ORIGINAL ARTICLE

Correlation between body mass index and body fat distribution with postural stability among female students in UiTM Puncak Alam

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Abstract:

Postural stability is an essential component to perform almost every activity in daily living and it may be affected by obesity. The main purposes of this study are to identify the correlation between body mass index (BMI) and body fat distribution with the postural stability and to compare the postural balance performance between the classifications of BMI, and between the types of body fat distributions. A total of 108 female physiotherapy students participated in this study. They were classified into underweight, ideal and overweight & obese groups according to their BMI and into gynoid, uniform, and android groups according to the waist-to-hip ratio (WHR). Postural stability was assessed with three trials of opened and closed eyes single leg stance test (SLST). There was significantly ($p< 0.05$) negative poor correlation between BMI ($r= -0.228$) and WHR ($r= -0.195$) with average score of SLST with vision. The overweight & obese group showed significantly poor postural balance performance with and without vision compare to the ideal group. Thus, being overweight or obese may impair the postural control ability, lead to diminishing in postural stability that may worsen if the individual also has an android type of body fat distributions.

Keywords: Body mass index, female young adult, postural balance, single-leg stance test, waist-to-hip ratio

1. INTRODUCTION

Postural stability is when the individual persisting their erect posture by maintaining their body's line of gravity (LOG) in their base of support (BOS). This is when the net force that acts on the body is equal to zero [1]. Intact postural control is the fundamental function to maintain good postural stability to prevent from fall and allowing to perform the activity daily living effectively. Postural control is any action to attain, preserve or restore balance in a position [1]. It arises from the interaction of external forces acting on the body and internally responds by generating movements as a postural reflex to maintain the postural stability that initiated by the afferent information released by visual, vestibular and somatosensory system [2-3].

Body mass index (BMI) and waist-to-hip ratio (WHR) are the common anthropometric calculation of adiposity [4] that complement each other. Even though BMI related to total body fat, it does not differentiate fat measurement from muscle or between different type of body fat distributions. Thus, other adiposity calculations need to be implemented, such as WHR. BMI is the method to classify the individual into underweight, ideal, overweight and obesity according to body mass and height. WHR distinguishing the different types of body fat distribution; android (fatty tissue is mainly accumulated around the trunk), uniform (fatty tissue distributed equally to upper and lower part of body) and gynoid (fatty tissues mainly accumulated at the area of hips, thighs, and bottom) [4-6].

The excessive amount of body fats may affect individuals postural control performance, lead to high risk of fall or related injuries [7-11] that probably due to their body size and shape will alter their body centre of mass (COM) position [12]. The stabilometry that most commonly used is a single leg stance test (SLST) as it can be used in a variety of settings and needs minimal tools or training.

In the aspect of healthy individuals, there is the limitation of data that focuses on the balance ability among the young population [13], causing difficulty to identify their postural control ability that associated to the factors that might impair the balance performance such as body height, weight and fat distribution. This insufficient knowledge also contributing a reduction of balance assessment and treatment application in clinical practices especially while dealing with the obese young adults. The previous study investigating the postural stability among obese young adult showed a reduction in their postural stability performance [14]. However, there some limitations of this study including small sample size; 12 obese individual and 12 non-obese people. Therefore, this current study was using a bigger sample size and only focus on the female young adult to increase the reliability of the result as the female and male may have different postural balance performance. Many researchers agreed that females tend to have greater postural instability than male [6, 15, 16]. Therefore, obesity problems in the female population may worsen their balance ability.

Hence, the objectives of this study are to determine the postural stability performance of female young adult, to identify the correlation between BMI and body fat distribution with postural stability, also, to compare the postural stability between the classifications of BMI and between body fat distributions types.

2. MATERIALS AND METHODS

2.1 Study design and participants

This cross-sectional study was conducted from March 2018 to May 2019 in UiTM Puncak Alam on a total of 108 female physiotherapy degree students, age range 19 -26 years, recruited using a convenience sampling method. The participants were excluded if they had known the history of balance impairment (for any reason); had orthopaedic lower extremity or lumbosacral conditions requiring consultation with a healthcare professional; feel pain, numeric rating scale (NRS) score more than 3/10 presenting at both or unilateral lower limb; were pregnant or feeling unwell during the assessment. The following criteria referred to the previous study by [18], to identify the normative values for single leg stance test in opened and closed eye condition across age groups and gender. This study was approved by the Research Ethical Committee of Universiti Teknologi MARA (UiTM).

