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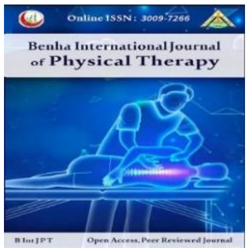

Original research

Static Posturographic Analysis for Different Weight Categories in Adolescents: A Cross Sectional Study

Dina S. Noaman[1*], Mohamed N. Al Khouli[2], Amira H. Mohammed [3]

1.Department of Physical Therapy for Pediatrics and its Surgeries, Faculty of Physical Therapy, Delta University for Science and Technology, Gamasa, Egypt.
2.Department of Physical Therapy for Pediatrics and its Surgeries, Faculty of Physical Therapy, Delta University for Science and Technology, Gamasa, Egypt.
3.Department of Physical Therapy for Pediatrics and its Surgeries, Faculty of Physical Therapy, Delta University for Science and Technology, Gamasa, Egypt.

***Correspondence to**
Dina S. Noaman: Demonstrator at Department of Physical Therapy for Pediatrics and its Surgeries, Faculty of Physical Therapy

E-mail: dinas2441@gmail.com

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Abstract

Background: Weight abnormalities are a growing global health concern, particularly among adolescents. While the association between weight abnormalities and postural instability has been explored in various populations, its impact on adolescent postural control remains less understood. **Purpose:** This study aimed to compare the effect of different weight statuses and postural control in adolescents. **Methods:** Two hundred adolescents ranging from 16 to 18 years were categorized into normal weight, obese, overweight, and underweight groups based on body mass index (BMI) percentiles. Postural stability was assessed using a force platform, measuring the anteroposterior (AP) and mediolateral (ML) sway length range of the center of pressure (COP) trajectory and average COP speed. **Results:** Obese, overweight, and underweight adolescents exhibited significant increased AP sway compared to their normal-weight peers, while there was no significant difference between the obese and overweight groups. Obese and underweight adolescents exhibited significantly greater ML sway compared to their normal-weight peers, while there was no significant difference between the normal and overweight groups. **Conclusion:** The findings indicate a strong association between weight abnormalities (obesity, overweight, or underweight) and impaired postural stability in adolescents. Increased or decreased body weight and altered body geometry likely contribute to these postural deficits. Early identification and targeted interventions are crucial for addressing postural instability in this population.

Keywords: Postural Stability, Adolescents, Center of Pressure, Body Mass Index.

Introduction

Overweight and obesity were categorized according to body mass index (BMI) thresholds with distinctions made based on gender[1]. While childhood is characterized by body fat accumulation in both sexes, divergent patterns emerge during puberty, with a tendency toward decreasing body fat percentage in boys and increasing percentage in girls[2]. The World Health Organization (WHO) and center for disease control and prevention categorizes adolescent obesity based on BMI percentiles relative to same-aged peers. An adolescent is classified as obese if their BMI exceeds 95th. Those with a BMI between the 85th and 95th percentiles are considered overweight. This approach acknowledges normal BMI variations during adolescence[3].

Underweight adolescents can be classified using CDC criteria when BMI below 5th percentile and adolescent with a BMI between the 5th and

85th percentile for their age and gender is of healthy weight [4,5].

Postural control is the mechanism employed to achieve the state of balance[6].Humans exhibit a dynamic interplay of sensory, motor, and vestibular systems to uphold an erect posture. Sensory systems detect deviations in this alignment, triggering neural responses that modulate muscle activation to restore equilibrium. This intricate process ensures postural control across both static and dynamic conditions[7].

The vertical ground reaction force (GRF) generated upon ground contact opposes gravitational forces and maintains upright posture. The specific point of GRF application on the foot is termed the center of pressure (COP). Variations in COP position and trajectory during static stance serve as indicators of balance control efficiency[8,9]. By analyzing COP dynamics, researchers can indirectly assess the body's ability to regulate its center of gravity[10.]

Emerging evidence suggests that pediatric obesity, particularly in prepubescent individuals, is associated with impaired proprioception, potentially contributing to balance and coordination difficulties. While the precise mechanisms remain elusive, proposed etiologies include excessive strain on joints and sensory receptors due to overweight, limited physical activity, and structural alterations in weight-bearing joints associated with obesity [11].

