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Effect of different balance training on limit of stability and motor control in overweight subjects.

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Abstract:

Background: Excessive weight limits daily activities by increasing the bulk of body segments and altering body proportions. In both eyes-open and eyes-closed settings during silent standing, being overweight is associated with postural instability.

Purpose: The purpose was to investigate the effect of balance training with the Biodex system on the limit of stability and motor control in overweight individuals.

Methods: Forty-six overweight individuals were assigned randomly to two groups: Group A (study group, n = 23) received Biodex balance training three sessions a week for six weeks. Group B (control group, n = 23) received conventional balance training thrice a week for six weeks. The limits of stability and motor control tests were evaluated using the Biodex balance system (BBS).

Results: A mixed MANOVA was conducted to examine the effects of treatment on Limit of Stability (LOS), static, and dynamic motor control. There was a significant increase in LOS (d = 0.94), static (d = 0.64), and dynamic motor control (d = 0.74) post-treatment of group A compared with that of group B ($p < 0.01$)

Conclusion: The Biodex balance training system using weight shift and motor control training was more significant than conventional balance training and significantly improved all variables (limits of stability and Motor control).

Key Words: Overweight, Biodex Balance system, Limit of stability, Motor Control, Balance training.

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Introduction:

The issue of excessive weight has emerged as a significant and unavoidable concern for individuals across all age groups. Being classified as overweight correlates with an undue or inappropriate accumulation of body fat, which poses various health risks. A Body Mass Index (BMI) of 25 or higher is categorized as overweight, whereas a BMI of 30 or above is classified as obese. According to the Global Burden of Disease report published in 2017, nearly 4 million individuals succumbed directly to complications arising from being overweight or obese. The prevalence of overweight individuals among both adults and children continues to escalate. From 1975 to 2016, the number of overweight children and adolescents aged 5 to 19 worldwide increased significantly fourfold, increasing from 4% to 18%. Most overweight children reside in developing countries, where the growth rate exceeds that of industrialized nations by 30 percent [1].

A lifestyle with poor dietary choices, lack of exercise, and psychosocial factors significantly contribute to weight gain. Excess weight increases lordotic curve, challenges weight distribution, and alters human biomechanics. These changes lead to postural instability, reducing balance. As a result, individuals who are overweight face a higher risk of falls and the injuries and disabilities that can follow [2].

Weight is considered a predictor for maintaining postural balance. In contrast, an increase in weight is regarded as a significant contributor to the incidence of falls. Research indicates that various kinetic and kinematic anomalies can disrupt appropriate musculoskeletal function due to weight gain. Consequently, a high Body Mass Index (BMI) is associated with increased postural sway among overweight individuals, particularly in the anteroposterior and medial-lateral directions for both males and females and a higher incidence of falls in adults. Compared to other anthropometric measures, waist circumference correlates strongly with stabilometric parameters and fall outcomes [3].

According to researchers, following weight reduction, the postural control of men who are overweight experiences enhancement. An analysis of the adult population aged 24 to 61 showed a substantial correlation between increased body weight and diminished postural stability [4]. Balance is the capacity to distribute one's weight to enable standing or moving without the risk of falling or recovering from a trip. It encompasses dynamic and static elements, constituting a sophisticated ability necessary to maintain the body's equilibrium [5].

The precise coordination of signals transmitted to the central nervous system from the visual, auditory, and somatosensory systems during static and dynamic equilibrium is essential for maintaining balance and postural stability. Any factor that disrupts the body's equilibrium, resulting in postural sway, may lead to an imbalance [6]. The Berg Balance Scale (BBS) is a multiaxial assessment tool utilized to evaluate and document an individual's objective capability to stabilize the affected joint under dynamic stress. It employs a circular platform that may oscillate simultaneously along the medial-lateral and anterior-posterior axes. Furthermore, this tool can also be employed in balance training [7].

Balance training programs have demonstrated a reduction in the incidence of lower-limb injuries. These epidemiological findings may be partially elucidated by the improved activation onsets and co-contraction levels of specific trunk and lower-limb muscles, as indicated by [8]. Furthermore, reports indicate that balance training contributes to a decrease in knee abduction moments, which may be partially attributed to alterations in trunk control [9].

