original article

# Balance and musculoskeletal flexibility in children with obesity: a cross-sectional study

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**Citation:** Bataweel EA, Ibrahim AI. Balance and musculoskeletal flexibility in children with obesity: a cross-sectional study. Ann Saudi Med 2020; 40(2): 120-125. DOI: 10.5144/0256-4947.2020.120

**Received:** November 19, 2019

**Accepted:** February 7, 2020

**Published:** April 2, 2020



**Funding:** None.

**BACKGROUND:** Studies on the influence of obesity on different physical parameters such as postural balance and musculoskeletal flexibility are limited and have reported varying results.

**OBJECTIVES:** Measure effect of childhood obesity on balance and musculoskeletal flexibility in Saudi children.

**DESIGN:** Cross-sectional.

**SETTING:** Physiotherapy laboratory.

**SUBJECTS AND METHODS:** The study included a representative sample of Saudi elementary school children selected from a convenience sample of 150 children. Balance was examined using the Biodex balance system. Calf muscle flexibility was measured by the weight-bearing ankle lunge test while the chest flexibility was measured by the chest expansion test.

**MAIN OUTCOME MEASURES:** Postural stability indices and flexibility parameters.

**SAMPLE SIZE:** 90 elementary school children aged 6 to 11 years, 47 of normal weight and 43 obese children.

**RESULTS:** All stability indices at different stability levels were significantly impaired in children with obesity ($P \leq .05$). In terms of musculoskeletal flexibility, the weight-bearing lunge test distance was shorter in children with obesity ($P$=.01). In the chest expansion test, there was no significant difference between the two groups ($P$=.32).

**CONCLUSIONS:** Postural balance at different stability levels was impaired in children with obesity and in all planes. The calf muscles were less flexible in obese children.

**LIMITATIONS:** Unblinded, convenience sample so findings are not generalizable.

**CONFLICT OF INTEREST:** None.

Obesity is one of the most serious health threats.[1] In 2014, the global prevalence of obesity in the adult population aged over 18 was 13%.[2] Moreover, the worldwide prevalence of childhood obesity is increasing quickly. Sedentary lifestyle, unhealthy diet, and psychosocial factors play a crucial role in pediatric weight gain.[3-5]

Researchers have claimed that the anthropometric modifications associated with obesity can alter balance.[6] A study at Al-Imam Abdulrahman Bin Faisal University in Saudi Arabia investigated the effect of obesity on dynamic postural stability in adolescent girls in bipedal stance with their eyes open. This study showed that participants with obesity had significantly higher postural sway scores from the least stable position in the anteroposterior (AP) plane versus normal weight controls. The mediolateral (ML) sways from the most stable position (level 12) were higher in participants with obesity.[7] However, individuals with morbid obesity reacted to postural perturbations somewhat similarly to individuals with normal weight. For instance, there was increased mechanical inertia as body mass index (BMI) increased up to 40 kg/m$^2$ in adult participants; this enhanced postural balance even during perturbation.[8]

A few researchers have found noticeable alterations of calf muscle extensibility and ankle joint kinematics in obese children.[9] These investigators found that obese children exhibited prolonged calf muscle activation that decreased ankle dorsiflexion of about three degrees during gait analysis versus normal weight peers. Moreover, ten children with obesity showed lower extensibility of the ankle dorsiflexion by about 10° from a non-weight-bearing position versus ten healthy weight participants.[9] Other studies have shown that body fat limits the flexibility of the rib cage muscles.[10,11]

In one study Saudi researchers found that chest expansion was inversely related with BMI (subdivided into five groups) and was significantly low in subjects with morbid obesity (mean of 1.89 cm) versus their healthy weight counterparts (mean of 3.06 cm).[11] The volunteers were female adults aged 18 to 44 years in the city of Hail; there is relatively little data on postural balance and musculoskeletal flexibility in obese children. There are conflicting results on the impact of obesity on postural balance.[6-8,12] Research into musculoskeletal flexibility in children is also extremely limited.[10,11]

Many researchers have reported that obese adults had a history of childhood obesity.[13] Therefore, there is a need to evaluate physical health domains such as postural balance and musculoskeletal flexibility in children with obesity from an early age. This data can be used as the basis for future obesity prevention programs including interventional strategies that consider these physical deficits. This study assessed the effect of obesity on postural balance and musculoskeletal flexibility in children with obesity. We hypothesized that obese children will have significantly worse postural balance, physical activity, anaerobic performance, and musculoskeletal flexibility versus normal weight controls.

