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Original Article

Association of the body mass index with the overall stability index in young adult Saudi males

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الملخص

أهداف البحث: ركزت الدراسات على البدانة الناجمة عن عدم استقرار الإتزان لدى كبار السن، في حين لم تتم دراستها لدى الشباب. تهدف هذه الدراسة لتحديد تأثير البدانة على استقرار الإتزان الحركي عند الذكور من الشباب السعوديين.

طرق البحث: أجريت دراسة مقطعية على ٧٠٤ من الشباب الذكور تتراوح أعمارهم بين ١٨ و ٣٥ عاما من جامعة أم القرى، مكة المكرمة، المملكة العربية السعودية. تم تقييم الإتزان الناجم عن البدانة باستخدام جهاز نظام الإتزان "بايودكس" ذي القرص المتحرك، وتم حساب مؤشر الثبات الكلي كدلالة على مقدار الإتزان الحركي كما أُعتُبِر المشاركون ذووا مؤشر كتلة الجسم أعلى من ٣٠ كغم/م٢ بدناء.

النتائج: كان متوسط أعمار ومؤشر كتلة الجسم للمشاركين ٢٠ عاما و ٢٥,٦ كغم/م٢، على التوالي. وكان متوسط مؤشر الثبات الكلي لكامل العينة ٠,٩ وقيمته تزداد بشكل ملحوظ كلما زاد مؤشر كتلة الجسم. كما كان الارتباط المعدل بين مؤشر الثبات الكلي ومؤشر كتلة الجسم ٠,٤٨٧. وبينت نتائج الانحدار اللوجستي أن كل زيادة وحدة في مؤشر كتلة الجسم، يرافقها زيادة متوقعة ٠,١١٥ وحدة في قيمة مؤشر الثبات الكلي. وأظهر منحنى تشغيل الجهاز أن القيمة المثلى لنقاط الفصل للوزن ومؤشر كتلة الجسم للحصول على أفضل قيم مؤشر الثبات الكلي عند ١٨,٨ كغم/م٢ و ٥٤,٥ كغم، على التوالي، مع قيم حساسية ونوعية عالية. بالإضافة، فإن مؤشر كتلة الجسم يؤثر بنسبة ٢٣٪ تقريبا من التباين الكلي على الإتزان.

الاستنتاجات: للبدانة تأثير واضح على الإتزان الحركي لدى الشباب الذكور في الدراسة. ينبغي تشجيع برامج خفض الوزن للأشخاص البدناء لتحسين مؤشر كتلة الجسم والوزن، التي يمكن أن تحافظ على استقرار الإتزان.

الكلمات المفتاحية: الإتزان؛ البدانة؛ مؤشر الثبات الكلي؛ برنامج خفض الوزن؛ مؤشر كتلة الجسم

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Abstract

Objectives: Studies have focused on obesity-induced balance instability in the older population, which has been understudied in young adults. This study aimed to determine the impact of obesity on dynamic balance in young adult Saudi males.

Methods: A cross-sectional study of 704 young adult males aged between 18 and 35 years from Umm Al-Qura University, Makkah, KSA, was performed. The obesity-induced balance was evaluated with a Biodex Balance System apparatus with a movable platform, and the overall stability index (OSI) was measured as an indicator of dynamic balance. Participants with a body mass index (BMI) $\geq$30 kg/m^2 were considered obese.

Results: The mean age and BMI of the participants was 20 years and 25.6 kg/m^2, respectively. The mean OSI of the entire sample was 0.9, and the OSI values increased significantly ($p < 0.001$) with increasing BMI. The adjusted correlation between OSI and BMI was 0.487 ($p < 0.001$). Logistic regression showed that for each one-unit increment in BMI, there was an expected rise of 0.115 units in the OSI value. The receiver operating characteristic curve showed that the optimal threshold of the weight and BMI cutoff points that optimized the OSI values were 18.8 kg/m^2 and 54.5 kg, respectively, with high sensitivity and specificity values. In addition, BMI affected approximately 23% of the total variability on balance (partial eta squared = 0.227, $p < 0.001$).

Conclusion: Obesity has a clear impact on dynamic balance in the selected young males. Weight management

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programs for obese subjects should be encouraged to optimize BMI and weight, which can attenuate balance stability.

