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RESEARCH ARTICLE

THE EFFECT OF DIFFERENT BODY MASS INDEX LEVELS ON STATIC AND DYNAMIC POSTURAL BALANCE PERFORMANCE IN ADULTS

Eren Timurtaş[1], Halit Selçuk[1], Ekin Uğur Canöz[2], Onur Salman Kortelli[3], İlkşan Demirbüken[1], Mine Gülden Polat[1]

[1] Marmara Unversity, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, İstanbul, Turkey
[2] Fenerbahçe Unversity, Vocational School of Health Services, Department of Physiotherapy, İstanbul, Turkey
[3] Beykent Unversity, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, İstanbul, Turkey

ORCID: E.T. 0000-0001-9033-4327; H.S. 0000-0003-2760-4130; E.U.C. 0000-0002-6061-4958; O.S.K. 0000-0003-3754-1065; İ.D. 0000-0003-0566-5784; M.G.P. 0000-0002-9705-9740

Corresponding author: Eren Timurtaş, **E-mail:** fzteren@gmail.com

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ABSTRACT

Purpose: It was aimed to estimate the static and dynamic postural balance performance in adults with different Body Mass Index (BMI) levels.
Material and Methods: The study was conducted in Üsküdar Diabetes and Obesity Treatment Center between September and October 2021. Participants were divided into 5 groups according to BMI scores: normal-weight, overweight, 1st degree obese, 2nd degree obese, and 3rd degree obese. In addition, participants' static and dynamic balance performance were assessed by the Limits of Stability (LOS) and modified Clinical Test of Sensory Integration of Balance (m-CTSIB) tests.
Results: For LOS parameters, there was a significant difference between groups in reaction time scores only for the backward direction ($p<0.05$). The endpoint and maximum excursion measurements except for the backward and directional control measurements except for the back and right were significantly different between groups, with the worst scores for 3rd degree obese group ($p<0.05$). For the m-CTSIB test, there was a significant difference between groups in all parameters except the eyes open condition on foam surface ($p<0.05$).
Conclusion: The 3rd degree obese individuals are the most affected subgroup in dynamic balance. We recommended that rehabilitation and fall prevention programs primarily focus on 3rd degree obese individuals.

Keywords: Limits of stability test, modified clinical test of sensory integration of balance, postural balance, body mass index

INTRODUCTION

Body mass index (BMI) is a frequently used measure of anthropometric characteristics, and increased BMI values, especially in individuals with obesity, have been associated with increased risk of morbidity and mortality (1,2). Obese people experience a higher chance of functional problems and an overall increase in mortality (3). The most common functional problems of balance problems due to biomechanical changes caused by obesity (4). The balance problems could cause limitations in participation in activities of daily living in obese individuals (5), and available studies have tried to define how increased body weight interferes with normal balance function through various clinical and computerized balance tests (4-9).

Any act of maintaining, achieving, or restoring balance in any static or dynamic posture is referred to as postural stability (10). It has been claimed that postural balance may be affected in obese individuals due to the anterior displacement of the body's center of gravity (11). According to another view, it is stated that excessive weight causes problems in the sensory receptors on the sole and balance problems arise due to the deterioration of sensory input (8). Postural balance is the ability to reach and maintain any activity or posture while maintaining balance (10). Static balance is the ability to maintain a support base with minimal movement, while dynamic balance reflects the ability to perform a task while maintaining or regaining a stable position (12).

Even though many studies focus on the relationship between obesity and balance, studies comparing the postural balance performances of individuals in different body mass index groups are lacking in the literature. For these reasons, objective, quantitative and multidimensional evaluation and comparison of balance in adults with different body mass index levels become important. This study aimed to estimate the static and dynamic postural balance performance in adults with different BMI levels.

MATERIAL AND METHODS

Study Design

Ethical approval for this study was obtained from the Ethics Committee of Marmara University School of Medicine (Date: 03/09/2021, decision no: 1039). The present study was conducted under the Helsinki Declaration of Good Clinical Practice.