## SUBJECTS AND METHODS

In this analytic cross-sectional study, a convenience sample of 150 healthy Saudi children ranging in age from 6 to 11 years were screened for eligibility. Participants were screened either via an interview or a medical health screening form completed by their parents. We recruited from seven primary governmental and private schools (from the 1st to 6th grades) at Al Khobar, Dhahran, and Dammam, Eastern Province, Saudi Arabia. Obesity was defined as ≥95th percentile for body mass index (BMI). Participants were divided into children with obesity and children with a normal weight using the universal BMI and International Obesity Task Force cut-off points for children.[14] The normal weight control group had a BMI from the 5th percentile to the 84th percentile and were matched by age, gender, and BMI to the obese group. Severely underweight (BMI <5th percentile) or overweight children (BMI from 85th to 94th) were excluded. Other exclusion criteria were the presence of metabolic, cardiac, neurological, pulmonary, visual, or vestibular disorders, cardiac pacemakers (to avoid any possible damage to the pacemaker by the surrounding electrical devices in the examination lab), and a history of lower limb soft tissue injuries or bone fractures within the past 6 months. Children who received medications that weaken muscles such as anti-spastic, anti-epileptic, or sedative medications within the past 6 months were also excluded. The required sample size was calculated from a Biomath sample size calculator with a significance level ≤.05 and power analysis of 80%. Based on the study conducted by Azzeh et al,[15] the required calculated sample size was 90 children (obese and normal weight).

The parents of all participants gave informed consent. This study was approved by the Institutional Review Board Committee, Deanship of Scientific Research at Imam Abdulrahman Bin Faisal University (IRB-PGS-2017-03-175) and was conducted in accordance with the Declaration of Helsinki 1964 and its later amendments.

The study procedures took place in the female physiotherapy laboratory at the University of Imam Abdulrahman Bin Faisal in Dammam. All measurement procedures were conducted by two physiotherapists who were well trained in the assessment of balance and musculoskeletal flexibility. The data was collected from November 2017 to April 2018. All physical assessments were carried out in a well-lit room and under the supervision of researchers to guarantee participant safety. To avoid participant fatigue, the subject had 5 minutes of rest between the tests and several rest periods between trials of each of the tests. There were no falls during the balance assessment. The physical examination was delivered in an isolated room. Data confidentiality was ensured via a private computer that was accessed only by the authors.

*Anthropometric measurements*

The height, weight, and BMI were measured for all participants using a comfortable digital weight and height scale (Detecto/PD300MHR/USA). The BMI was calculated using the formula: BMI=weight in kilograms / [height in meters]$^2$. The BMI was then referred to the child growth reference as per the International Obesity Task Force for the pediatric population.[14]

*Balance assessment*

All participants received an assessment of postural balance using the Biodex balance system (BBS) (Biodex Inc, 950-302, Shirley, NY). The BBS has a round foot platform that moves in all planes. It grants 20 degrees of foot platform motion in different directions. The platform has foot angles and heel coordinates for proper foot placement before starting the balance test trial. The foot angles range from 0° to 45° and heel coordinates are expressed as the intersection of letters from A to P and numbers from 1 to 21. The participants were asked to centralize their body while they placed their feet in the most comfortable position and their feet 10 cm apart with eyes open. They were asked to hold the rails in case they felt unbalanced. The machine measured the magnitude of their postural sways: higher scores for postural sway indicate impaired balance, and a lower score indicate excellent balance.

The postural stability testing mode in the Biodex system was designed to have moderate to good reliability and validity.[15] The postural stability test mode has three stability indices: mediolateral, anteroposterior, and overall. Each stability index has different levels from level 1 (most dynamic) to level 12 (most static). Two levels of stability were adopted: level 8 (more stable) and level 4 (less stable).[16,17] These indices are the standard deviations and indicate the fluctuations of balance scores from the horizontal level. The participants were instructed to maintain their balance. Children with refractive error were asked to wear their corrective eyeglasses during the balance assessment. The average of three trials was recorded. To avoid fatigue, participants were given a 10-second rest period between the trials as well as a 2-minute rest period between the levels.

