Original Article



# Associations of obesity with balance and gait among young adults in Bangladesh

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**Background:** Obesity decreases balance capacity and impairs gait quality of an individual, mostly the older ones. We aimed to investigate the associations of obesity with balance and gait among young adults, which are quite limited.

**Methods:** An analytical cross-sectional study was conducted among a total of 60 obese [body mass index (BMI) ≥30.0 kg/m$^2$] and normal weight (BMI 18.5–24.9 kg/m$^2$) young adults (aged 20–40 years) in Dhaka city. The sex-matched normal weight participants were deliberately selected equal as many as obese (1:1) using a convenience sampling method. Functional reach test for the forward balance, and footprint method for step length, step width and foot angle in terms of spatio-temporal characteristics of gait, and a clinical assessment for gait abnormalities were executed to assess overall balance and gait. The outcomes were the lower forward balance and step length, and higher step width and foot angle for those who (for both groups) had respective values < mean − 1SD and > mean + 1SD, respectively, compared to the sex-specific cut-off points as the references (≥ mean − 1SD and ≤ mean + 1SD, respectively) derived from normal weight participants. Both univariable and multivariable logistic regression analyses were performed.

**Results:** Age- and occupation-adjusted odds of lower forward balance was 8.9 (95% CI: 2.5–32.4) times; occupation-adjusted odds of lower step length and higher foot angle were 7.7 (95% CI: 2.2–27.8) and 142.3 (95% CI: 12.1–1,667.1) times, respectively; and unadjusted higher step width was 91.0 (95% CI: 15.4–539.3) times statistically significantly higher in obese, compared with normal weight participants.

**Conclusion:** Obesity is substantially associated with balance and gait among young adults in Bangladesh.

**Keywords:** Associations; obesity; balance; gait; young adults; Bangladesh

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## Introduction

Obesity is a global epidemic, and is one of the major intermediate risk factors of chronic noncommunicable diseases (1), including several types of musculoskeletal disorders (2,3). Excessive fat accumulation especially in the abdominal area in obesity causes abnormally increased lordotic curvature, followed by a disturbance in the weight shifting and faulty biomechanics (4-6). These altered biomechanics causes postural instability, and ultimately leads to improper balancing capacity as well as discoordination in the gait patterns (3-7). Consequently, obesity is linked to high chance of fall and fall-related injuries and disabilities (8-10).

Although, older obese individuals are more prone to be affected by obesity induced impaired balance, falls, injuries, and disabilities (10,11), young adult obese are not an exception (6,12,13). Poor posture, balance, and gait have been reported among obese young adults also (6,12,13). However, the association of obesity with balance and gait among healthy young adult individuals, most importantly eliminating the potential biological, sociodemographic, and behavioral risk factor's effects is quite limited. There is no relevant information exploring the association of obesity with balance and gait in Bangladesh also, based on the available published data. Overweight and obesity is an emerging public health problem in Bangladesh. Nearly one in every five (20%) adults is overweight or obese here (14-16). This study was designed to assess the associations of obesity with balance and gait pattern among young adult individuals in Bangladesh.

We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/jxym-21-19).

## Methods

### *Design, settings, and participants*

It was an analytical cross-sectional study, conducted in 2015 in Dhanmondi area of Dhaka North City Corporation. We recruited a total of 30 obese (men 15; women 15) and 30 normal weight (men 15; women 15) young adult participants aged between 20 to 40 years. We deliberately selected equal (1:1) as many normal weight participants as obese participants and also as many men as women in each group considering the sex-matched equal comparison subjects. Young adults are defined as those who are aged between 20–45 years, according to Erikson's theory (17). However, we restricted the age within 20–40 years in our study considering the substantial increase of degenerative changes after 40 years of age (18), assuming consequential aging effect on our study problem. Participants were selected following a convenience sampling technique. Participants who were able to stand and walk normally without support, had full range of motions in the shoulder, hip, knee and ankle joints were included in this study. Conversely, those who had a history of chronic conditions (such as musculoskeletal disorders and type II diabetes mellitus), neurological disorders (such as stroke, brain and spinal cord injury), any amputation, contracture or deformity in the upper and/or lower limb(s), any kind of visual impairments and also pregnant women were excluded.