This was a cross-sectional analysis of data obtained from the participants with different ranges of BMI levels. The participants were recruited from the healthy and obese individuals consulted in Üsküdar Diabetes and Obesity Treatment Center between September 15, 2021, and October 15, 2021**.**

Participants

Participants aged 40 and over who could consent and understand the instructions were recruited for this study. Participants with any orthopedic, neurological, respiratory, or rheumatological disease that could impact balance, diagnosed with diabetes, pregnant women, and BMI <= 18.5 (underweight) were excluded from the study.

Methods

BMI of the participants were calculated by using the formula weight measured in kilograms divided by the square of height measured in meters (13). A weighing scale was used to measure weight, and a tape mounted on a wall was used to record height. Participants were divided into 5 groups according to their BMI values such as healthy (BMI between 18.5-25 kg/m2), overweight (BMI between 25,0- 29,9 kg/m2), 1st degree obese (BMI, between 30,0- 4.9 kg/m2), 2nd degree obese (BMI, between 35,0- 39,9 kg/m2) and 3rd degree obese (BMI ≥ 40kg/m2) groups (13).

Outcome Measures

Although various methods are used for the evaluation of static and dynamic balance, it is stated that a multidimensional evaluation provides an optimal reflection of the true balance construct. Several clinical and computerized balance tests are available for evaluating balance (6). NeuroCom Balance Master System (BMS) is such computerized system that allows measuring postural balance and can provide an objective, quantitative balance assessment (9).

The BMS device was used to assess the balance performance of participants by the limits of stability test (LOS) and modified clinical test of sensory integration of balance test (m-CTSIB) tests. The BMS device has two 22.89 cm x 45.72 cm footplates connected by a pin. The device consists of dual force plates and a movable monitor.

Limits of stability test: Measured parameters were reaction time, endpoint excursion, maximum excursion, and directional control. In the trial, participants were asked to stand on the force platform, follow the target on the screen, and move the cursor of the center of gravity of the body according to the point on the screen, without foot movements. The 4 movement directions in the LOS were used in this study; are forward, backward, right, and left. The participant adjusted the body's center of gravity cursor according to the directions where the point is located.

Reaction time (RT) scores are a measure of how quickly a participant was able to reach the target on the screen. Delay in RT may indicate a central nervous system involvement such as sensory-

Table 1. Descriptive characteristics of participants

Parameters	Sub-parameters	Healthy (n= 23)	Overweight (n= 37)	1st degree obese (n= 21)	2nd degree obese (n= 26)	3rd degree obese (n= 28)	All participants (n= 135)	p
Age, Mean±SD		48.1± 6.7	51.3± 9.4	51.9± 8.1	51.8± 8.8	50.6± 8.2	50.8± 8.4	0.367
BMI, Mean±SD		23.0±1.1	28.0± 1.3	32.1± 1.2	36.8± 1.8	43.7± 3.0	32.7± 7.3	<0.001
Sex, n (%)	Female	11 (47.8%)	18 (48.6%)	11 (52.4%)	16 (61.5%)	28 (100%)	84 (62.2%)	<0.001

BMI: Body mass index; SD: Standard deviation.

perceptual or motor planning deficits. The movement accuracy is defined as the endpoint excursion, which is the ability to reach the target on the first initial attempt and the maximum excursion, which is the furthest distance travelled by the center of gravity when reaching the target. The endpoint excursion indicates the accuracy of the pre-planned initial movement attempt. In contrast, the maximum excursion indicates the “true” physical limitation (due to joint contracture, weakness, etc.) or the “perceived” limitation (due to inexperience, fear, or perceptual difficulty). Directional control indicates whether or not progress toward the target was smooth and consistent and reflects the individual’s movement coordination. Central nervous system disorders such as ballismus or cerebellar ataxia may cause poor directional control.

A modified clinical test of sensory integration of balance test: m-CTSIB is a balance test in which the participant is evaluated on a firm (stable) and foam (unstable) floor in different conditions with eyes open and closed. The original CTSIB has been modified with the addition of measurement of postural sway velocity in four test positions and computerized analysis of functional balance control. In the m-CTSIB, participants were asked to stand on the force plate and maintain a standing position with their eyes open for 10 seconds and then their eyes closed for 10 seconds. The amount of postural sway and the patient's movement strategy were quantitatively evaluated in terms of (degrees/second). This assessment aims to identify abnormalities in the somatosensory, visual, and vestibular system contributions to postural control. All three sensory systems are accurate and available in eyes open-firm surface conditions. The contribution of each system to postural control is determined by changing the test conditions (i.e. eliminating visual information by closing the eyes or interfering with somatosensory information by using foam surface).