*Calf flexibility*

Calf muscle flexibility was evaluated via the validated weight-bearing lunge test (WBLT) from the most functional position.[18] In a standing position, the participants stood 10 cm away from the wall and were then asked to lunge the knee of the tested leg toward the wall; the other leg was extended posteriorly. If they could maintain the tested knee against the wall with the tested foot on the floor (but without moving the tested leg in varus or valgus positions), then they would repeat that test one cm further away from the wall. The maximum distance from the big toe of the tested leg toward the wall was recorded in cm. The average of three attempts was recorded.

*Chest flexibility*

Chest flexibility was assessed by chest expansion (CE) in cm with a tape measure around the upper chest. This test has good intra-rater and inter-rater reliability.[19] In the standing position, the participant put their hands on their head and the measurement of the upper aspect of the chest was taken. The upper chest width was measured from the nipple line toward the fifth thoracic vertebrae. The participants were asked to breathe in from the nose and then out from the mouth forcibly; the chest mobility was assessed with a tape measure. The CE was obtained by subtracting the forced expiration from the forced inspiration, and the mean of three attempts was recorded in cm.

*Statistical analysis*

Statistical analyses were conducted using the IBM SPSS program version 20.00 (Armonk, NY: IBM Corp). Descriptive statistics including mean and standard deviation were obtained for all parameters. The independent *t* test was used to compare the groups with obesity and the group with normal weight with respect to all outcome measures. A 5% level of probability was used to indicate statistical significance.[20]

## RESULTS

Only 98 children of 150 screened children met the inclusion criteria and gave consent. We excluded 8 children because the data was incomplete as they did not attend some measurements. Finally, data of 90 children was included and analyzed in this study. Eight participants were excluded due to missing data leaving 90 participants, including 40 males and 50 females with a mean age of 8.99 (1.54) years (**Table 1**). There were no statistically significant differences between the weight groups for age or gender. All anthropometric characteristics were significantly higher in the obese group ($P \leq .05$). There were no statistically significant differences in mean (SD) BMI between males and females in either the normal or overweight/obese groups (16.2 [1.4] in males and 16.2 [1.1] in females in the normal weight group [$P$=.95]; 26.0 [5.6] in males and 24.9 [3.8] in females in the overweight/obese group [$P$=.44]). In the postural stability indices at stability levels of 8 and 4, the obese children showed a statistically significant deterioration in all postural stability indices (OSI, AP, and ML) ($P<.001$) (**Table 2**). In WBLT for both feet, children with obesity were less flexible than their counterparts with normal weight: right foot: 8.6 (2.2) and left foot 8.8 (2.6) in children with obesity versus right foot: 9.7 (1.8) and left foot 10.3 (2.2) in children with normal weight (**Table 3**). There were no significant differences in the chest expansion tests between groups.

## DISCUSSION

This study investigated the influence of childhood obesity on postural balance and musculoskeletal flexibility in obese children aged 6 to 11 years. Children with obesity had more postural sways during balance testing across different stability levels than children with normal weight. These results were consistent with other reports showing that obese people have impaired balance in AP and ML directions at different stability levels.[7] There are several rationales for the impaired balance concomitant with obesity: decreased sensitivity of the mechanoreceptors in the feet, anterior shift in the center of mass, motor delay, reduced intensity of the gray matter of the cerebellum on magnetic resonance imaging, and neuromuscular fatigue.[21-25] The postural sway was reported to increase the exposure to high ground reaction force during walking, and this can lead to gait abnormalities and a high risk of falling.[26,27]

A 2.5-year cohort prospective study in England investigated the subject of injuries in children with obesity aged seven to twelve years. The results showed a greater prevalence of lower limb traumas in those children because of balance impairment.[28] In contrast to our findings, that group claimed that the obese participants were as stable during the dynamic balance testing as in their normal weight counterparts.[8] They attributed that to the increased mechanical inertia, which facilitated resistance to postural perturbations.[29] The researchers claimed that obesity increases the torque at ankle joints, which in turn corrects the postural imbalance during ankle perturbation.[29]

Our research used the WBLT to investigate calf muscle flexibility. The obese children had lower degrees of calf muscle flexibility than normal weight controls ($P$=.01 and .005 for the right foot and left foot, respectively). Other researchers claimed that childhood obesity affected the range of ankle dorsiflexion negatively with a 10° difference between the study and control groups.[30] The most obvious explanation for this finding was that obese individuals activated their calf muscle more than the tibialis anterior while walking, and this pattern may decrease the ankle dorsiflexion range of motion.[30] Moreover, the decreased ankle dorsiflexion contributes to a flat foot posture and difficulty in recovering from ankle perturbations.[29] The participants had homogenous findings for chest expansion with mean values equal to 3.0 (1.2) in obese children vs 2.8 (1.0) in normal weight controls ($P$=.32). In agreement with these results, Fayed et al[10] concluded that adults with obesity had thoracic muscular flexibility similar to their normal weight peers. On the other hand, they stated that morbid obesity neg-