Consequently, balance training improves motor coordination, which is defined as the ability to generate muscle contractions that facilitate appropriate whole-body and segmental movements. Balance training may contribute to preventing sports-related injuries by enhancing dynamic postural control, as previous research has indicated advantageous neuromuscular adaptations associated with this form of training. However, there remains a lack of conclusive evidence regarding the effectiveness of balance training programs in mitigating the impact of external disturbances on postural control [10].

This study aimed to examine the differences between Biodex balance training and traditional balance training regarding the limit of stability and motor control in overweight individuals.

Materials and methods:

Study design: This is a randomized control trial conducted on 46 overweight young adults. Subjects were tested by BBS (using limits of stability and motor control). Subjects were selected from Daraya University students and doctors in New Minia. The patients were split into two groups equally, the Study and Control groups, as shown in the flow chart (Figure 1).

Each subject provided written consent and was then accepted into the study. The randomization method was that patients with odd numbers were enrolled in the study group, and patients with even numbers were enrolled in the control group.

Sample size: Sample size calculation was performed using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) based on data of stability index derived from **Eftekhar-Sadat** [11] and revealed that the required sample size for this study was 23 subjects in each group. The calculation is made with α=0.05, power = 80%, and effect size = 0.86

Inclusion criteria: Overweight young male adults aged 20–30 years, People with sufficient cognitive abilities that enable them to understand and follow instructions, and a BMI of 25-29.9

Exclusion criteria: Athletes, Family history of mental illness, Neurological or musculoskeletal disorders, History of trauma or surgery, Unable to cooperate with the study protocols, and Patients who had any medical problem in their foot.

Instrumentation for Measurement:

I- A Generic Digital Scale was used to obtain the subject's weight and height.

II- Biodex balance system was used as an assessment tool for Limits of Stability and Motor control.

a) Limits of Stability (LOS) test: The Limits of Stability (LOS) test assesses an individual's ability to maintain control of their center of gravity within a defined support base. This evaluation quantifies the extent to which the

patient can sway from their center of gravity, measured in degrees from the neutral position, which is designated as 0 degrees. The estimated center of gravity is 55% of the individual's height.
The LOS test is a reliable indicator of motor control within the sway envelope. Poor control, inconsistencies, or prolonged sway times may necessitate further assessment of lower extremity strength, proprioceptive capabilities, and potential vestibular or visual deficiencies.

b) Motor control test: The Motor Control assessment evaluates patients' ability to manage their center of gravity within a defined support base. Like the Limits of Stability assessment, patients must shift their weight to navigate the cursor from the central target to a blinking target and return to the center promptly and with as minimal deviation as possible. This procedure is reiterated for each target presented—the targets on the display illuminate in a random sequence. Three distinct skill levels permit the targets to be arranged in closer proximity or further apart, while the platform setting can remain static or dynamic.
This assessment is a reliable indicator of dynamic control within a sway envelope. Inadequate control and inconsistent or prolonged response times may warrant further evaluation of lower extremity strength, proprioception, vestibular, or visual impairments.