Statistical Analysis

Using the G Power 3.1 program, the sample size of this study was calculated to be 130 participants with an effect size of 0.31, 5% type I error, 80% power, and 95% confidence intervals (14). The data were evaluated using the SPSS 20.0 (Statistical Package for the Social Sciences) statistical software (15). Descriptive statistics (frequency, mean and standard deviation) were used to characterize the population. Shapiro- Wilk's test was used to assess the distribution of the data. Levene tests were performed to assess normality and homoscedasticity, respectively. Our data were found to be normally distributed, and thus a parametric test was used for the statistical analysis. Demographic characteristics of the groups were presented using their descriptive statistics, and comparisons of groups were conducted with one-way ANOVA for continuous variables. Multiple comparisons of score differences in LOS and m-CTSIB tests were carried out using Post Hoc Test. The results of all analyses were regarded as significant at a p-value of less than 0.05, using Tukey HSD equality at an alpha level of 0.05. Eta-square was used for measuring effect sizes. Changes in variable scores within groups were expressed as the means (95% confidence interval).

RESULTS

A total of 135 participants included in the study, of which 84 (62%) were women. The average age was 50.8±8.4 years, and there was no significant difference between groups in terms of age (p=0.367). Participants were divided into 5 groups according to BMI levels. And the average BMI was 32.7±7.3. The descriptive characteristics of the participants are shown in Table 1.

Table 2. Intergroup comparison of Limits of Stability parameters between five groups

Limits of Stability Assessment	**Directions**	**Groups**					**ANOVA (p)**	**Effect Size**
		Healthy	Overweight	1st degree obese	2nd degree obese	3rd degree obese		
		Mean (SD)						
Reaction Time	Forward	1.4 (0.2)	1.1 (0.5)	1.0 (0.6)	1.2 (0.4)	1.2 (0.6)	0.188	0.046**
	Backward	0.6 (0.2)	1.1 (0.4)	0.9 (0.6)	1.2 (0.6)	1.0 (0.5)	**0.002***	0.125***
	Right	1.34 (0.71)	1.5 (0.6)	1.4 (0.7)	1.7 (0.8)	1.6 (0.6)	0.443	0.028**
	Left	0.92 (0.34)	1.1 (0.5)	1.0 (0.5)	1.2 (0.6)	1.2 (0.7)	0.462	0.027**
	Complete	1.14 (0.35)	1.2 (0.4)	1.1 (0.5)	1.3 (0.5)	1.2 (0.5)	0.582	0.022**
Endpoint Excursions	Forward	63.6 (17.5)	59.8 (17.8)	60.8 (19.0)	54.8 (20.4)	49.1 (13.4)	**0.030***	0.079***
	Backward	65.9 (7.1)	59.8 (19.8)	58.5 (17.7)	58.5 (14.7)	51.7 (22.4)	0.085	0.061**
	Right	83.6 (12.9)	83.2 (17.2)	82.1 (19.6)	75.2 (14.2)	70.9 (22.1)	**0.025***	0.082***
	Left	94.7 (13.6)	88.6 (15.1)	89.1 (21.4)	90.9 (13.7)	77.9 (22.6)	**0.011***	0.095***
	Complete	83.9 (15.3)	73.9 (8.6)	74.1 (14.9)	68.2 (11.9)	62.8 (16.0)	**0.000***	0.218****
Maximum Excursions	Forward	81.2 (17.9)	75.4 (18.5)	80.0 (17.3)	66.7 (19.4)	66.1 (18.3)	**0.006***	0.104***
	Backward	81.7 (9.4)	74.0 (15.5)	70.2 (21.3)	75.1 (13.2)	66.9 (26.0)	0.059	0.067***
	Right	102.8 (8.4)	98.2 (13.0)	92.1 (18.2)	85.6 (16.1)	86.6 (14.7)	**0.000***	0.179****
	Left	110.5 (7.0)	100.8 (8.0)	101.6 (17.4)	103.7 (11.4)	93.1 (17.8)	**0.000***	0.159****
	Complete	89.7 (11.0)	87.3 (6.3)	86. 8 (15.1)	79.8 (14.6)	78.1 (14.2)	**0.001***	0.127***
Directional Control	Forward	82.0 (7.8)	78.3 (11.3)	77.8 (16.1)	70.0 (20.5)	74.2 (11.3)	**0.033***	0.077***
	Backward	68.5 (16.0)	70.3 (14.2)	67.4 (16.5)	70.0 (13.4)	59.5 (22.8)	0.099	0.058**
	Right	81.0 (6.8)	78.4 (10.3)	74.6 (14.6)	75.4 (16.4)	71.9 (10.9)	0.071	0.064***
	Left	82.2 (6.2)	80.2 (8.5)	78.2 (7.0)	75.3 (9.6)	70.2 (10.9)	**0.000***	0.195****
	Complete	79.2 (7.1)	78.4 (6.8)	78.8 (10.6)	73.0 (12.1)	69.0 (11.7)	**0.001***	0.136***

