VA) was used to the dynamic balance. It consisted of a single central stance platform which is attached to three plastic tubes with three adjustable reach indicators located anteriorly, posteromedially, and posterolaterally (Figure 1). Each tube is labelled at one-centimetre (Cm) intervals (Plisky et al., 2009). The reach distances in three directions and the YBT composite score were the outcome measures of interest. According to Plisky et al. (Plisky et al., 2009) protocol the YBT-LQ test was conducted; The barefooted individuals began the YBT by performing 6 practice trials in each of the reach directions: right AT, left AT, right PM, left PM, right PL, left PL. The testing trials were conducted in the same sequence as the practice trials, with 3 trials in each direction.

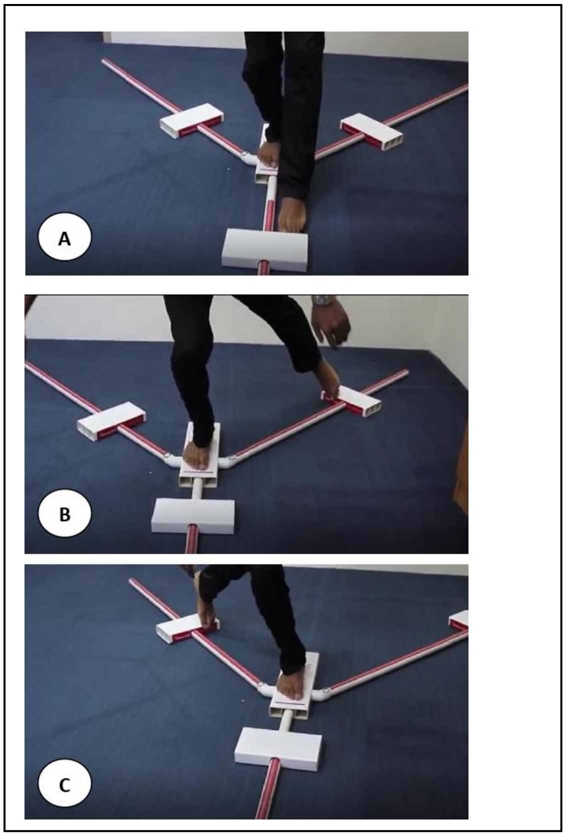

Figure 1. The A) anterior, B) posterolateral, and C) posteromedial directions of the Y-balance kit test

In each trial, the subjects were told to reach as far as they could can their reach foot while keeping it in contact with the reach indicator, then return to the beginning point while maintaining their balance on the stance leg. In each reach trial, the greatest reach distance was measured to the closest 0.5 Cm. For the analysis, the maximum reach distance of the three formal trials in each direction was analysed. To account for the influence of the leg length on test performance, reach distances recorded in Cm were additionally normalized to each participant’s leg length by dividing the reach distance by limb length and then multiplying by 100 (Kwon & Williams, 2017). Each participant's lower-limb length was measured using a tape measure from the anterior superior iliac spine to the most distal point of the medial malleolus while in the supine posture. The participants' dominant lower extremity was identified by their response to the question "which foot do you use to kick a ball with?"

If the participant did any of the following: 1) moved the stance leg's foot from the platform or crossed the marked line, 2) pushed, kicked, or stepped on the reach indicator, 3) touched the floor with the non-stance leg's foot, or 4) lost balance before returning the non-stance leg's foot to the starting position, the trial was discarded and repeated. To fatigue, the participants were given at least

10 seconds of rest between each trial and at least 30 seconds of rest between each reach direction (Kwon & Williams, 2017).

2.3. Statistical Analysis

Statistical Package for Social Sciences version 20.0 (Armonk, NY: IBM Corp.) was used to analyze the data. The Chi-square test was utilized to examine the frequencies of sex and leg dominancy. An independent t-test was used to compare age, weight, height, BMI, both leg length, and the different directions of YBT-LQ between sex groups, as well as to study the effect of leg dominancy on the different directions of YBT-LQ. Furthermore, the influence of BMI on the different orientations of YBT-LQ was investigated using analysis of variance (ANOVA). The significance level for all tests was set to 0.05.

3. RESULTS

One hundred and five males, and one hundred and three females included in the study. The males were significantly younger, had higher body weight, and were taller, and had longer right and left legs length than the females (p= 0.001). However, there was no significant between males and females regarding the BMI (Table 1).