Research has shown that sensory input can either trigger or prevent changes in body balance. This suggests that the body uses information from these senses to automatically adjust its position and maintain stability[12-14].

Body sway, measured during static standing, is commonly used to assess postural control. This sway reflects the body's continuous adjustments to maintain balance under minimal external and internal disturbances. It allows for quantitative measurement of postural stability[15,16].

Static posturography is a valuable tool for the accurate and objective evaluation of postural stability. The methodology involves utilizing a specialized force platform to record the distribution of ground reaction forces exerted by the feet. Subsequent computer-based analysis of these data yields quantitative measures of the individual's center of pressure (COP) fluctuations, providing insights into postural control mechanisms[17,18].

In bipedal stance, weight distribution is typically evenly distributed across both feet [19,20]. However, shifts in the center of gravity necessitate alterations in weight distribution, underscoring the foot's role in preserving postural stability. Pressure plate technology offers a valuable means of assessing these balance dynamics[21,22].

Previous research has established a link between obesity and impaired postural stability, particularly as measured by center of pressure displacement, across adult, elderly, and pediatric populations. However, the specific influence of varying weight categories (normal weight, obese, overweight, and underweight) on static balance and postural stability within the adolescent demographic (aged 16-18 years) remains underexplored. This study aimed to compare the effect of different weight status and postural control in adolescents.

Methods

Study Design

This retrospective observational study was conducted in accordance with ethical principles of the 1975 Helsinki Declaration at Delta University for Science and Technology's biomechanics laboratory from November 2023 to April 2024. Registered on ClinicalTrials.gov (NCT06458621 on 21/06/2024), the study protocol was approved by the Faculty of Physical Therapy's Ethics Review Committee at Delta University (NO F.P.T2407025). Prior to participation, all subjects provided written informed consent.

Participants:

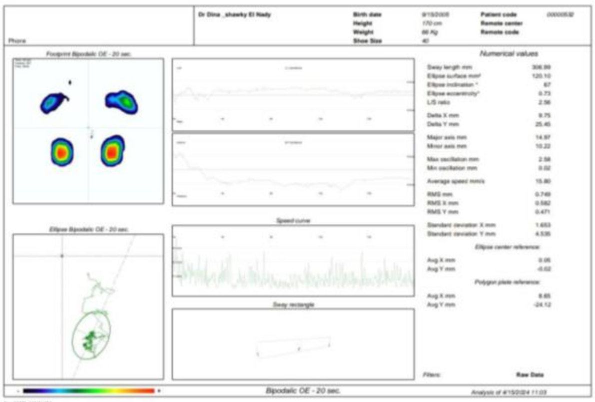
Two hundred adolescents from both sexes with age range between (16-18) years were participated in this study. They were selected from a secondary school student from El Ryad secondary school Kafer Elsheikh governorate and first level university students from Delta University for Science and Technology classified to four equal-sized groups: obese, overweight, underweight, and normal weight. Inclusion criteria mandated the absence of musculoskeletal deformities, foot abnormalities, peripheral neuropathies, prior orthopedic procedures. While morbid obesity (BMI > 99th percentile) was excluded[23].

Assessment tools

Participant selection adhered to CDC growth charts for children and adolescents aged 2 to 20 years to assess growth parameters and identify potential health concerns. Anthropometric measurements were obtained using a medical electronic scale (model Tcs-200 Rt, Perlong Medical Equipment Co., Ltd., China) with a precision of 100 grams for mass and 5 mm for height, accommodating a measurement range of up to 200 kg and 2.1 meters[24]. Balance and gait analysis were conducted using the FREEMED platform and FREESTEP software (Sensor Medica, Inc., Italy)[24,25]. The portable and lightweight FREEMED platform, equipped with a high-resolution 160-sensor array, captured plantar pressure distribution at a sampling rate of 500 Hz. Subsequent analysis was performed using FREESTEP software, which employed 3D isobaric analysis to quantify parameters such as center of gravity, pressure distribution, and foot contact patterns. These data were automatically compared to normative values to the following parameters would be tested**:** Anteroposterior (AP) sway length rang of COP trajectory on (Y-Axis) (Delta Y), **Figure (1).** Mediolateral (ML) sway length rang of COP trajectory on (x-Axis) (Delta X), **Figure (1).** Average COP speed or velocity, **Figure (2).**

Assessment procedures

Participant weight was determined using a platform electronic scale (TCS-200-RT). To minimize measurement error, participants were instructed to remove footwear, jewelry, and outerwear before ascending the scale platform. Subjects were required to maintain a still, upright posture with equal weight distribution across both feet[26]. Weight measurements were rounded down to the nearest 0.1 kg. Height measurements were obtained using a stadiometer (TCS-200-RT) with a precision of 0.5 cm.