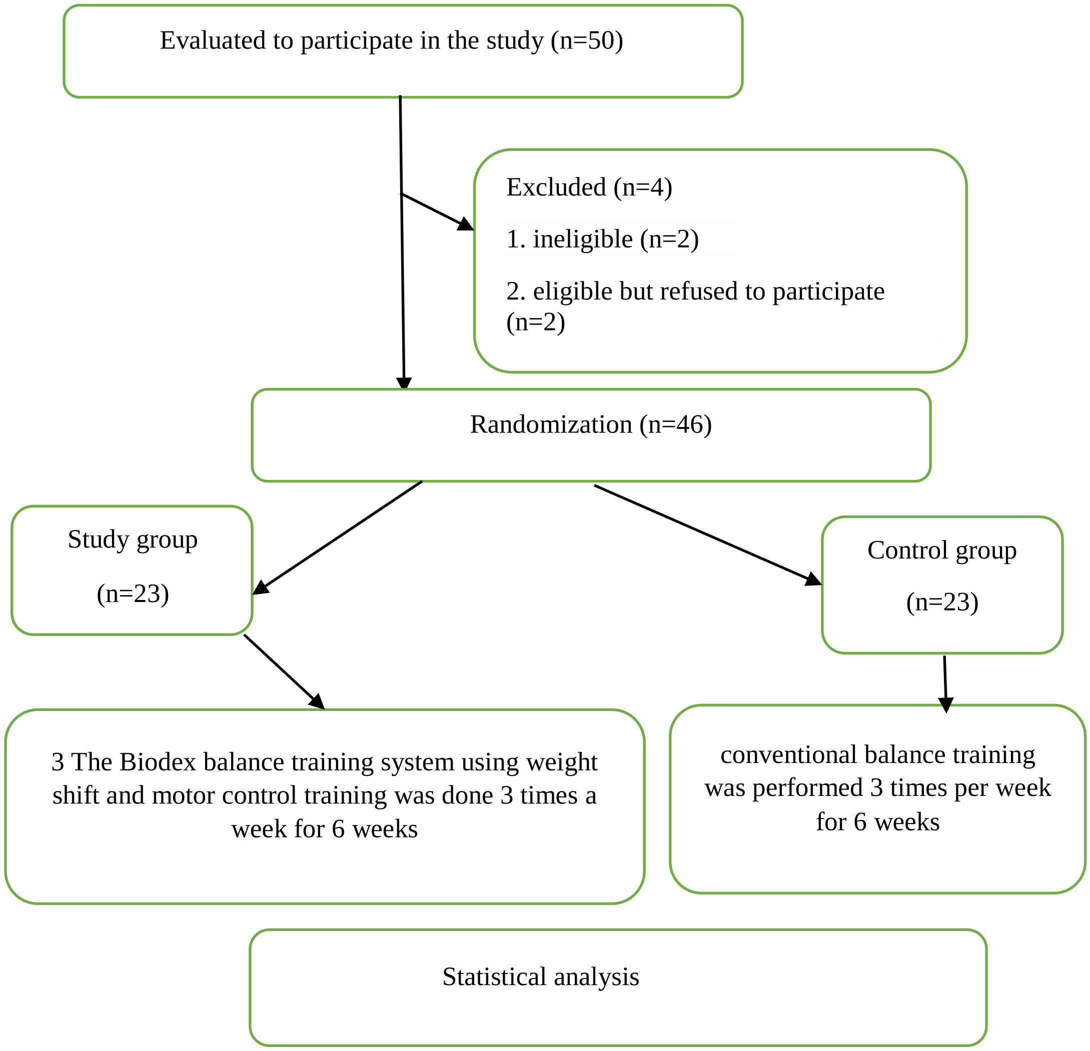
Instrumentation for study training:

Subjects in this group received Biodex balance training systems, including weight shift and Motor control training.
a) Weight shift training: Weight Shift Training facilitates patients' practicing shifting their weight in medial/lateral, anterior/posterior, or diagonal directions. This exercise may be conducted with the platform in a static or dynamic state. The user determines the orientation and target range while the patient maintains the center of gravity within the designated target box, as the cursor indicates.
Scoring is computed as a percentage of the net good hits divided by the total target hits. Any hits outside the established boundary are deducted from the target hits, yielding the net good hits. If the cursor crosses a red boundary, one hit is subtracted from the total of good hits.
For instance, if a patient obtains ten target hits but permits the cursor to exceed the boundary four times, the training results yield 10 - 4 = 6 good hits, thus resulting in a score of 6/10 or 60%. There are 12 difficulty levels, commencing from level one and advancing by one level with each subsequent session.

b) Motor control training: The Motor Control Training mode challenges the patient by requiring the utilization of the sway envelope, which delineates the range within which an individual can adjust their center of gravity (COG) while remaining within the confines of their base of support. The COG allows for approximately 8 degrees of movement in each lateral direction, summing up 16 degrees of sway, 8 degrees of forward movement, and 4 degrees of backward movement, culminating in 12 degrees of sway.
A sequence of targets is presented, with one target indicated by a blinking signal. The patient is tasked with maneuvering the cursor from the central target to the blinking target and returning it to the central target. The scoring system is based on the percentage of movement that exceeds the defined sway envelope, thus assessing the precision of the movement executed. A more direct movement corresponds to enhanced stability.
For instance, if the minimal distance from the central target to the perimeter target amounts to an excursion of 8 degrees, and the patient swayed 16 degrees, the resulting score would be 50%. This modality encompasses 12 difficulty levels, commencing from level one and progressively increasing by one level with each session.