Table 1. Characteristics of participants

Variables	**Male, *n*= 105** Mean ± SD	**Female, *n*= 103** Mean ± SD	***p***
Age, years	19.59 ± 1.57	20.41 ± 1.44	0.001*
Weight, kg	68.26 ± 12.09	57.95 ± 13.22	0.001*
Height, cm	171.86 ± 6.74	158.34 ± 6.11	0.001*
BMI, body weight/body height^2	23.15 ± 4.11	22.90 ± 5.00	0.702
Right leg length, cm	92.23 ± 4.36	85.14 ± 4.12	0.001*
Left leg length, cm	92.25 ± 4.39	85.12 ± 4.09	0.001*
Dominant/non-dominant	66/39	60/43	0.497

*Significant difference between males and females (p < 0.05), SD: standard deviation

3.1. Effect of sex

The normalized YBT-LQ right leg values of the males were significantly longer than females in the PM, PL directions, and composite value (p= 0.002, 0.047, 0.017, respectively), and no significant difference between both sexes in anterior direction (p= 0.717). For the normalized YBT-LQ left leg values, there were no significant difference between both sexes in AN, PM, PL directions and composite value (p= 0.940, 0.096, 0.078, 0.94 respectively), as shown in Table 2.

Table 2. The effect of sex on the normalized YBT-LQ values (%)

	Variables	Males, *n*= 105 Mean ± SD	Females, *n*= 103 Mean ± SD	*p*
Right leg	Anterior	75.94 ± 9.07	75.48 ± 9.23	0.717
	Posteromedial	111.65 ± 15.67	105.43 ± 12.25	0.002*
	Posterolateral	110.32 ± 15.84	106.10 ± 14.49	0.047*
	Composite	99.30 ± 11.84	95.59 ± 9.27	0.013*
Left leg	Anterior	75.44 ± 9.36	75.35 ± 8.58	0.940
	Posteromedial	113.03 ± 15.24	109.59 ± 14.56	0.096
	Posterolateral	108.58 ± 15.67	105.27 ± 10.87	0.078
	Composite	99.16 ± 12.05	96.66 ± 9.20	0.094

3.2. Effect of leg dominancy

Table 3 showed that there were no significant differences between the normalized YBT-LQ right values of the dominant and non-dominant legs in the AT, PM, PL directions, and composite value (p= 0.743, 0.763, 0.890, 0.950 respectively). However, the normalized YBT-LQ left values of the non-dominant legs were longer than the dominant leg in the AT, PM, PL directions, and composite value (p= 0.010, 0.018, 0.038, 0.008 respectively).

Table 3. The effect of leg dominancy on the YBT-LQ values (%)

Variables		Dominant, *n*= 126 Mean ± SD	Non-dominant, *n*= 82 Mean ± SD	*p*
Right leg	Anterior	75.54 ± 9.21	75.97 ± 9.07	0.743
	Posteromedial	108.81 ± 14.96	108.19 ± 13.54	0.763
	Posterolateral	108.35 ± 17.32	108.05 ± 11.61	0.890
	Composite	97.50 ± 11.64	97.40 ± 9.38	0.950
Left leg	Anterior	74.11 ± 8.91	77.37 ± 8.73	0.010*
	Posteromedial	109.34 ± 14.60	114.36 ± 15.11	0.018*
	Posterolateral	105.37 ± 14.19	109.35 ± 12.27	0.038*
	Composite	96.34 ± 11.22	100.36 ± 9.64	0.008*

3.3. Effect of BMI

Regarding the normalized YBT-LQ values of the right leg; the AT, PM and composite values of the average BMI subjects was greater than the over-weight and obese subjects (p= 0.004, 0.013, 0.024, 0.040, 0.012, 0.008 respectively), and no significant difference between over-weight and obese subjects (p= 0.793, 0.778, 0.516 respectively). For the PL values, there was no significant difference between the average BMI and over-weight subjects (p= 0.234), the value of the average BMI subjects was greater than obese subjects (p= 0.035) and no significant difference between over-weight and obese subjects (p= 0.301), as shown in Table 4.

For the normalized YBT-LQ values of the left leg; the AT and composite values of the average BMI subjects was greater than over-weight and obese subjects (p= 0.003, 0.001, 0.008, 0.001 respectively), and no significant difference between over-weight and obese subjects (p= 0.346, 0.283 respectively). For the PM, and PL values, there was no significant difference between the average BMI and over-weight subjects (p= 0.064, 0.068 respectively), the value of the average BMI subjects value was greater than obese subjects (p= 0.007, 0.033 respectively), and no significant difference between over-weight and obese subjects (p= 0.271, 0.519 respectively), as shown in Table 4.