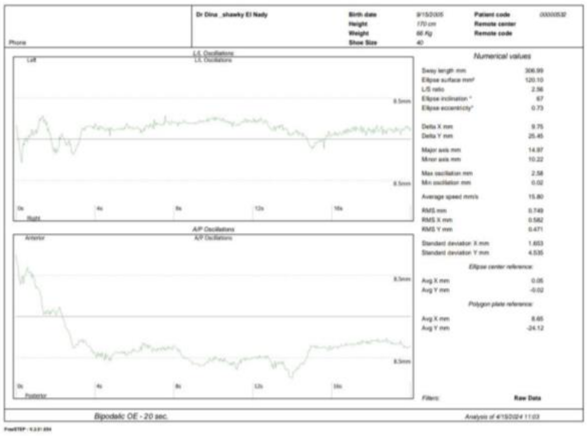


Figure (1): Anteroposterior (AP) sway length rang of COP trajectory on (Y-Axis) (Delta Y) and mediolateral (ML) sway length rang of COP trajectory on (x-Axis) (Delta X).

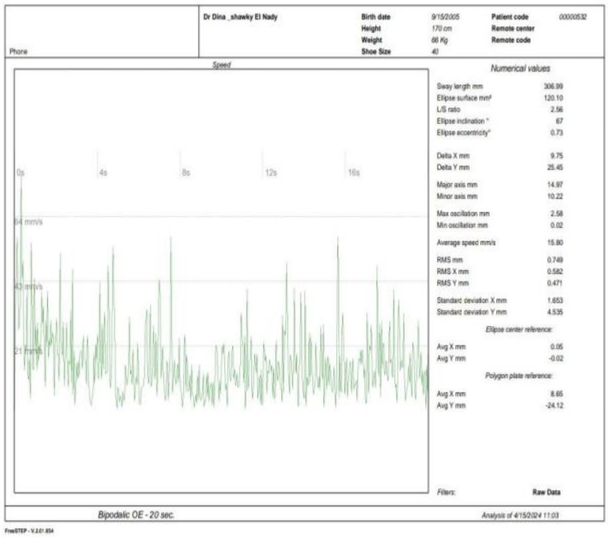


Figure (2): Average COP speed or velocity.

Participants were measured barefoot in the Frankfort horizontal plane. The sliding headpiece of the stadiometer was carefully adjusted to the highest point of the participant's head[27]. Participants aged 2 to 18 were categorized using CDC growth charts. Weight, height, and BMI were measured. The appropriate growth chart based on age and sex was selected. BMI was calculated using weight and height and plotted on the chosen chart. The plotted point's position relative to percentile curves indicated the child's growth status compared to peers. Percentiles outside the 5th to 95th range suggested potential nutritional concerns and required further evaluation. Participants were be classified according to the percentile into four statuses as represented in **table (1)**.

Table (1): Status of participants according to CDC Growth Charts 5th and 95th percentile		
Anthropometric Index	Percentile Cut-off Values	Nutritional Status Indicator
BMI-for-age	≥ 95th	Obesity
BMI-for-age	≥ 85th and < 95th	Overweight
BMI-for-age	< 5th	Underweight

Participants stood on a force platform in a quiet room for a static standing trial. They were free to converse with a partner positioned two meters away. Data on the anterior-posterior (AP) and mediolateral (ML) for the center of pressure (COP) displacement were collected over an 80-second period[28,29]. The testing protocols usually included performing an experimental testing trial before applying the actual trial, involving six trials with varying visual and proprioceptive conditions[30,31].

For both trials, participants adopted a standardized posture with feet shoulder-width apart and a 45-degree ankle angle. Data was collected at a sampling frequency of 25 Hz to ensure comparability with previous studies (www.sensormedica.com). The test trials comprised six conditions: eyes open (EO) and eyes closed (EC) with both feet on the platform, followed by EO and EC conditions with the right and left leg lifted, respectively. Each condition lasted 20 seconds for the bilateral feet support standing trials and 10 seconds for the single-leg trials, resulting in an 80-second total test duration[31].