2.2 Measurements

All the subject was given a booklet that consists of the subject's information sheet, the consent form that needs to be filled and signed before participation, and data collection form. The BMI was calculated by dividing the body weight (kg) with height (m^2) and recorded to the nearest 2 decimals point. To compare the postural balance performance between the BMI classification groups, the participants were classified into the underweight group (<18.50 kgm^{-2}), ideal group (18.50 to 24.99 kgm^{-2}), and overweight and & obese group (≥25.00 kgm^{-2}). The hip circumference was measured around the widest part of the buttocks while the waist circumference was measured at the midpoint between the lower edge of the costal arch and the top of the iliac crest. The ratio calculated by dividing waist measurement (cm) with hip measurement (cm) (W ÷ H) and were recorded to the nearest 2 decimals point.

To compare the body fat distribution and postural stability, the participants were separated into three different groups according to their WHR; gynoid group (WHR ≤ 0.76), uniform group (WHR from 0.77 to 0.86), and android group (WHR > 0.86).

Postural stability was assessed with three trials of opened and closed eyes single leg balance test (SLST) using dominant leg, alternately between opened and closed eye condition until the participant had done 3 times SLST in opened eye condition and 3 times SLST in the closed condition The participants' dominant leg was determined by asking the participants to kick a ball placed on the floor in front of them, and the kicking leg will be considered as the dominant leg [17]. During the SLST, the subjects were asked to stand barefoot on a firm surface using their ‘dominant leg' while the other leg raised until it near but not touching the ankle of the stance limb. Before raising the non-dominant leg, the subject asked to cross their arms over chest. During open eyes condition, the participant had to focus on a spot at eye level. The time taken for the ability of stable single-leg stance was taken using a digital stopwatch and recorded in a unit of seconds (s) to the nearest 2 decimal points. Time starts when the subject raises their foot off the floor and stop when subject start to either use their arm, raised foot or stance foot to maintain their balance such as an uncrossed arm, moved the raised foot toward or away from the standing limb or touched the floor, the standing foot rotates on the ground until it creates a new base of support. Also, the time will stop if a maximum of 45 seconds had elapsed or opened eyes during eyes-closed trials. Rest at least 3 minutes were provided to prevent fatigue. The best and average result was recorded on the data collection sheet. The scores then had been classified into ‘normal' or ‘abnormal' that means poor balance performance. For individuals who in age between 18 to 39-year-old, their normal range scores for the opened and closed eyes condition are 43.5 to 45.1 seconds and 8.5 to 13.1 seconds respectively [18].

2.3 Statistical analysis

The data were analyzed using IBM Statistical Package for Social Sciences, version 21.0. The Kolmogorov-Smirnov test was used to verify the variables normality. The descriptive analyses were used to calculate the mean and standard deviation of all the variables. The correlation between the variables was determined using the Pearson correlation test and Spearman’s rank-order correlation test. The Kruskal-Wallis and one-way ANOVA test were used to determine the difference of continuous variables between the groups. Statistical significance was accepted for $p<0.05$.

3. RESULTS AND DISCUSSION

3.1 Participants demographic data

The descriptive analysis of the studied samples' anthropometric characteristics was presented in Table 1. Each group of WHR have the participants from all the BMI groups is shown in Table 2.

To further understand the participants' anthropometric characteristics, each group of BMI were analyzed using correlation test and descriptive analysis according to the WHR groups. As expected, the higher the BMI the higher the WHR. There was a significant (p< 0.001), positive fair correlation (r= 0.330) between the BMI and WHR.

Table 1: Descriptive analysis of the anthropometric characteristic of all the participants

	Sample (n= 108)		
Variable	Mean (SD)	Median (IQR)	n (%)
Age (years)	21.42 (1.45)		
Weight (kg)		55.00 (17.80)	
Height (m)	1.58 (0.06)		
BMI (kg/m^2)		21.98 (6.73)	
Underweight			19 (17.6%)
Ideal			59 (54.6%)
Overweight & Obese			30 (27.8%)
Hip circumference (cm)		95.78 (14.59)	
Waist circumference (cm)		76.53 (16.69)	
WHR		0.80 (0.10)	
Gynoid			31 (28.7%)
Uniform			58 (53.7%)
Android			19 (17.6%)

Note: BMI, body mass index; WHR, waist-to-hip ratio.