### *Exposure, outcomes, and other covariates*

The primary exposure was obesity, measured using body mass index (BMI). Obese (BMI ≥30.0 kg/m$^2$) and normal weight (BMI 18.5–24.9 kg/m$^2$) participants (using WHO criteria for BMI classification (19), were regarded as the exposed and unexposed participants, respectively. Participant's weights and heights measured by standard guidelines (20) were used to calculate their corresponding BMIs by dividing their weights in kg with the square of heights in meter (19). The outcomes were the lower forward balance, lower step length, higher step width, and higher foot angle. And, the participant's demographic and behavioral risk factors (detailed in the following "data collection instruments and methods" section) were regarded as the covariates.

### *Data collection instruments and methods*

We developed a semi-structured questionnaire adapted from the relevant available literatures. The questionnaire was comprised of socio-demographic information (such as sex, age, and occupation), behavioral risk factors (such as smoking, alcohol consumption, and regular physical exercise), anthropometric measurements (such as height and weight), balance, spatio-temporal characteristics of gait, and gait evaluation. We pre-tested the questionnaire before the final data collection with the subject equivalent to 10% of the total estimated samples. Participants were asked about their demographic, and behavioral risk factors related information. Details of the other methods are as following.

#### Balance testing

Functional reach test (FRT) was used to assess the forward balance. A leveled yardstick was mounted on the wall and positioned at the height of the participant's acromion. To measure the forward balance, participants were instructed to stand sideward next to the wall (without touching), feet with normal stance width and weight equally distributed on both feet. Then they were instructed to flex the shoulder at 90 degree and extend the elbow, wrist, metacarpophalangeal and inter-phalangeal joints. An initial measurement was taken for the position of the tip of the 3rd finger along the yardstick and recorded. Then, they were instructed to lean forward as far as possible without losing balance or taking a step, and the 2nd measurement was taken in the same way and recorded. The 2nd measurement was repeated three times for each participant, and the average of the three values was calculated. The initial measurement was then subtracted from the calculated average and finally recorded as the maximum forward balance (12).

**Testing of spatio-temporal characteristics of gait**

Step length, step width, and foot angle were evaluated as spatio-temporal characteristics of gait using the footprint method. At first, the participant's soles of both feet were painted with white color using chalk-powder and water; then they were instructed to walk maintaining their normal rhythm on a 10×3 feet black walking sheet which was printed with multiple evenly distributed parallel and perpendicular lines. As a result, there were clear white impressions of feet printed over the black sheet (21). Then, the step length (the linear distance between the midpoint of heel of one foot and the same point of other foot), step width (also known as walking base; the linear distance between two opposite feet), and foot angle (also known as degree of toe out; the angle between each foot's line of progression and a line intersecting the center of the heel and the second toe) were measured following the standard method and recorded. Foot angles were measured using Goniometer. All the measurements were repeated three times for each participant, and the average values were recorded (12). Printed steps over the middle of the 10-feet black sheet were considered for the measurement to get the normal rhythm of gait resulting normal spatio-temporal characteristics.

**Evaluation of gait**

A clinical assessment of visual observation method was used to evaluate the pattern of gait, such as looking for lordotic gait, excessive lateral pelvic shift, excessive pelvic tilt, and waddling gait.

**Determination of balance and spatio-temporal characteristics of gait as lower and higher**

Firstly, the sex-specific cut-off points were determined for the forward balance, step length, step width, and foot angle using respective mean ± 1SD from the normal weight participants as the respective references. Thereafter, the lower forward balance and step length, and higher step width and foot angle were determined for those who (for both groups) had respective values < mean – 1SD and > mean + 1SD, respectively, compared to the sex-specific cut-off points as references (≥ mean – 1SD and ≤ mean + 1SD, respectively).

***Data processing and statistical analysis***

SPSS software (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) was used for data processing and statistical analyses. Descriptive statistics were used to illustrate the participant's socio-demographic, anthropometric, behavioral risk factors, and recent history of fall related information, and expressed as mean, standard deviation, percentage where appropriate. Inferential statistics such as Chi-square test, Fisher's exact test, and independent sample t-test were executed to see the significant difference between obese and normal weight groups against covariates. Wilcoxon matched pairs test, Chi-square test, and Fisher's exact test were executed to assess the relationships between obesity and all the balance and spatio-temporal gait characteristics where appropriate. Mann-Whitney U tests were done to see the men-women differences for all the characteristics within groups. Univariable binary logistic regression analyses were executed on each variable (i.e., primary exposure and covariates) against all outcome variables, individually, to compute crude odds ratios (ORs) [with 95% confidence intervals (CIs)] and to also assess the association. The covariate(s) which showed a significant or near to significant level of association ($P<0.1$) against each outcome variable, individually, was regarded as the potential confounder(s) in the association between primary exposure and the corresponding outcome variable. Further, multivariable binary logistic regression analyses were executed to explore the association between obesity and each outcome variable, individually, after adjusting for the corresponding confounder(s) to compute adjusted ORs (with 95% CIs). P value <0.05 was considered as the level of statistical significance for all associations of obesity with all outcome variables. Although, all of the data of balance and spatio-temporal characteristics of gait were normally distributed (in terms of Shapiro-Wilk's test, visual inspection of histograms, normal Q-Q plots, box