Keywords: Balance; Body mass index; Obesity; Overall stability index; Weight management program

Introduction

Obesity is an epidemic health concern with a growing trend in incidence worldwide.[1] KSA is considered one of the leading countries in obesity prevalence. A recent cohort survey in KSA indicated that 28.7% of the adult population, or 3.6 million individuals, were obese.[2] Obesity is a risk factor for numerous health consequences, such as diabetes, hypertension, cancer, ischemic heart disease, stroke, asthma, and polycystic ovary syndrome.[3] Balance instability is considered to be another health problem that is relevant to obesity in any age group, especially in developing countries.[4]

Balance and postural stability may be sustained by the complete coordination of inputs from visual, vestibular, and somatosensory systems into the central nervous system for static or locomotion equilibrium. Any factor that affects this equilibrium disrupts the balance and causes postural sway.[5] Balance is greatly affected by weight in adulthood,[6–10] and even in childhood.[11,12] Ku et al.[13] affirmed that obese adults exhibited poorer balance performance and more postural sway than normal and underweight subjects. Greve et al.[4] demonstrated that general stability index had a significant positive correlation with postural instability on the dominant ($r = 0.723$) and non-dominant ($r = 0.705$) sides. In addition, obese children were found to be more exposed to balance instability in terms of medial/lateral direction and extended postural sway than lean children.[12–14] Several studies also demonstrated the negative outcome of weight on balance stability for the elderly, since the risk of falling is one of the main problems in this age group.[15–17] Many clinical instruments exist for the assessment of balance stability, and one of them is the Biodex Balance System (BBS) device.[13] Various reliable and convenient measures can be obtained by BBS; however, the overall stability index (OSI) is considered to be a superior indicator of dynamic balance.[13]

Among young boys, obesity not only reduces motor skills but also verbal and social skills and daily life activities, such as standing and sitting.[11,12] However, to our knowledge, no detailed research has attempted to explain the correlation between obesity and dynamic balance in young adults. Moreover, the optimal weight and body mass index (BMI) that will increase balance stability has not been covered. Therefore, the determination of the impact of obesity on dynamic balance at earlier ages is worthy of attention to diminish and possibly recover the undesirable outcomes that worsen with age. This paper investigates the impact of obesity on the OSI of asymptomatic young adult males from Western KSA, and determines the optimal BMI and weight cutoff points that maximize balance stability.

Materials and Methods

Participants

From November 2013 to April 2014, 704 adult male students and staff members from Umm Al-Qura University (Makkah, KSA) were recruited for this observational cross-sectional study. The majority of the sample was selected from the first-year students at the university. Inclusion criteria included: Saudi men aged between 18 and 35 years old, and participants free from any disease that affected balance stability. Exclusion criteria included: having one or more diseases, such as a disturbance in proprioceptive sensation, any vestibular disease, muscle tone disturbance, cardiovascular disease, diabetes, any neurological or autoimmune disease, metabolic bone disease, hypercortisolism, malignancy, and malabsorption; the use of medications that influence bone metabolism or interfere with balance stability. According to the previous exclusion criteria, five participants were excluded at the onset of this study: two diabetic patients, one with rheumatoid arthritis, and two other participants who used high doses of vitamin D supplementation.

Participants in this study were categorized based on their BMI (kg/m^2). A subject with a BMI $\geq$ 30 kg/m^2 was considered obese, while overweight was defined as a BMI between 25 kg/m^2 and <30 kg/m^2. Normal weight was recognized as a BMI between 18 kg/m^2 to <25 kg/m^2, and a BMI < 18 kg/m^2 was defined as underweight.[18] A Detecto physician's scale was used to measure weight and height to the nearest one decimal, then BMI was calculated by dividing the weight in kilograms by the height in meters squared.

Dynamic balance measurement

A biomechanical assessment of stability was performed with the BBS apparatus (BBS-SD, 950-441 model, Jan-2013, Shirley, NY, USA) with a movable platform. The OSI parameter was measured in eligible participants as an indicator of dynamic balance, which denotes deviations from a standard level of force platform in both sagittal and frontal body planes.[19] The higher the OSI values, the lower the dynamic balance stability.[20]

Dynamic balance (OSI) was determined according to the Biodex Fall Risk Assessment Program settings as found in the device's instruction manual. The conditions that were tested in this study were: bilateral stance, eyes open, stability level 8 (12 is the most stable level), 10° slope in each foot angle, and three repeated trials for 20 s with a 30-s break between trials. The normal OSI value for the studied age group from 18 to 35 years is 0.82–2.26.[21] Balance instability was considered in participants with an OSI value higher than 2.3.[19]