Table 4. The effect of BMI on the normalized YBT-LQ values (%)

	Variables	**Normal, *n*= 153 Mean ± SD**	**Over-weight, *n*= 36 Mean ± SD**	**Obese, *n*= 19 Mean ± SD**	***p***
Right leg	Anterior	77.03 ± 8.91	72.26 ± 8.57	71.59 ± 9.51	0.002*
	Posteromedial	110.25 ± 14.16	104.43 ± 15.12	103.14 ± 12.27	0.017*
	Posterolateral	109.53 ± 16.28	106.17 ± 12.72	101.71 ± 8.47	0.073
	Composite	98.94 ± 10.86	94.01 ± 10.18	92.07 ± 8.06	0.003*
Left leg	Anterior	76.90 ± 8.40	72.02 ± 8.34	69.71 ± 10.77	0.001*
	Posteromedial	113.08 ± 15.23	108.01 ± 13.02	103.41 ± 13.21	0.010*
	Posterolateral	108.37 ± 13.72	103.81 ± 13.86	101.35 ± 9.39	0.032*
	Composite	99.58 ± 10.71	94.42 ± 10.22	91.23 ± 8.42	0.001*

4. DISCUSSION

The effects of sex, BMI, and dominance on dynamic postural control measures assessed by the YBT-LQ in normal young adults were studied in this study. The major findings were that across the various directions and values of the YBT-LQ, postural control measures differ significantly between limbs dominancy, sexes, and BMI.

The men in this study had higher normalized reach scores in the YBT-LQ test's right PM, right PL, and right composite scores. On the other hand, the results showed no significant differences between both sexes when the left side is the balanced foot except for the composite scores. Better performance for males compared to females while standing on the right side may be attributed to large percentage of male dominant side were the right side compared to females. The present results come in some agreement with a study by Alnahdi et al. (2015) which showed that males have greater normalized reach scores in all three directions of the YBT-LQ, as well as higher composite reach scores, than females. Also, the results were in line with a study conducted on military service members showed that the male average YBT-LQ values were higher than females (Teyhen et al., 2014). In contrast, another study found no significant sex differences in YBT-LQ reach distances (raw and normalized) for any direction, with the exception of the normalized AT direction of the

YBT-LQ, and the females showing superior achievement than males (Alawna et al., 2019; Fuscoa et al., 2020). The observed difference between males and females may possibly be attributed to issues not assessed in the present work, for instance the hip width, women's habit of wearing higher heels, lower limb strength, ankle mobility measurements and conjunction of trunk extension and ankle dorsiflexion (Kang et al., 2015; Neves et al., 2017; Overmoyer & Reiser, 2015).

Another study that contradicted the present results looked at the effect of sex on Y balance in 52 cross fit athletes (26 males and 26 females) aged from 18 to 70 years (Morrone & Spaccarotella, 2018). The results revealed no differences in reach directions between males and females; however, the female right composite score was significantly higher than males. This discrepancy may be attributed to the wider age range of this study compared to ours 18-25 years and the smaller sample size compared to ours (250 male and females), as well as the population investigated as the cross fit athlete uses core stability and strength programs compared to the population investigated in our study not participating in sports. In contrast to the current findings, Miller et al. (2017) investigated the effect of sex on anterior Y-balance performance in 295 high school athletes and found a consistent sex effect, with male having more anterior reach asymmetry and shorter anterior reach distance than women.

The participants in this study performed better when standing on their left leg than when standing on their right leg, In addition, the non-dominant leg performed better than the dominant leg in the AT, PM, and PL orientations, as well as in the composite value. This could be due to the nature of the task required. In contrast to this findings, the earlier studies demonstrated no differences between dominant and non-dominant side (Alnahdi et al., 2015; Nizamudheen & Ebrahim, 2020). Since the current study showed a difference in balance performance between the dominant and non-dominant sides, therefore, one side should not be considered without the other when measuring the balance performance. This contradicts the results of the recent review study of Schorderet et al. (2021) who concluded that no effect of dominant side on balance performance and when analyzing unilateral balance, both legs can be utilized as a reference. Their data were assigned into seven balancing test categories, no one of them was the YBT-LQ, which may be the cause of contradiction.