Table 2: Analysis of the BMI groups according to the WHR groups

Variables	Gynoid n (%)	Uniform n (%)	Android n (%)
Underweight	6 (19.4)	11 (19.0)	2 (10.5)
Ideal	21 (67.7)	33 (56.9)	5 (26.3)
Overweight & obese	4 (12.9)	14 (24.1)	12 (63.2)
Total	31 (100.0)	58 (100.0)	19 (100.0)

Data are expressed as frequency (%) of the participants in WHR groups according to their BMI.

3.2 The participants' postural balance performance

The analysis of the opened and closed eyes SLST score for all the studied samples is summarized in Table 3. Overall, all the participants' balance performances were better during the opened eyes SLST compares to closed eyes condition. This may due to most of the participants used their visual functions to control their postural balance. The previous study by [15] to identify the predominant sensory systems (visual, vestibular, and somatosensory) that use by young adults to maintain their postural stability, believed that visual sense is the main sensory system use to control postural stability.

Besides, the total students who show normal balance performance are lesser than students who had poor balance performance. This possibly due to balance ability in a young adult is still under the phase which it continues to be refined. Thus, the training to improve this ability is very helpful to gain better balance performance [19]. This may contribute to allowing several factors such as the physical activity status, body anthropometry, body fitness level, the visual health status and more, to affect their postural balance performance. This result also justifies that the balance assessment and intervention should be considered not just for elderly patients but also for young patients in the clinical setting.

Table 3: Single leg stance test (SLST) descriptive analysis for all the participants

		Sample (n= 108)		
Trial	Variable	Mean (SD)	Median (IQR)	Frequency (%)
Opened eye	Best score (s)		45 (0.07)	
	Normal			83 (76.9%)
	Abnormal			25 (23.1%)
	Average score (s)	35.33 (11.03)		
	Normal			47 (43.5%)
	Abnormal			61 (56.5%)
Closed eye	Best score (s)		7.91 (8.75)	
	Normal			52 (48.1%)
	Abnormal			56 (51.9%)
	Average score (s)		5.05 (6.36)	
	Normal			31 (28.7%)
	Abnormal			77 (71.3%)

3.3 The correlation and the effect of BMI to postural stability performance

The correlation of BMI with the SLST performance was analyzed in Table 4. In opened eyes SLST condition, there were significant (p< 0.05), negative poor correlation between BMI (r= -0.228) and the average score of the balance performance. However, for the correlation of the BMI with the other variables of SLST except for the average score of opened eyes SLST, showed no statistically significant (p>0.05) with negative poor correlation.

Table 4: Correlation analysis between BMI and WHR with the SLST performance

		BMI		WHR	
Trial	Variables	r value	p-value	r value	p-value
Opened eyes	Best score	-0.106^b	0.277	-0.173^a	0.073
	Average score	-0.228^a	0.017*	-0.195^a	0.043*
Closed eyes	Best score	-0.135^b	0.163	-0.092^b	0.343
	Average score	-0.153^b	0.113	-0.081^b	0.406

^{a} Pearson correlation
^{b} Spearman rank correlation
*statistically significant (p< 0.05)

The median values for the postural balance variables analyzed in BMI groups were presented in Table 5. There were significant results presented between the BMI groups when analyzing the best and average scores of SLST in closed eyes condition. To further identify which pair of groups had significantly different, three Mann-Whitney tests were used and showed, there are significantly poor single leg stance test (SLST) performance in closed eyes condition for both best (5.74; P = 0.009) and average score (3.45; P = 0.010) were observed in the overweight & obese group when compared with the ideal group.