Statistical analysis

Statistical analyses were performed with SPSS version 20, and significant data were determined as having *p*-values less than 0.05. The *p*-value between groups and the pairwise comparison of groups was obtained with the Kruskal—Wallis test and the Mann—Whitney U test, respectively, for non-parametric data. Correlations between OSI and other independent variables were evaluated with the linear regression test (Beta Standardized Coefficients), then adjusted correlations for age and BMI were obtained. The overall estimate of effect size as partial eta squared (partial η^2) for weight and BMI variables on OSI values was achieved with a univariate general linear test (full factorial model). Logistic regression was used to determine the odds ratio (OR) and 95% confidence interval (CI) for BMI and weight as predictors of dynamic balance instability. In addition, ROC curve (receiver operating characteristic) analysis was used to determine the optimal threshold of weight and BMI cutoff points that optimized OSI values. The area under the curve (AUC), sensitivity, and specificity were all determined with the ROC curve.

Results

Table 1 shows the characteristics of the study group based on BMI. Overall, 20.6% (n = 145) of participants were obese, and 24.7% (n = 174) were overweight. The mean OSI for the entire sample was 0.9. No significant differences were observed in age and height within the different groups. On the other hand, OSI values exerted highly significant ($p < 0.001$) differences among groups. Compared to other groups, OSI for the obese group demonstrated the highest significant value ($p < 0.001$). Figure 1 illustrates the boxplots for the OSI values of studied groups. Median OSI values (interquartile range) were 1.2 (0.9—1.5) for the obese group, 0.8 (0.7—1.0) for

Table 1: Characteristics of the study sample (n = 704) according to BMI categories (mean ± SD).

Parameter	Total (n = 704)	BMI group				*p*-Value
		Underweight (n = 59)	Normal (n = 326)	Overweight (n = 174)	Obese (n = 145)	
Age (years)	20.0 ± 1.6	19.7 ± 1.0	19.8 ± 1.2	19.9 ± 1.4	20.5 ± 2.6	0.378
OSI (min, max)	0.9 ± 0.4 (0.3—3.2)	0.7^{a} ± 0.3 (0.3—1.5)	0.8^{ab} ± 0.4 (0.3—2.2)	0.9^{b} ± 0.3 (0.4—3.2)	1.3^{c} ± 0.6 (0.5—3.2)	<0.001

p-Value was determined with the Kruskal—Wallis test. Letters with different superscripts in the same row are significantly ($p < 0.05$) different according to Mann-Whitney U test.
Abbreviations: OSI, overall stability index; BMI, body mass index.