Statistical analysis

Prior to the final analysis, data were assessed for normality using the Shapiro-Wilk test. As the data for all four groups deviated from a normal distribution, non-parametric tests were employed to compare results across different BMI categories. Specifically, the Mann-Whitney U test was used for independent sample comparisons, with Z-values and corresponding significance levels reported. Statistical analyses were performed using SPSS version 25, and descriptive statistics were calculated for each BMI group to provide a comprehensive overview of the results. The significance level was set at $p < 0.05$ to determine statistical significance.

Results

This study included 200 participants of high school and undergraduate students. They were divided into 4 categories, with equal numbers according to BMI values, Gender values: 98 males and 102 females. The average values subgroups of these groups are summarized in **Table (2)**.

Table (2): Central tendency indicators by investigated subgroups (gender, age, anthropometric indicators and BMI values)						
Group	Parameters	Minimum	Maximum	Mean	SD	Variance
Obese N=50 Gender (M/F) 24 (48%): 26 (52%)	Age	16	18	17.56	0.667	0.445
	Weight	69	130	101.82	13.65	86.31
	Height	1.49	1.89	1.727	0.097	0.010
	BMI	30	42.20	33.89	2.510	6.301
Normal N=50 Gender (M/F) 22(44%): 28(56%)	Age	16	18	17.47	0.655	0.429
	Weight	47	95	65.26	1.054	11.12
	Height	1.48	1.89	1.684	0.079	0.017
	BMI	19.30	28	22.646	2.006	4.027
Overweight N=50 Gender (M/F) 24(48%): 26(52%)	Age	16	18	17.61	0.680	0.462
	Weight	68	99	83.34	7.912	62.59
	Height	1.53	1.89	1.681	0.817	0.007
	BMI	26.90	31	29.24	1.024	1.051
Under Weight N=50 Gender (M/F) 23(46%): 27(58%)	Age	16	17	17.54	0.699	0.488
	Weight	43	70	54.47	7.458	55.62
	Height	1.56	1.96	1.726	0.1134	0.013
	BMI	16.50	19	18.09	0.4882	0.238

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The comparison of the results between the 4 groups (by ranks) means of the nonparametric Mann-Whitney U test, with the expression of Z values and the associated significance thresholds are summarized in tables 3-5.

The comparison of the results between the groups for Delta Y (AP) Axis -mm test shown that there were no significant differences between the obese and overweight groups (P > 0.05), on the other hand, there were significant differences between the obese and normal weight groups, between the results of the obese and underweight groups, between overweight and underweight groups, between normal weight and overweight groups, between normal weight and underweight groups (P < 0.05), T**able (3)**.

Table 3: The comparison of the results between the groups for Delta Y (AP) Axis- mm test.

Item	Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Sig. (2-tailed)
Delta Y (AP) Axis/mm	Normal Obese	50 50	42.13 58.87	2106.50 2943.50	831.500	-2.885	0,004*
	Normal overweight	50 50	43.60 57.40	2180.00 2870.00	905.000	-2.379	0,025*
	Normal under weight	50 50	43.24 57.76	2167.00 2888.00	887.000	-1.503	0,012*
	overweight under weight	50 50	47.50 52.50	2425.00 2625.00	876.000	-3.689	0,033*
	Obese overweight	50 50	52.78 48.22	2639.00 2411.00	1136.000	-0.786	0,432
	Obese under weight	50 50	50.72 50.28	2536.00 2514.00	1239.000	-1.167	0,011*

Correlation bivariate was significant at the 0.05 level (2 - tailed). *: significant.

Table (4) shown the comparison of the results between the groups for Delta X (ML) Axis - mm test. There were significant differences between the obese and normal weight groups, between the obese and overweight groups, between the obese and underweight groups, between normal weight and underweight groups, between overweight and underweight groups (P < 0.05), on the other hand, there were non-significant differences between the results of the normal weight and overweight groups (P > 0.05).

Table 4: The comparison of the results between the groups for Delta X (ML) Axis - mm test.