 

**Table 1** Socio-demographic information and behavioral risk factors among the population (total n=60; obese 30; normal weight 30)

| Characteristics | Normal weight (%) | Obese (%) | P value |
|---|---|---|---|
| Sex (n) | | | |
| Men | 15 | 15 | – |
| Women | 15 | 15 | |
| Age (in years) | | | |
| Mean ± SD | 28.2±3.9 | 32.2±6.0 | 0.004* |
| Less than 30 | 73.3 | 43.3 | 0.018* |
| 30 and above | 26.7 | 56.7 | |
| Occupation | | | |
| Employee | 16.7 | 20.0 | 0.035* |
| Business owner | 0 | 20.0 | |
| Housewife | 46.7 | 43.3 | |
| Others | 36.7 | 16.7 | |
| Height (cm), mean ± SD | 158.2±9.6 | 158.7±8.9 | 0.824 |
| Body mass index (kg/m$^2$), mean ± SD | 22.8±1.8 | 33.9±3.7 | <0.001* |
| History of smoking (current) | | | |
| No | 83.3 | 83.3 | 1.000 |
| Yes (men; women) | 16.7 (33.3; 0) | 16.7 (33.3; 0) | |
| Alcohol consumption (current) | | | |
| No | 90.0 | 83.3 | 0.706 |
| Yes (men; women) | 10.0 (20.0; 0) | 16.7 (33.3; 0) | |
| Regular physical exercise | | | |
| No | 60.0 | 46.7 | 0.301 |
| Yes | 40.0 | 53.3 | |

Chi-square test, Fisher's exact test, and independent sample *t*-test were done where appropriate. The current smokers and alcohol consumers were those who were used to practice these during the study period. Physical exercise was defined as a type of physical activity that is planned, structural and repetitive that intended for physical fitness. Star (*) sign indicates significant differences. SD, standard deviation.

plots as well as skewness and kurtosis) for normal weight participants, however the data of step width and foot angle weren't the same for obese participants.

### *Ethical implications*

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional ethics committee of State College of Health Sciences (ID No. 051610004), Dhaka, Bangladesh. Both verbal and written informed consents were taken from each respondent prior to data collection.

## Results

### *Socio-demographic, anthropometric and behavioral risk factors related information*

The mean ± SD age of obese and normal weight participants were 28.2±3.9 and 32.2±6.0 years, respectively, and there was significant difference (P=0.004). There was also a significant occupational difference between the groups. The mean heights of obese and normal weight participants were 158.2±9.6 and 158.7±8.9 cm, respectively. Alcohol consumption and regular physical exercise behaviors were bit higher in obese compared to their counterparts, however the differences weren't significant (see details in *Table 1*).

### *Inferential analyses: relationship of obesity with balance and gait*

The mean ± SD of forward balance capacity and step length have been found significantly (P<0.05) lower (abnormally) with a significantly (P<0.05) higher (abnormally) mean ± SD of step width and foot angle among obese than the normal weight participants, irrespective of their sex. It has also been found that women had poorer balance and spatio-temporal gait characteristics than men in both groups (details in *Table 2*).

Also, significant relationships of obesity with balance and gait characteristics were found among participants, whereas a vast proportion of the obese participants were found with lower forward balance, lower step length, higher step width, and higher foot angle (details in *Table 3*).

### *Univariable analyses: unadjusted association of obesity with balance and gait*

*Table 4* shows the unadjusted associations of obesity with balance and spatio-temporal gait characteristics. When compared with the normal weight participants, the crude odds of lower forward balance, lower step length,