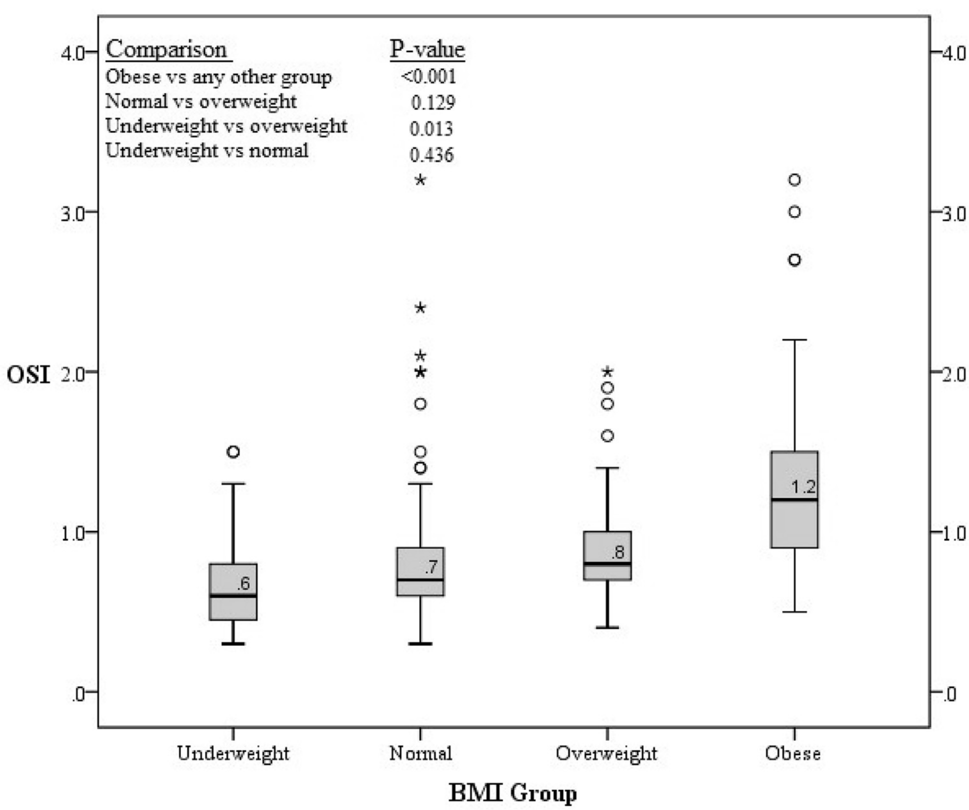

Figure 1: Boxplots of median OSI values according to BMI categories and interquartile ranges.

overweight subjects, 0.7 (0.6–0.9) for normal weight subjects, and 0.6 (0.5–0.8) for underweight participants. However, the obese group presented with the highest significant ($p < 0.001$) median OSI and interquartile limits compared to the other groups. Regarding frequencies according to OSI categories, normal OSI values were found in 56.1% (n = 395) of the total sample, while below and greater than normal OSI values were noticed in 43% (n = 303) and 0.9% (n = 6) of the population, respectively. Only six participants showed balance instability (OSI > 2.3), and hence disproportional groups appeared as a result.

Correlations between OSI and other variables are revealed in Table 2. OSI values showed significant ($p < 0.05$) positive correlations with all uncontrolled variables (age, weight, height, and BMI). Adjusted correlations showed positive correlations with weight (r = 0.55, $p = 0.001$) and BMI (r = 0.487, $p < 0.001$), but age and height did not exert significant correlations after adjustment. Furthermore, Figure 2 demonstrates the correlation curve between OSI and BMI, which showed solid positive and significant correlations ($r^2 = 0.246$ and adjusted $r^2 = 0.244$, $p < 0.001$). The estimate of effect size, as measured by partial η^2, for weight was 0.231 ($p < 0.001$) and for BMI was 0.227 ($p < 0.001$), but age (partial $\eta^2 = 0.004$, $p = 0.233$) and height (partial $\eta^2 = 0.001$, $p = 0.962$) showed no significant outcomes.

Table 3 displays the logistic regression for BMI and weight as predictors for abnormal dynamic balance. Compared to normal OSI subjects, respondents with lower than normal OSI values had an OR = 0.857 (95% CI: 0.818–0.898, $p < 0.001$) and a beta coefficient of −0.154, while participants with greater than normal OSI values had an OR = 1.122 (95% CI: 1.016–1.238, $p = 0.022$) and a beta coefficient of 0.115. Regarding weight, the ORs for respondents with OSI values that were lower and higher than normal were 0.948 (95% CI: 0.934–0.963, $p < 0.001$) and 1.039 (95% CI: 1.008–1.071, $p = 0.014$), respectively, compared to normal OSI subjects. The corresponding beta coefficients for previous groups were −0.053 and 0.038, respectively.

Figure 3 exhibits the optimal weight and BMI cutoff points for obtaining optimum balance stability according to the ROC curve analysis. The optimal weight cutoff

Table 2: Correlations between OSI and other independent variables (n = 704).

Independent variable	Unadjusted β (*p*-value)	Adjusted β (*p*-value)
Age (year)	0.135 (0.009)	0.052 (0.261)
Wt (kg)	0.517 (<0.001)	0.55 (0.001)
Ht (cm)	0.184 (<0.001)	0.13 (0.346)
BMI (kg/m^2)	0.496 (<0.001)	0.487 (<0.001)

Correlation: the Beta Standardized Coefficient (β) was determined with a linear regression test. The dependent variable is OSI.
Adjusted correlations were performed for age and BMI.
Abbreviations: Wt, weight; Ht, height; BMI, body mass index.

Table 3: Logistic regression for BMI and weight as predictors for abnormal dynamic balance.

Dependent variable	Covariate	B	OR	95% CI	*p*-Value
OSI lower than normal	BMI	−0.154	0.857	0.818–0.898	<0.001
	Weight	−0.053	0.948	0.934–0.963	<0.001
OSI greater than normal	BMI	0.115	1.122	1.016–1.238	0.022
	Weight	0.038	1.039	1.008–1.071	0.014

The reference category: normal OSI.
Abbreviations: OR, odds ratio; CI, confidence interval.