Instrumentation For the control group training:

Subjects in this group received only the conventional balance training, which was divided into:
Flexibility: Calf, hamstring, quadriceps, hip flexors, hip adductors (15-sec hold and five repetitions).
Strength: Curl-ups (Abdominal), hamstring (prone knee flexion), side lying with a weight around the ankle (hip abductors), prone extension (spinal extensors), hip extensors (in prone), and quadriceps (knee extension in high sitting): 10 repetitions each.
Postural control: Stepping in all directions, reaching to limits of stability in different positions (kneeling, half kneeling, standing: on hard surface and foam surface), stepping up and down, tandem standing and walking, single limb standing (eyes open and closed) [12].



Flow chart Figure 1

Statistical analysis:

An unpaired t-test was conducted to compare the subject characteristics between groups. The normal distribution of data was checked using the Shapiro-Wilk test. Levene's test for homogeneity of variances was conducted to test the homogeneity between groups. Mixed MANOVA was conducted to investigate the effect of treatment on LOS, static, and dynamic motor control. Post-hoc tests using the Bonferroni correction were carried out for subsequent multiple comparisons. The significance level for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social sciences (SPSS), version 25, for Windows (IBM SPSS, Chicago, IL, USA).

Results:

***Subject characteristics*:**

Table (1) shows the subject characteristics of groups A and B. There was no significant difference between groups in age, weight, height, and BMI ($p > 0.05$).

Table 1. Comparison of subject characteristics between groups A and B:

	Group A	Group B			
	Mean ±SD	Mean ±SD	MD	t- value	p-value
Age (years)	23.74 ± 2.73	23.91 ± 3.09	-0.17	-0.20	0.84
Weight (kg)	85.91 ± 7.15	86.04 ± 6.21	-0.13	-0.07	0.95
Height (cm)	174.35 ± 6.26	175.22 ± 5.17	-0.87	-0.51	0.61
BMI (kg/m²)	28.29 ± 0.97	28.00 ± 0.80	0.29	1.09	0.28

SD, Standard deviation; MD, mean difference; p-value, Probability value

Effect of treatment on LOS, static and dynamic motor control:

Mixed MANOVA revealed a significant interaction effect of treatment and time (F = 41.60, p = 0.001, partial eta squared = 0.75). Treatment had a significant main effect (F = 4.58, p = 0.007, partial eta squared = 0.25). There was a significant main effect time (F = 182.01, p = 0.001, partial eta squared = 0.93).

Within group comparison: There was a significant increase in LOS, static, and dynamic motor control post-treatment in both groups compared with pre-treatment (p > 0.001). The percent change of LOS, static, and dynamic motor control in group A was 16.36, 30.92, and 82.93%, and that in group B was 10.91, 11.85, and 27.32%, respectively (Table 2).

Between-group comparison: There was a significant increase in LOS (d = 0.94), static (d = 0.64), and dynamic motor control (d = 0.74) post-treatment of group A compared with that of group B (p < 0.01). (Table 2)

Table 2. Mean LOS, static and dynamic motor control pre and post-treatment of groups A and B:

	Pre-treatment	Post-treatment			
	Mean ±SD	Mean ±SD	MD	% of change	p-value
LOS (degrees)					
Group A	7.64 ± 1.09	8.89 ± 0.57	-1.25	16.36	0.001
Group B	7.24 ± 1.07	8.03 ± 0.52	-0.79	10.91	0.001
MD	0.40	0.86			
	p = 0.21	***p = 0.001***			
		d = 0.94			
Static motor control (%)					
Group A	50.74 ± 10.41	66.43 ± 6.85	-15.69	30.92	0.001
Group B	53.91 ± 10.00	60.30 ± 9.95	-6.39	11.85	0.001
MD	-3.17	6.13			
	p = 0.29	***p = 0.01***			
		d = 0.64			
Dynamic motor control (%)					
Group A	30.52 ± 12.51	55.83 ± 8.26	-25.31	82.93	0.001
Group B	29.61 ± 10.70	37.70 ± 11.26	-8.09	27.32	0.001
MD	0.91	18.13			
	p = 0.79	***p = 0.001***			
		d = 0.74			

SD, Standard deviation; MD, Mean difference; p value, Probability value; d, Effect size

Discussion:

Gaining weight constitutes a global crisis and stands as one of the primary intermediary risks associated with chronic non-communicable diseases. According to the WHO, being overweight represents one of the most prevalent, albeit underreported, societal challenges affecting developing and developed nations. The WHO World Health Statistics Survey of 2012 indicated that one in every six individuals globally is classified as overweight, resulting in an estimated 2.8 million deaths annually worldwide. Overweight is linked to an elevated risk of complications such as atherosclerosis, coronary artery disease, colorectal cancer, hypercholesterolemia, hypertension, gallbladder disease, and various metabolic disorders, in addition to being associated with a higher mortality rate. Factors contributing to weight gain include a sedentary lifestyle, an unhealthy diet, and psychosocial influences [13].