p: one-way ANOVA test, * It refers the significance level of 0.05; SD: Standard deviation; ** It refers to a small effect size; *** It refers to a medium effect size; **** It refers to a large effect size

Table 2 represents the scores in the LOS test, indicated that the significant and insignificant mean differences between groups. For reaction time measurement, there was a significant difference between groups only for the backward direction ($p<0.05$). For endpoint excursions measurement, likewise maximum excursions measurement, there was a significant difference between groups except only for the backward direction ($p<0.05$). Lastly, there was a significant difference between groups in all directions except for the backward and right directions of the directional control assessment ($p<0.05$).

Table 3 illustrates the scores in the m-CTSIB test showed significant and insignificant mean differences between groups. For firm surface measurements, there was a significant difference between groups in both eyes open and eyes closed conditions ($p<0.05$). On the other hand, the foam surface measurements with eyes closed condition showed a significant difference between groups ($p<0.05$), while in open eyes conditions did not ($p>0.05$). Lastly, a complete

Table 3. Intergroup comparison of m-CTSIB parameters between five groups

m-CTSIB		Groups					ANOVA (P)	Effect Size
		Healthy	Overweight	1st degree obese	2nd degree obese	3rd degree obese		
		Mean (SD)						
Firm surface	Eyes open	0.6 (0.6)	0.4 (0.1)	0.3 (0.1)	0.4 (0.1)	0.4 (0.1)	**0.005***	0.106***
	Eyes closed	0.4 (0.1)	0.4 (0.2)	0.4 (0.1)	0.4 (0.1)	0.5 (0.2)	**0.001***	0.126***
Foam surface	Eyes open	0.7 (0.1)	0.7 (0.1)	0.7 (0.1)	0.7 (0.2)	0.7 (0.2)	0.322	0.035**
	Eyes closed	1.5 (0.3)	1.2 (0.3)	1.1 90.3)	1.2 (0.3)	1.3 (0.5)	**0.012***	0.093***
Complete		0.8 (0.2)	0.7 (0.1)	0.6 (0.1)	0.7 (0.1)	0.7 (0.2)	**0.042***	0.073***

p: one-way ANOVA test; * It refers the significance level of 0.05; SD: Standard deviation; m-CTSIB: modified Clinical Test of Sensory Integration of Balance; ** It refers to a small effect size; *** It refers to a medium effect size

assessment for m-CTSIB has shown a significant difference between groups (p<0.05).

Table 4 shows LOS test pairwise comparisons in healthy, overweight, and obese (1st, 2nd, 3rd degrees) groups, indicating that 15 multiple comparisons were significant at 0.05 level.

Table 5, presenting measurements of the m-CTSIB test within-group comparisons in healthy, overweight, and obese (1st, 2nd, 3rd degrees) groups, indicated that 9 different comparisons were significant at 0.05.