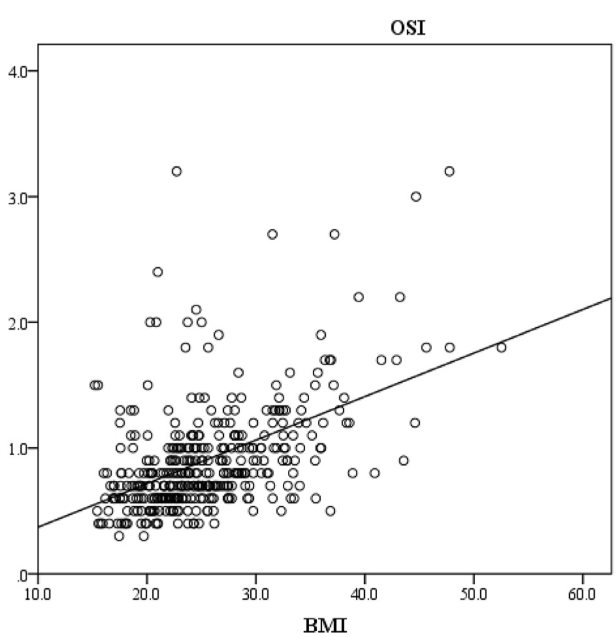

Figure 2: Correlation curve between BMI and OSI values.

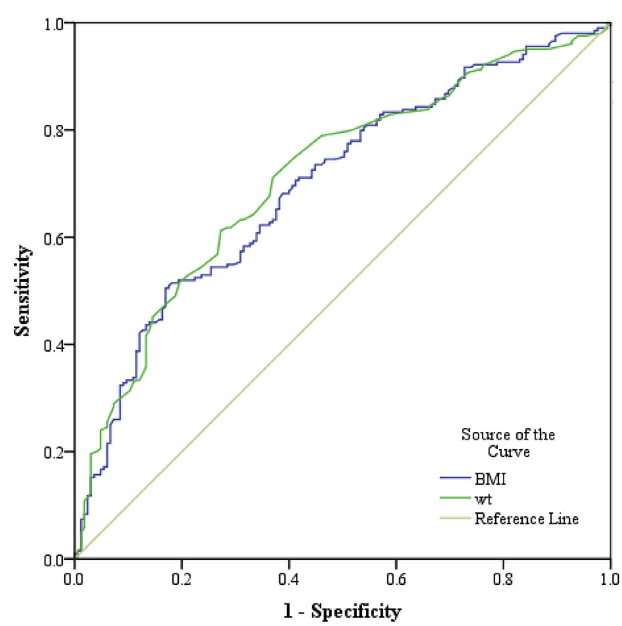

Figure 3: ROC curve of BMI and weight for the identification of optimal stability.

point was 54.5 kg (AUC = 0.713, 95% CI = 0.66−0.765, sensitivity = 0.941, specificity = 0.812, p-value < 0.001), whereas the optimal BMI cutoff point was 18.8 kg/m^2 (AUC = 0.699, 95% CI = 0.646−0.752, sensitivity = 0.931, specificity = 0.836, p-value < 0.001).

Discussion

In this paper, we investigated the impact of obesity on dynamic balance as determined by OSI values in young adult Saudi males. Obese participants showed the highest mean and median OSI values compared to other BMI groups. Additionally, a significant positive correlation was found between OSI and BMI, which indicated that obesity increased OSI values and, consequently, decreased dynamic balance.

Although the BBS device has different balance parameters, such as postural stability, anterior−posterior stability index, and medial−lateral stability index, the authors in this study decided to use the OSI value for several reasons, including: i) it is the best parameter for overall balance measurement,[20] and simultaneously measures the anterior/posterior and medial/lateral directions[19]; ii) it has the highest reliability value compared to other balance measures[21]; and iii) it has a normative range (0.82−2.26) for the selected age group (18−35 years).[19]

Study results found that 20.6% and 24.7% of the respondents were obese and overweight, respectively. KSA is considered one of the top 10 countries in the world with respect to rising obesity.[22] A recent cohort study in young Saudis found that the occurrence of obesity in men was 13.9% and that 24.9% of the population was overweight.[23] Globally, in 2014, the WHO[24] reported that 11% of adult men were obese, and approximately 38% were overweight. There is no doubt that obesity is a global threat with expanding possibilities over the succeeding years. Accordingly, health consequences that are related to obesity are expected to increase, and dynamic balance will be substantially affected.