Item	Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Sig. (2-tailed)
Delta X (ML) Axis/mm	Normal Obese	50 50	41.74 59.26	2078.00 2963.00	812.000	-3.020	0.034*
	Normal overweight	50 50	45.91 55.09	2295.50 2754.50	1020.500	-1.582	0.114
	Normal under weight	50 50	41.50 59.50	2075.00 2975.00	800.000	-3.103	0.002*
	overweight under weight	50 50	44.74 56.26	2237.00 2813.00	962.000	-1.986	0.047*
	Obese overweight	50 50	56.58 44.42	2829.00 2221.50	946.000	-2.096	0.036*
	Obese under weight	50 50	53.01 47.99	2650.50 2399.50	1124.500	-2.824	0.026 *

Correlation bivariate was significant at the 0.05 level (2 - tailed). *: significant.

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The comparison of the results between the groups for the Average speed -mm test for shown there were significant differences between the obese and normal weigh groups, between the obese and overweight groups, between the obese and underweight groups, between the results of overweight and underweight groups, between normal weight and underweight groups (P <0.05), on the other hand, there were non-significant differences between the results of the normal weight and overweight groups (P > 0.05), Table (5).

Table 5: The comparison of the results between the groups for the average speed -mm test

Item	Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Sig. (2-tailed)
Average speed /mm. s	Normal Obese	50 50	47.14 53.86	2357.00 2693.00	128.000	-1.167	0.050*
	Normal overweight	50 50	55.75 45.25	2787.50 2262.50	987.500	-1.810	0.070
	Normal under weight	50 50	45.31 55.21	2265.00 2784.00	1190.000	-2.849	0.040*
	overweight under weight	50 50	39.53 61.47	1976.50 3073.50	701.500	-3.782	0.041*
	Obese overweight	50 50	58.80 42.20	2940.00 2110.00	835.000	-2.861	0.046*
	Obese under weight	50 50	48.61 52.39	2430.50 2619.50	1155.500	-2.456	0.005*

Correlation bivariate was significant at the 0.05 level (2 - tailed). *: significant.

Discussion

This study aimed to investigate the relationship between different weight categories and postural stability parameters in adolescents between (16-18) years based on recommendation in children and adults' studies that adolescents have different feet morphology compared to these categories of ages which requires for further investigation in COP sway changes, limited researches for balance investigation in underweight. Anteroposterior (AP) sway length rang of COP trajectory on (Y-Axis) (Delta Y), Mediolateral (ML) sway length rang of COP trajectory on (x-Axis) (Delta X) and average COP speed or velocity were measured as parameters representing the and postural stability. The study findings provide a significant difference between obese and normal adolescents in both delta Y and delta X. This suggests that that obese individuals have less ability to maintain postural stability when compared with individuals with normal weight. The increased overall body weight leading to greater AP and ML shifts during stance could be explained by the contribution made by an altered body geometry in obese individuals and of the relationship between postural stability and increased body weight relates to the contribution made by foot mechanoreceptors to balance control revealed by previous studies.

The altered body geometry in obese individuals exhibited significantly greater anterior pelvic tilt compared to non-obese individuals. This postural alteration can contribute to excessive lumbar lordosis due to the anatomical connection between the pelvis and lumbar spine[32]. Obesity may contribute to increased anterior pelvic tilt due to alterations in body geometry resulting from excessive abdominal adiposity. This postural deviation is often accompanied by a significantly enhanced lumbar lordosis angle[33]. Excess abdominal fat shifts the body's center of gravity forward, resulting in an increased anterior pelvic tilt[34.35], consequently, obese individuals require a more substantial ankle torque to offset the increased gravitational force. Corbeil et al [34] suggested that obese individuals with excess abdominal fat may be more likely to fall than those with normal weight.

Previous research has established a positive correlation between postural instability and increased body mass index (BMI). The current study findings corroborate these results, indicating that individuals with obesity exhibit greater postural sway in both the mediolateral and anteroposterior planes compared to normal-weight counterparts. Moreover, we observed a significant association between increased body mass and exaggerated postural responses to perturbations. These findings suggest that obesity may contribute to postural instability through alterations in static and dynamic balance control mechanisms[36].

The link between increased body weight and poorer postural stability might be explained by changes in how the feet provide balance information. Studies show that heavier people have larger foot contact areas and distribution their pressure increased on the heel, midfoot, and metatarsal regions the compared to those of normal weight[37-41]. Research by Hills and colleagues[39] found that obese individuals exert notably higher pressure on their heels, midfoot, and forefoot compared to others. This is significant as it could potentially affect the body's sensory receptors.