DISCUSSION

This study aims to estimate the effects of different BMI levels on static and dynamic postural balance. The only parameter significantly different between groups for reaction time was the backward direction, with the fastest reaction time for the healthy group. Still, there was no difference in other directions. There was a significant difference in movement accuracy between the groups except for the backward direction, with the best scores for the healthy group. In addition, the directional control of the movement was significantly different between the groups except for the backward and right directions, with the best scores for the healthy group. Also, a significant difference was found between the groups in the m-CTSIB tests, except on the foam surface with eyes open test with the lowest oscillations for 1st degree obese group.

The LOS is a highly reliable and easily applicable test that plays an essential role in the detection of balance problems and early detection and prevention of falls (16). Nascimento et al. (11) included young adults between 18 and 40 years and compared the dynamic postural balance performances of obese and normal-weight individuals. They indicated that the obese participants had worse results in total LOS scores and other dynamic postural tests than normal-weight participants however, there was no difference between groups in static postural balance measurements (11). Bucko et al. (17) also included healthy and obese individuals under the age of forty and showed that the forward incline ability in the LOS test was lower in obese individuals. Similar to these results, the dynamic balance of obese individuals was worse than normal-weight individuals, with normal-weight individuals having the best scores and 3rd degree obese group having the worst scores in this study. This study contributes to the current studies by showing that the dynamic balance of obese individuals over the age of forty is also affected, and the rate of dynamic balance impairment is higher with increasing obesity levels.

In this study, there was no significant difference between the groups for reaction time except for the backward direction. This might be due to the fact the fear of movement has been shown to be more prevalent in obese individuals (18), and this fear might aggravate in the backward direction due to insecurity and lack of visual information. The lack of difference in other directions and the total score might be explained by the fact that the sensory integration and motor planning processes of obese individuals are not affected. It could also be because normal-weight individuals focused on the accuracy and control of the movement rather than moving as quickly as possible.

It has been shown that mediolateral sway is higher in obese individuals, and postural control is worse than in individuals with normal body mass index, leading to the inaccuracy of targeted movement (19). The fact that obese individuals have relatively weaker muscle

Table 4. Pairwise comparisons between groups for Limits of Stability parameters

Limits of Stability Assessment	**Directions**	**Comparative Groups**	**Mean difference**	**P-value**
Reaction Time	Backward	Healthy vs. Overweight	**-0.482***	0.003
		Healthy vs. 2nd degree obese	**-0.525***	0.002
Endpoint Excursions	Forward	Healthy vs. 3rd degree obese	**14.450***	0.033
	Right	Overweight vs. 3rd degree obese	**12.387***	0.045
	Left	Healthy v s. 3rd degree obese	**16.882***	0.007
	Complete	Healthy vs. Overweight	**10.005***	0.040
		Healthy vs. 2nd degree obese	**15.716***	0.001
		Healthy vs. 3rd degree obese	**21.298***	0.000
		Overweight vs. 3rd degree obese	**11.293***	0.008
		1st degree obese vs. 3rd degree obese	**11.571***	0.024
Maximum Excursions	Forward	Healthy vs. 3rd degree obese	**15.102***	0.033
	Right	Healthy vs. 2nd degree obese	**17.167***	0.000
		Healthy vs. 3rd degree obese	**16.140***	0.001
		Overweight vs. 2nd degree obese	**12.628***	0.007
		Overweight vs. 3rd degree obese	**11.600***	0.013
	Left	Healthy vs. Overweight	**9.684***	0.039
		Healthy vs. 3rd degree obese	**17.450***	0.000
		2nd degree obese vs. 3rd degree obese	**10.621***	0.022
	Complete	Healthy vs. 2nd degree obese	**9.883***	0.037
		Healthy vs. 3rd degree obese	**11.509***	0.008
		Overweight vs. 3rd degree obese	**9.181***	0.022
Directional Control	Forward	Healthy vs. 2nd degree obese	**12.000***	0.025
	Left	Healthy vs. 3rd degree obese	**12.003***	0.000
		Overweight vs. 3rd degree obese	**10.002***	0.000
		1st degree obese vs. 3rd degree obese	**7.976***	0.016
	Complete	Healthy vs. 3rd degree obese	**10.217***	0.003
		Overweight vs. 3rd degree obese	**9.378***	0.002