Table 5: SLST analysis for best score in opened eyes condition and the best and average score in closed eyes condition according to BMI groups

Variables	Underweight	Ideal	Overweight & obese	P-value
Opened eyes				
Best score (s)	45.00 (2.35)[a]	45.00 (0.00)[a]	45.00 (12.02)[a]	0.050
Average score (s)	37.49 (10.6)[b]	37.17 (10.26)[b]	30.34 (11.66)[b]	0.013*
Closed eyes				
Best score (s)	9.66 (9.00)[a]	10.45 (10.37)[a]	5.74 (7.68)[a]	0.031*
Average score (s)	6.07 (7.42)[a]	5.50 (6.73)[a]	3.45 (3.16)[a]	0.033*

[a]Value are expressed as median (IQR), as the p-value were analyzed using the Kruskal-Wallis test.
[b]Values are expressed as mean (SD), as the p-value were analyzed using the one-way ANOVA test.
*Significant difference ($p < 0.05$).

One-way ANOVA test was used to analyze the comparison between BMI average score for SLST in opened eyes condition (Table 3.3(b)). The result showed at least one pair among the BMI groups were significantly different. Subsequent post-hoc analysis (Scheffe procedure) suggest that the mean average score for opened eyes SLST are significantly different between the ideal group and overweight & obese groups, which there was significantly better average score of opened eyes SLST in an ideal group compare to overweight & obese group.

Holistically, from the analysed data between BMI and SLST, overweight and obesity may give a negative effect to postural stability. Several factors can be highlighted to this balance impairment. Obesity may alter an individual's body posture. Most of the obese individuals tend to have postural alteration such as a head protrusion, hyper-kyphosis and hyper-lordosis due to the increase in anterior pelvic tilt angle [14, 20]. These changes of body posture will modify the position of the COG to a more forward position, increase the AP instability, caused the obese individuals to require implementing a larger corrective ankle reaction to maintain in the stable state. Larger ankle reaction requires a greater muscle force to be generated. However, they may have some reduction of the muscular force production to control the displacement of the COG, which will worsen the reduction of their postural control ability [21].

Besides, the intact function of mechanoreceptor of the foot sole or plantar also important to get a good balance performance. There was a significant poor to the moderate negative correlation between postural sway and plantar sensitivity [22]. This indicates that the reduction in plantar sensitivity caused an increase in postural instability. The obese individual may have a larger plantar contact area and pressure, compare to the non-obese individual [9]. This result in reductions of quality and/or quantity of the sensory information produce from the plantar mechanoreceptor, cause the normal reaction to counter the balance perturbation also reduce or insufficient to control the postural stability [14].

Therefore, this study also suggests that the weight loss intervention in overweight and obese individuals may help to improve their postural stability, thus reducing the risk of injury caused by falling. Also, it was believed that weight loss able to improve the obese men postural stability, which the improvement will directly base on the amount of weight loss [11].

However, there are a few previous studies that contradict the findings of this present study. Findings by Nascimento et al. (2017) [20] denied that BMI compromising the young adult postural balance. Also, the increase in BMI is associated with better postural stability [23]. Obesity also might not impair the postural balance ability in the erect posture and increase in body weight may create new biomechanical constraints, result in the reduction of postural sway [12].

This discrepancy might due to the different method used in the study produce a different result [24]. One of those studies uses force-plate posturography to identify their postural balance performance. Although this method is commonly used in studies to measure the postural sway, the increase in postural sway is not commonly a certain proof to indicate postural instability [12].

Although the underweight group showed no significant difference neither with ideal group nor overweight & obese group, they demonstrated better average postural balance performance in both opened and closed eyes, compare to ideal and overweight & obese group. This finding was partially consistent with the other study Ku et al. (2012) [6], which their primary findings revealed that individual with underweight showed better balance performance in unilateral leg stance and bilateral leg stance.

3.4 The correlation and the effect of WHR to postural stability performance

There were no statistically significant ($p>0.05$) negative poor correlation between WHR with all the SLST variables except with the average score of opened eye SLST (Table 4). There was significant ($p< 0.05$), negative poor correlation between WHR ($r= -0.195$) and the average score of the balance performance. These findings were partially agreed by Alonso et al. (2012) [25] who stated that there was poor to fair positive correlation between WHR and ML direction of body sway in both opened and closed eyes conditions, which indicates the higher the WHR the poor the postural balance performance during with or without vision.