It's generally accepted that the hip and torso are crucial for maintaining balance side-to-side, while the pelvis contributes to sideways movements[21]. During downward body movements, the head initiates motion, followed by the trunk and hips. The findings indicate significantly greater mediolateral sway among individuals with obesity[42].

Obesity can negatively impact one's ability to withstand muscle fatigue. This fatigue can hinder balance and demand more mental effort to maintain stability[36]. Previous studies have shown that individuals with excess body fat experience greater difficulty maintaining posture and balance. Park et al. found that increased fat mass is associated with higher perceived exertion during postural challenges[43]. Additionally, Maffiuletti et al. demonstrated that obesity weakens the quadriceps muscles, making it harder to counteract postural disturbances[44].

Chronic obesity may compromise mechanoreceptor function, thereby hindering the body's capacity to respond effectively to postural perturbations. Regardless of the precise mechanism, individuals with obesity demonstrate impaired balance recovery following postural instability. Weight reduction, achieved through either hypocaloric intervention or bariatric surgery, has been associated with improvements in balance control parameters, including center of pressure displacement speed and range in both anteroposterior and mediolateral directions[44]. The relationship between obesity and postural stability remains inconclusive. Previous studies have yielded varying findings regarding COP displacement in individuals with obesity compared to normal-weight controls. While some research has indicated no significant differences in mediolateral COP sway between these groups[45], others have reported increased COP oscillations in individuals with obesity[47,48]. Furthermore, the impact of weight loss interventions on postural stability parameters, such as COP velocity, has demonstrated inconsistent results, with some studies showing no significant changes following weight reduction[42]. Contrary to expectations, obese women exhibited reduced mediolateral sway compared to their normal-weight counterparts. This counterintuitive finding can be attributed to a compensatory widening of the base of support due to increased body mass and lower limb adiposity. The resulting enhanced lateral stability may mitigate the anticipated risk of falls associated with obesity. These results align with the absence of significant differences in ML sway between overweight and normal-weight participants[42].

Contemporary findings indicate a correlation between increased weight and an anterior shift in the body's center of gravity. This anterior displacement is associated with altered postural control, as evidenced by increased AP center of pressure excursion. However, we observed minimal changes in mediolateral COP displacement in overweight individuals compared to their normal-weight counterparts[49].

Paschalis et al., (2013) proposed that excessive body mass in overweight individuals may contribute to the development of neuromuscular imbalances. These imbalances are likely influenced by alterations in body geometry and posture. Given the critical role of proprioception from leg muscles in maintaining postural stability, reduced position sense in overweight individuals could increase their risk of falls. The study's findings suggest a correlation between abnormal BMI and significant impairments in lower limb proprioception during static conditions [50]. A sedentary lifestyle has been associated with diminished lower limb proprioceptive function, accompanied by reductions in muscle strength and mass, which may subsequently compromise motor control, particularly postural stability [51-53].

This study examined the relationship between weight category and postural stability among adolescents. Findings revealed a significant association between obesity and increased postural sway in both AP and ML directions, indicating poorer balance control compared to normal-weight peers. While obesity typically contributes to postural instability, an unexpected finding was the reduced mediolateral sway in the obese group. This counterintuitive result is attributed to a compensatory widening of the base of support due to increased body mass. These findings underscore the complex interplay between obesity, body geometry, and postural control mechanisms.

A cross-sectional study involving 75 young adults aged 18-23 was conducted to examine postural sway. Participants were categorized into underweight, normal weight, and obese groups based on BMI. Postural sway was assessed under both eyes-open and eyes-closed conditions. While underweight individuals exhibited a predominant AP sway pattern, no significant differences in sway magnitude were observed compared to the normal weight group. These findings suggest a potential association between underweight and altered postural control mechanisms, warranting further investigation into factors such as plantar flexor muscle function[54].

The present findings replicated previous research demonstrating increased AP sway in underweight compared to normal weight individuals. However, in contrast to prior study, we observed a statistically significant divergence in mediolateral sway, with underweight participants exhibiting greater sway than their normal weight counterparts. Paschalis et al., (2013) posit that reduced body mass in underweight individuals may contribute to alterations in foot morphology. Such morphological changes could potentially exacerbate neuromuscular imbalances, thereby increasing the risk of falls and associated injuries in daily life activities[50].