An increasing body of evidence suggests that excess weight adversely impacts functional capabilities, including standing, walking, balance, and stability. Numerous studies indicate significantly poorer static and dynamic postural stability in individuals classified as obese when compared to normal BMI values [14].

The current study is designed to evaluate the effect of balance training on the limit of stability and motor control in overweight subjects. There was a significant increase in LOS, static, and dynamic motor control post-treatment in both groups compared with pre-treatment, with dynamic motor control being the most affected. It also shows a significant increase in LOS, static, and dynamic motor control in the study group (GA) more than in the control group (GB), especially in dynamic motor control.

The results of our study are as follows: **Zamanian** [15] conducted a study involving forty older women capable of ambulating six meters or more without an assistive device. The participants were assigned randomly to either group. Those in the intervention group engaged in one hour of balance training exercises thrice weekly over eight weeks. Conversely, the control group did not receive any balance training. The results indicated a notable improvement in balance control within the intervention group.

Our findings concur with those presented in the study by **Clemson** [16], which investigated the Lifestyle Integrated Functional Exercise (LIFE) program. This program incorporated balance and strength activities among participants with a mean age of 70 years over 12 months. The investigation results indicated a marked improvement in static balance among the subjects. In alignment with our study, the research demonstrated that balance training effectively enhances balance control. Furthermore, studies conducted by **Binder** [17]**, King** [18]**, and Gao** [19] substantiated that engaging in activities and exercises, including balance training, significantly improves balance control.

Our findings corroborate the research conducted by **Chaharmahali** [20], who reported that the balance training program utilizing the Berg Balance Scale (BBS) effectively stimulates the neuromuscular control mechanisms essential for maintaining balance and posture. Furthermore, our study aligns with **Allam's** [21] findings, which indicated that when a task is performed repetitively, the relationship between movement capabilities, environmental conditions, and the action goal becomes increasingly nuanced, enhancing the likelihood of successfully achieving the goal. The six-week balance training program implemented in this study, conducted at a frequency of three times per week, is an adequate duration to promote the reflex muscular activation patterns necessary for maintaining postural balance in individuals with overweight status.

The findings of our study align with those of **Ibrahim's** [22], who demonstrated that a six-week balance training program reduced pain and enhanced static and dynamic balance among patients experiencing low back pain. Furthermore, our results corroborate the work of **Steadman**[23], who found that a balance training program over six weeks significantly improved balance, mobility, confidence, and overall quality of life in patients facing balance-related challenges. Additionally, several studies examining athletes from various sports have reported improved balance following a four-to-eight-week balance training program (BTP) [24,25,26]**.**

Notably, a relevant study revealed improved balance skills merely two weeks after initiating a Balance Training Program (BTP) [24]. The observed enhancement in balance can be primarily attributed to adaptations within the nervous system, specifically the development of neuromuscular coordination and increased neuromuscular control. These changes result from the reduced excitability of the H-reflex and the myotatic reflex noted in closed-chain kinetic exercises[27,28], which may further elucidate our findings.

In contrast to these findings, a study by **Benetti** [29] noted that no differences were observed in the displacement area or velocity from the center of pressure in both the mediolateral and anteroposterior directions. This evaluation was performed using a force platform on 16 bariatric surgery patients. Furthermore, the three-month exercise program and the rapid weight loss documented in our study did not significantly impact the total length of the center of force (COF) sway, whether in the anteroposterior or mediolateral directions, nor did it affect the speed of COF.

Conclusion:

It was concluded that the Biodex balance training system using weight shift and motor control training was more effective than conventional balance training and significantly improved all variables (limits of stability and Motor control).

Recommendation:

Further studies are needed to examine the effect of other therapeutic modalities on the limit of stability and motor control in overweight subjects.

Data availability:

The corresponding author can request the datasets utilized and analyzed in this study under reasonable conditions.

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