**Table 2** Mean ± SD of balance and spatio-temporal characteristics of gait among normal weight (total n=60; obese 30; normal weight 30)

| Variables | Normal weight group | | Obese group | | Z [overall (men; women)] | P value [overall (men; women)] |
|---|---|---|---|---|---|---|
| | Overall (men; women) | P value | Overall (men; women) | P value | | |
| Forward balance (inches) | 15.0±1.9 (16.2±1.6; 13.8±1.3) | <0.001* | 12.2±2.3 (13.3±2.2; 11.2±2.0) | 0.015* | −4.119 (−2.840; −2.982) | <0.001* (0.005*; 0.003*) |
| Step length (cm) | 55.2±4.8 (58.4±3.3; 52.0±3.8) | <0.001* | 47.5±5.9 (49.6±5.8; 45.4±5.3) | 0.059 | −4.336 (−3.239; −2.826) | <0.001* (0.001*; 0.005*) |
| Step width (cm) | 10.1±2.3 (10.4±2.1; 9.8±2.4) | 0.371 | 14.4±2.0 (15.2±2.2; 13.6±1.3) | 0.022* | −4.661 (−3.297; −3.298) | <0.001* (0.001*; 0.001*) |
| Foot angle (degree) | 7.8±2.0 (8.0±2.1; 7.5±1.9) | 0.405 | 13.1±2.7 (13.9±2.8; 12.3±2.4) | 0.157 | −4.722 (−3.408; −3.295) | <0.001* (0.001*; 0.001*) |

Wilcoxon matched pairs tests were done for balance and spatio-temporal characteristics of gait between obese and non-obese groups (overall and sex-specific). Mann-Whitney U tests were done to see the men-women differences within groups. Forward balance denoted maximum forward leaning capacity without losing control; step length denoted the linear distance between the midpoints of two heels; step width denoted the linear distance between two opposite feet; and foot angle denoted the angle between foot's line of progression and the line intersecting the center of the heel and second toe. Star (*) sign indicates significant differences. SD, standard deviation.

**Table 3** Relationship of obesity with balance and gait characteristics among the population (total n=60; obese 30; normal weight 30)

| Balance and spatio-temporal gait characteristics (only the "yes" outcomes were counted within groups) | Obesity exposer | | P value |
|---|---|---|---|
| | Normal weight, n (%) | Obese, n (%) | |
| Lower forward balance (<13.1 inch) | 6 (20.0) | 22 (73.3) | <0.001* |
| Lower step length (<50.4 cm) | 6 (20.0) | 22 (73.3) | <0.001* |
| Higher step width (>12.4 cm) | 4 (13.3) | 28 (93.3) | <0.001* |
| Higher foot angle (>10.1 degrees) | 5 (16.7) | 28 (93.3) | <0.001* |

The outcome variables were binary ("No" and "Yes"). "Yes" outcomes were determined based on the higher (> mean + 1SD) or lower (< mean − 1SD) values of balance and spatio-temporal gait characteristics. P values were obtained from Chi-square test and Fisher's exact test where appropriate. Star (*) sign represents significant difference.

**Table 4** Crude and adjusted odds ratios of balance and spatio-temporal gait characteristics by obesity (total n=60; obese 30; normal weight 30)

| Balance and gait characteristics (OVs) | Obesity exposure | Crude (unadjusted) | | Adjusted for corresponding confounder(s) if any | |
|---|---|---|---|---|---|
| | | OR | 95% CI; P value | OR | 95% CI; P value |
| Lower forward balance (<13.1 inch) | Normal weight | Reference | | Reference | |
| | Obese | 11.0 | 3.3–36.8; <0.001* | 8.9 | 2.5–32.4; 0.001 |
| Lower step length (<50.4 cm) | Normal weight | Reference | | Reference | |
| | Obese | 11.0 | 3.3–36.8; <0.001* | 7.7 | 2.2–27.8; 0.002 |
| Higher step width (>12.4 cm) | Normal weight | Reference | | Reference | |
| | Obese | 91.0 | 15.4–539.3; <0.001* | – | – |
| Higher foot angle (>10.1 degrees) | Normal weight | Reference | | Reference | |
| | Obese | 70.0 | 12.5–393.4; <0.001* | 142.3 | 12.1–1,667.1; <0.001 |

Association of obesity with lower forward balance was adjusted for age and occupation; and lower step length and higher foot angle were adjusted for occupation. The outcome variables were binary ("No" and "Yes"). "Yes" outcomes were determined based on the higher (> mean + 1SD) or lower (< mean − 1SD) values of balance and spatio-temporal gait characteristics. Star (*) sign represents significant difference. OVs, outcome variables; OR, odds ratio; CI, confidence interval.

higher step width, and higher foot angle were statistically significantly 11.0 (95% CI: 3.3–36.8), 11.0 (95% CI: 3.3–36.8), and 91.0 (95% CI: 15.4–539.3), 70.0 (95% CI: 12.5–393.4) times higher, respectively, in obese participants.