p: post-hoc Tukey's test; * It refers the significance level of 0.05

strength when normalized by the bodyweight than individuals with normal weight could further worsen dynamic control of the movement (20). Beside the increase in mediolateral sway degress, stability in anteroposterior direction is altered as well by getting weight. One of the possible biomechanical explanation of disturbed anteroposteior stability is related with an anterior displacament of center of mass in obese individuals. As a result, these alterations would place obese individuals closer to the edge of their stability boundaries (21). For instance, a previous study suggested that more ankle torque is required for stabilization of the body due to the forward displacement of the body's center of gravity in obese individuals, which may adversely affect directional control of the movement in these individuals (22). Consistent with these findings, the accuracy and directional control of the movement in this study were worse with increasing BMI levels. In addition, increasing body weight in obesity may affect postural balance by affecting whole-body angular momentum. The range of whole-body angular momentum may be changeable through gait training and rehabilitation, and it's a valuable metric for confirming the efficacy of weight-loss therapies.

The literature suggests that obese individuals show increased body oscillations and postural balance problems due to biomechanical changes and weaker muscles (23), and BMI was negatively associated with static and dynamic postural balance (24). Similar to the literature, this study also showed that body mass index affects dynamic postural balance negatively.

m-CTSIB is a valid test used to assess sensory interactions required for balance in adults (25). Benetti et al. (26) evaluated static postural balances before and after bariatric surgery and found that although the mean body mass index was 44.6, it decreased to 32.6 6 months after surgery and 31 after 12 months. There was no significant change in static postural balance scores. On the other hand, Emara et al. (27) showed that body mass index had adverse effects on balance in their studies, in which the Sensory of Organization (SOT) test, which is the

Table 5. Pairwise comparisons between groups for m-CTSIB parameters

m-CTSIB		**Comparative Groups**	**Mean difference**	**P-value**
Firm surface	Eyes open	Healthy vs. Overweight	**0.187***	0.045
		Healthy vs. 1st degree obese	**0.269***	0.005
		Healthy vs. 2nd degree obese	**0.228***	0.016
	Eyes closed	Healthy vs. 3rd degree obese	**-0.178***	0.001
		Overweight vs. 3rd degree obese	**-0.119***	0.026
		1st degree obese vs. 3rd degree obese	**-0.143***	0.018
Foam surface	Eyes closed	Healthy vs. Overweight	**0.281***	0.026
		Healthy vs. 1st degree obese	**0.333***	0.018
Complete		Healthy vs. 1st degree obese	**0.153***	0.027

p: post-hoc Tukey's test; * It refers the significance level of 0.05; m-CTSIB: modified Clinical Test of Sensory Integration of Balance

equivalent of the m-CTSIB test, was used in our study. Izquierdo et al. (28) found no significant difference in SOT scores between the obese and non-obese groups in their study using the SOT test. The researchers emphasized that the disadvantage of the SOT test is that it only measures the ability to hold an involuntary and silent posture under specific conditions (28). In a study, obese individuals have been shown to have a greater body center of gravity swing in an eyes-open stance (29). According to Garcia et al. (7), obese individuals showed more postural sway when their eyes were closed on an unstable surface than individuals with a normal body mass index. However, they did not find any difference in the stable surface. In our study, it is seen that individuals in the obese groups had better results than the healthy group in the m-CTSIB scores used in the evaluation of static balance. These results are interesting in this respect, but it is seen that there is no consensus in the literature on the relationship between obesity and static balance. It is also stated that the assessments made on foam ground might get affected by the body weight of an individual, which could lead to errors in measured scores (30). Therefore, further studies on this subject are needed. The fact that 3rd degree obese group consisted of only females might be a limitation of the current study due to the possible gender effect on balance performance.

CONCLUSION

In conclusion, this study showed that movement control worsened with an increasing degree of obesity, and there was no difference in reaction time other than the backward direction. Therefore, the detection and the prevention of balance problems in this population might be important to prevent falls, injuries and their severe consequences. Since the 3rd degree obese individuals were the most affected subgroup in dynamic balance, we recommended that rehabilitation and fall prevention programs primarily focus on 3rd degree obese individuals.

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