A 30-second quiet standing trial was conducted among 26 adult women classified into four weight categories: obese, overweight, normal weight, and underweight. Analysis of mean velocity revealed significant differences between the underweight group and the other weight categories, except for the obese and overweight groups. These findings align with the study hypothesis, indicating a relationship between underweight status and increased mean velocity during quiet standing[55].

Variations in body mass index have been associated with alterations in muscle tone, which may subsequently influence overall balance [56]. Muscle strength is a critical factor influencing postural stability. Individuals within an ideal BMI range tend to exhibit superior muscle strength compared to those with suboptimal BMI. Consequently, individuals with a healthier body composition often demonstrate enhanced postural balance[56,57]. Underweight due to malnutrition is associated with a reduction in muscle strength[55]. Individuals with suboptimal BMI may exhibit decreased muscle strength, which can subsequently compromise postural balance. Reduced muscle mass, tone, and strength, particularly evident in underweight individuals, can impair proprioception and coordination, leading to increased postural instability [56-59].

Limitations:

The present study, while offering valuable insights, is subject to certain methodological limitations. The cross-sectional design precludes the establishment of causal relationships between weight category and postural stability, necessitating longitudinal studies to elucidate temporal dynamics. Additionally, the focus on a limited set of postural stability parameters may not comprehensively capture the intricate factors influencing balance. Incorporating a broader assessment of postural control would provide a more holistic understanding.

Furthermore, the study did not account for potential confounding variables such as physical activity levels, muscle strength, and neuromuscular factors, which could influence postural stability independently of weight category. The generalizability of the findings may be limited by the specific characteristics of the adolescent population studied.

The mechanisms underlying the observed relationship between weight category and postural stability remain partially understood especially underweight category. Future research should explore the contributions of body fat distribution, alterations in body geometry, and changes in sensory and motor function to postural control in this population. By acknowledging these limitations, future studies can refine research methodologies and delve deeper into the complex interplay between weight category and postural stability.

Conclusion:

This study examined the relationship between different weight categories and postural stability parameters in adolescents. Findings revealed a significant association between obesity, overweight, underweight and increased AP sway, indicating compromised postural control in this population. Also, Obese and underweight adolescents exhibited significantly greater ML sway compared to normal-weight peers. Adolescents, particularly those with underweight or overweight status, demonstrated compromised postural stability compared to their normal-weight peers. These findings underscore the importance of comprehensive postural assessments as part of routine healthcare for this age group. To mitigate the heightened fall risk associated with postural instability in obese adolescents, targeted interventions such as balance training, core strengthening exercises, and weight management strategies are recommended. Healthcare providers should incorporate these strategies into their care plans.

Further research is imperative to elucidate the underlying mechanisms linking weight status and postural control. This knowledge will inform the development of tailored interventions aimed at improving postural stability across the weight spectrum.

ABBREVIATIONS

AP: anterior-posterior, BMI: body mass index, CDC: Centers for Disease Control and Prevention, COP: center of pressure, ML: mediolateral.

DECLARATIONS:

Ethics approval and consent to participate

This study adhered to the ethical principles outlined in the Declaration of Helsinki (1975). Prior to participation, all subjects provided written informed consent after a comprehensive explanation of the study procedures. Ethical approval was granted by the Ethics Review Committee for Human Research at Delta University for Science and Technology's Faculty of Physical Therapy, Egypt. Participants were assured of their right to withdraw from the study at any point without incurring negative consequences.

Consent for publication

NA

Availability of data and materials

The data underpinning this study are accessible upon reasonable request from the corresponding author.

Competing interests

The authors declare no competing financial interests.

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The authors declare no competing financial interests regarding the research presented in this manuscript.

Authors' contributions

Amira H. Mohammed, Dina S. Noaman and Mohamed N. Al Khouli, and were involved in study conception and design, as well as implementation, analysis and interpretation of data, and manuscript preparation. Dina S. Noaman and Amira H. Mohammed, carried out the experiments and made substantial contributions to the drafting of the article and design of the study. Amira H. Mohammed, Dina S. Noaman and Mohamed N. Al Khouli, and Dina S. Noaman made the analysis and interpretation of the data and revised the article. All authors have reviewed and approved the final manuscript.

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