The mean OSI value of the whole sample represented a stable dynamic balance group (Table 1), mostly due to the age of the participants, which ranged between 18 and 35 years. Nevertheless, only six participants showed unstable balance (OSI > 2.3) as seen in Figure 2, and 4 of them were obese. Excessive fat accumulation, as indicated by a higher BMI, led to balance impairment in many investigations, as discussed earlier.[6−10] This consequence might be related to the generated ankle torque, which is associated with the distance between the ankle joint and the center of mass (COM). This distance is positively correlated with the generated ankle torque to achieve stable balance,[24] and obese participants with a larger distance showed greater corrective ankle torque to exert a normal stance than that required by lean participants.[6,25] Therefore, impaired balance is the ultimate outcome of excessive fat accumulation. Among this age group, the overall influence of BMI on balance was approximately 23% (partial η^2), which was a huge contribution to balance stability, while age and height did not exert this effect. Simoneau and Teasdale[26] measured the center of pressure (COP) speed as the final yield from ankle torque. They found that the COP speed in obese participants (0.84 cm/s ± 0.2) was significantly higher than that in the control group (0.61 cm/s ± 0.1). In addition, the net ankle torque value was significantly developed in obese subjects compared to participants of normal weights. Morbidly obese participants also exhibited a significantly greater COP speed and net ankle torque than both the obese and control groups.[26] Previous researchers have concluded that motor balance commands are commonly affected by fat deposition in a linear relationship.[26] Recent research has discussed the correlation between body fat percentages (% Fat_{TOTAL}) and postural control in young adults with a mean age of 24 ± 4 years,[27] and showed that a higher % Fat_{TOTAL} was associated with a significant increase in anteroposterior path length, larger COP areas, and lower ankle-hip strategy-scores. The preceding parameters demonstrate that the higher the total body fat of young adult, the lower the postural balance.

The logistic regression (Table 3) results demonstrated that for each 1 kg/m^2 increment in the BMI, the OSI value would be expected to rise by 0.115 units. Conversely, a decrease in BMI by 1 kg/m^2 was predicted to improve OSI by 0.154 units. Weight also displayed similar results in which each 1 kg increase in weight was associated with an increase in OSI by 0.038 units, and each 1 kg decrease in weight was related to a decrease in OSI of 0.053 units. The finding that weight control is a protective factor for balance stability has been confirmed by other researchers.[28,29] Teasdale et al.[30] showed a significant correlation between weight reduction and balance stability with an adjusted $r^2 = 0.65$ ($p < 0.001$). Similarly, a significant correlation between lower weight and general stability (r = 0.445, p = 0.015) was observed in obese children between 6 and 14 years old who joined a 6-month exercise program.[31] In agreement with the previous findings, the results of our ROC analysis (Figure 3) suggested that to obtain optimum balance stability for the selected sample, BMI should be as low as 18.8 kg/m^2, or weight should be 54.5 kg. Optimal cutoff points were measured according to the method described by Akobeng[32] as the Youden index. The sensitivity of the optimal BMI cutoff point was 93.1%, and the specificity was 83.6%, while the sensitivity and specificity for the optimal weight cutoff point were 94.1% and 81.2%, respectively. An AUC between 0.7 and 0.9 characterizes moderate accuracy,[32] and both variables showed reasonable accuracy for describing optimal balance stability. Therefore, effective weight loss programs should be adopted to address body weight, and hence augment physical fitness and balance stability.

Limitations

This study is limited in that it did not include females, the population was not heterogeneous, and other balance parameters could be measured as anterior/posterior and medial/lateral stability indices.

Conclusions

Based on the study results, obesity has a critical impact on dynamic balance in young adult males from Western KSA. The increasing burden of obesity over time, mainly in Middle

Eastern countries, could affect the daily activities and injury incidence of obese individuals, even in younger age groups.

Ethical approval

This study was approved by the Umm Al-Qura University Ethical Committee (approval number ASE-21-2013) based on the Helsinki Declaration.

Consent

Informed consent was obtained from all of the individual participants that were included in the study.

Authors' contributions

OAK and EMA conceived and designed the study. EMA, FSA, and OFH conducted the research, provided research materials, and collected and organized data. FSA and OFH analyzed and interpreted the data. FSA and OAK wrote the initial and final drafts of the article and provided logistic support. All of the authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Conflict of interest

The authors have no conflict of interest to declare.

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