### *Univariable analyses: associations of covariates with balance and gait (exploration of confounders)*

There were several covariates remarkably associated (P<0.1) with balance and gait characteristics, individually, which were regarded as the potential effect modifiers (confounders) in the association between obesity and the corresponding balance and gait characteristics. When compared with younger participants (aged below 30 years), the older aged had potentially higher crude odds [OR (95% CI); P value] of lower forward balance [2.5 (0.89–7.28); 0.083]. Compared with "others" occupational category, odds of lower forward balance was potentially higher in business owners [11.0 (1.01–120.4); 0.050], odds of lower step length was potentially higher in employees [5.3 (0.99–27.9); 0.052], and odds of higher foot angle were potentially higher in business owners [11.0 (1.01–120.4); 0.050] and also housewives [3.2 (0.87–11.8); 0.081]. No further potential associations were found as confounders in this study (not shown in table).

### *Multivariable analyses: adjusted association of obesity with balance and gait*

*Table 4* also shows the adjusted [for the corresponding confounder(s)] associations of obesity with balance and gait characteristics. Here, compared with the normal weight participants, the adjusted (for age and occupation) odds of lower forward balance was statistically significantly 8.9 (95% CI: 2.5–32.4) times higher in obese participants. The adjusted (for occupation) odds of lower step length and higher foot angle were statistically significantly 7.7 (95% CI: 2.2–27.8) and 142.3 (95% CI: 12.1–1,667.1) times higher, respectively, in obese compared with the normal weight participants.

### *Gait evaluation*

It has also been observed that all of the obese had lordotic and waddling gait. Conversely, none of the normal weight participant had any. Again, excessive lateral pelvic shift and excessive pelvic tilt have been observed more among obese than the counterpart [93.3% *vs.* 13.3% and 90.0% *vs.* 6.7%, respectively (not shown in table)].

## Discussion

Overweight and obesity are now growing concern in Bangladesh (14-16), and related health problems have also been found commonly among them (2). We report here a strong association of obesity with poor balance and gait abnormalities in young adults for the first time in Bangladesh, from our best knowledge based on published data. This study revealed a remarkable vulnerability of obese individuals to poor balance and gait abnormalities.

Obesity interferes the proper interaction of bodily joints and muscles, and significantly changes the way of movements. Excessive adiposity in the abdominal area causes abnormally increased lordotic curvature in lumber the spine. This potential change causes development of faulty biomechanics followed by a disturbance in the proper weight shifting of the body (4-6). Ultimately, the altered biomechanics and disturbed weight shifting cause postural instability that consequence to poor balancing capacity along with arrhythmic gait (3-7).

Our findings are similar to the findings of an Indian study among young adults (12). Shorter step length was also found among Brazilian obese young women than the non-obese women (13). Similar forms of shorter step lengths and larger step widths have also been reported by the studies on US children (22) and Egyptian children (23). Another study in US has reported lordotic gait, excessive lateral pelvic shift, excessive pelvic tilt and waddling gait in adults similar to our study findings (8).

Moreover, the finding of this study potentially reflects that the early young adult individuals aged below 30 years possess the highest level of balance capacity. Woman sex has clearly poorer balance and spatio-temporal gait characteristics, therefore, it is rational and highly recommended to consider the sex-specific cut-off points of lower forward balance, lower step length, higher step width and higher foot angle as the references when further designing the relevant studies. Certain occupations have a negative impact on balance and gait, mostly the business ownership. Employees and housewives are also more prone to have poorer gait characteristics. Almost all of the obese individuals may have any of the gait abnormalities. These sorts of findings will enrich the existing literature in the light of exploring the new information from this Bangladeshi study.

The use of young adults in analytical cross-sectional design provides strength to our study, because the decline in the ability to perform balance-related tests and also poor gait are evidence-based among higher aged individuals (24-28). However, the leg length and standing step width weren't measured in this study that may affect forward balance. Furthermore, there was an absence of a standard for height-specific functional reach balance as well as for spatio-temporal characteristics of gait for young adults, therefore we couldn't use cut-off points as the references. Obesity and also balance and gait variables were measured at the same time, therefore we can't provide solution to the cause-and-effect problem. A cohort design is necessary to answer this research problem more efficiently.

## Conclusions

Current study reports that obesity has a very strong association with balance and gait among young adults in Bangladesh. Pragmatic weight control, balancing exercise, and gait rehabilitation programs are highly recommended for them.

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional ethics committee of State College of Health Sciences (ID No. 051610004), Dhaka, Bangladesh. Both verbal and written informed consents were taken from each respondent prior to data collection.



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