No statistically significant differences found in all the variables of SLST among the WHR groups (Table 6). Although it was not significant, it still gives warrant attention to the android group who showed the worse SLST performance with or without vision. Meanwhile, the uniform group showed the best performance in opened and closed eye SLST. Previous studies agreed that the abnormal distribution of body fat, particularly in the chest and abdominal area or android type of WHR was associated with a higher risk of fall [4, 26]. The excessive accumulation of body fat tissues will alter the body geometry by adding passive mass to different body regions, and this probably affects the individual biomechanics of activities daily living, which possibly predisposing to injury from falling [27]. In this present study, the poor balance performance of android groups probably due to android body shape involves a greater amount of load over the hips, resulting in the increase in ML instability [4, 28-30], that makes them more harder to maintain stable in limited base of support.

Table 6: SLST analysis for opened and closed eyes average scores and best score in opened eye condition according to WHR groups

Variables	Gynoid	Uniform	Android	P-value
Opened eye				
Best score (s)[b]	45.00 (7.06)	45.00 (0.00)	45.00 (8.78)	0.064
Average score (s)[a]	33.60 (11.00)	37.04 (10.47)	32.92 (12.40)	0.218
Closed eye				
Best score (s)[b]	8.16 (13.98)	8.63 (7.91)	6.69 (11.42)	0.535
Average score (s)[b]	4.61 (6.30)	5.31 (6.47)	4.23 (5.61)	0.656

[a] One-way ANOVA. Data are expressed as mean (SD).
[b] Kruskal-Wallis test. Data are expressed as the median (IQR).

Although the result of this present study did not achieve the significance level, the worst performance of android group can give a warrant that those individual require the intervention to improve their postural balance and reduce their body fat that especially to get back normal WHR. The earlier awareness of this impairment may improve their balance performance during older age. As the women grow older, there is an increase in transformation from gynoid to android body type especially during the postmenopausal period due to the oestrogen deficiency is associated with the increase in visceral fat that accumulates on upper portion of abdomen instead of on hips, like normally body type of premenopausal women [4, 29]. Thus, the earlier balance training may prevent or decelerate the deterioration of balance performance in later life.

The non-exist of correlation between WHR and closed eyes postural stability shows visual sensory as the vital sensory systems that regulating the postural stability [15] used by the young adults regardless of their type of body fat distribution. This result corroborates the finding from the previous study of 40 obese women which the balance ability was tested using force platform, and their finding showed no correlation of WHR with all the balance parameter used [31]. The absent of visual cue possibly indicates that other factors were affecting the participants, causing the non-linear data.

There are several possible uncontrolled factors in this study that may affect the significance of this study result such as level of physical activity or musculoskeletal fitness. Lower extremity strength is a strong variable that can influence the body movement and postural balance [7]. Also, the higher the individual physical activity level, the better postural balance [32]. Also, balance is the ability that trainable [33], therefore the subject who is an athlete may possess better balance performance compare to the non-athlete subject, through their daily sports training. Besides, the type of the participant's foot arch also can affect their postural stability, which cavus feet or high arched feet show significantly larger deviation of COP compare to rectus feet (normal feet) during single-leg balance test on a force platform [34]. Besides, bad eyesight also common among university students. As mentioned before, the visual system is a predominant sensory system for the young adult to maintain their postural balance. Any impairment in this system probably will affect the balance ability [15]. Therefore, by more specifying the participants' characteristics according to the other factors that can affect the postural balance may improve the significance of the result.

4. CONCLUSION

Ability to control postural stability is a fundamental prerequisite in daily life. Our results revealed that there is a negative poor correlation between BMI and WHR with opened eyes SLST average score, which indicates that postural stability with vision was diminished as the individual’s BMI or WHR value increased. Besides, being overweight and obese may impair the individual postural stability with or without vision. Even though the result is not significant, the android body shape participants demonstrated the worst postural control with or without vision. Majority of the participants who have android body shape will also have overweight or obese BMI. Thus, being overweight or obese as well as has android body shape probably more worsen the postural control impairment as overweight and obese will compromise the plantar mechanoreceptor function to regulate the body sway and modify the position of COG that will increase in AP instability, also there might be an increase in ML instability that caused by the accumulation of body fat particularly in abdominal and chest region.

ACKNOWLEDGEMENTS

Gratitude was extended to Dr. Siti Nor Ismalina Isa for her guidance and advice in analyzing the data obtained.

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