Furthermore, the current findings emphasized the importance of taking the preferred leg into account when assessing balance and stability, particularly in a normal population that does not participate in elite sports. Which is consistent with other studies who concluded that leg dominance is determined by the type of activity required. Most subjects will use their dominant leg when performing manipulative tasks like side walking and obstacle walking; however, when performing stabilization tasks like standing on one leg, squatting, and hopping on one leg, more than 60-70 percent of adults prefer the left leg regardless of which leg is dominant to complete the task in a comfortable manner (Bhise & Patil, 2016; Promsri et al., 2020).

In contrast to which was discovered, Stoddard et al. (2022) concluded that among 26 non-athletic teenagers, limb dominance does not appear to be a determinant in YBT-LQ performance (22 girls, and 4 boys). The difference between the findings of this study and the current results could be explained by wearing athletic shoes during the YBT-LQ and small sample size with significant difference in the numbers of boys and girls compared to the present study. Another source of disagreement has been the study's population, as training programs focusing on bilateral exercises during sport could explain why no significant differences in limb performance during YBT-LQ performance were found among athletes (Muehlbauer et al., 2019).

Body weight is suggested to be a strong predictor of postural balance maintenance among the numerous factors that could influence it, obesity has a strong association with decreased mobility, increased postural sway, and falls (Ganesan et al., 2018). To our knowledge, no research has looked at the impact of BMI classification on Y-balance performance in young normal people using normalized reaching values or composite scores. The current study discovered that the non-obese adults performed better in all right YBT-LQ reach values than overweight and obese healthy adults, with the exception of the right PL reach value, where both normal and overweight young adults performed better than obese participants. Also, the left AT and composite values of the Y-balance test were higher in normal subjects than in over-weight and obese subjects, while both normal and overweight participants performed better than obese adults in the left PM and PL values.

The results showed agreement with Swarnalatha et al. (2018) who found a positive link between BMI and dynamic postural control in the anterolateral, lateral, and PL directions of the star excursion balancing test, but a negative correlation in the other five directions. The results of the current study aligned with other literatures that found the greater BMI are strongly correlated with poor performance on Y- balance and SEBT (Alawna et al., 2019; Gribble et al., 2012; Hartleya et al., 2018). Furthermore, they found the BMI as a noteworthy indicator of lower extremity injury in addition the poor performance in the AT direction was considerably correlated to ankle sprain injury within different athletic population (Gribble et al., 2016; Hartleya et al., 2018). These variations in reach values may be accounted due to lack of equal number of participants distributed into three groups on the basis of their BMI.

This study finding disagreed with a study investigated the correlation between BMI and YBT-LQ performance in 149 normal collegiate students (100 males and 49 females), with age range 17-25, where the study showed no correlation of BMI and normalized reach values of the YBT for both limbs (Suvarna et al., 2021). This contradiction may be due to that the participants of the present study not were equally distributed between groups based on their BMI, in addition to another factors not assessed in our study and including core muscle strength and ROM and visual feedback (Hassan, 2017).

Although the sample recruited by Nascimento et al. (2017) was relatively small (10 normal-weight and 15 obese), their results were consistent with the present work. They evaluated the obese young adults' postural regulation under dynamic postural situations (walking speed and stability limits). They reported that most obese subjects had significantly higher mediolateral dynamic displacement, falling risk, and average time to achieve the limits of stability test, and timed up and go test than non-obese subjects, resulting in a longer time to complete daily activities and a higher risk of injury.

5. LIMITATIONS

This study was limited to participants from local without considerations of professional or recreational athletes, younger individuals or elderly. So, the external validity of the current findings is restricted. The physical activity level of the participants was not determined before commencement of the study, so this may affect the measured outcomes. A prospective study should discover the YBT-LQ values for populations at injury risk within each occupation specialty, sports, sex, and age. It is recommended to conduct a further study to examine the effect of the electromyography activities of the trunk and lower extremity muscles on different directions of the YBT-LQ.

6. CONCLUSIONS

This was the first study to offer sex, leg dominancy, and BMI reference values for the YBT-LQ in normal young people aged 18 to 25 years. When compared to females, males had a larger right leg reach distance in the PM, PL, and composite directions. The right leg dominant participants have longer reach distance of the left leg in all directions. In comparison to over-weight and obese people, average body weight subjects have bilaterally larger anterior and composite reach distance. So, these findings should be considered by coaches, and clinicians to discriminate between different levels of dynamic balance control.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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