**Table 1.** Demographic and anthropometric characteristics of study participants (n=90).

| | Normal weight (n=47) | Obese (n=43) | Difference (Mean) | 95% Confidence interval | | t | *P* |
|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | |
| **Gender** | | | | | | | |
| Male | 23 (48.9) | 17 (39.5) | - | - | - | - | .37 |
| Female | 24 (51.1) | 26 (60.5) | | | | | |
| Age (years) | 8.8 (1.6) | 9.2(1.5) | 0.38 | -0.26 | 1.03 | 1.19 | .24 |
| Weight (kg) | 27.4 (5.6) | 47.5(15.0) | 20.06 | 15.39 | 24.72 | 8.55 | **<.001** |
| Height (m) | 1.3 (0.1) | 1.4 (0.11) | 0.06 | 0.01 | 0.11 | 2.60 | .06 |
| BMI (kg/m$^2$) | 16.2 (1.2) | 25.3(4.6) | 9.17 | 7.80 | 10.54 | 13.28 | **<.001** |

Data are number (%) or mean (standard deviation).

**Table 2.** Comparison of postural stability indices.

| | Normal weight (n=47) | Obese (n=43) | Difference | 95% Confidence interval | | t | *P* |
|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | |
| Overall Stability Level 8 | 0.81 (0.32) | 1.52 (0.88) | 0.81 | 0.54 | 1.09 | 5.89 | **<.001** |
| Anteroposterior Stability Level 8 | 0.58 (0.29) | 1.23 (0.77) | 0.64 | 0.40 | 0.88 | 5.27 | **<.001** |
| Mediolateral Stability Level 8 | 0.42 (0.24) | 0.81 (0.50) | 0.40 | 0.24 | 0.56 | 4.89 | **<.001** |
| Overall Stability Level 4 | 0.94 (0.47) | 2.02 (0.96) | 1.08 | 0.77 | 1.40 | 6.89 | **<.001** |
| Anteroposterior Stability Level 4 | 0.62 (0.34) | 1.45 (0.66) | 0.83 | 0.61 | 1.04 | 7.60 | **<.001** |
| Mediolateral Stability Level 4 | 0.53 (0.32) | 1.15 (0.59) | 0.62 | 4.27 | 0.82 | 6.30 | **<.001** |

Data are mean (standard deviation). Independent *t* test.

**Table 3.** Comparison of flexibility parameters.

| | Normal weight (n=47) | Obese (n=43) | Difference | 95% Confidence interval | | t | *P* |
|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | |
| Chest expansion | 2.8 (1.0) | 3.0 (1.2) | 0.23 | -0.23 | 0.70 | 1.0 | .32 |
| Weight Bearing Lunge Test (Right Foot) | 9.7 (1.8) | 8.6 (2.2) | -1.1 | -1.88 | -0.23 | -2.5 | **.01** |
| Weight Bearing Lunge Test (Left Foot) | 10.3 (2.2) | 8.8 (2.6) | -1.5 | -2.48 | -0.47 | -2.9 | **.005** |

Data are mean (standard deviation). Units are centimeters. Independent *t* test.

atively affected the range of chest expansion with mean values equal 1.89 cm in individuals with morbid obesity vs 3.06 cm in individuals with normal weight (*P*=.0001). They further speculated that morbid or severe obesity, with BMI ≥99th percentile, cannot impact chest flexibility but it may decrease thoracic expansion.[10]

Our study does have some limitations. It was not blinded, and the sample was selected by convenience, which can lead to bias. Moreover, the study was limited to children with obesity as defined by BMI ≥95th percentile. Overweight or severely obese children were not enrolled, and this could affect the generalizability of the results. Furthermore, participants were only recruited from schools in the Eastern Province, and this also could affect the generalizability of the results across the Saudi Arabia or the world.

We strongly recommend that clinicians emphasize obesity-related physical impairments and consider them during physical examinations and therapeutic interventions. At the national level, obesity-prevention programs should be implemented from early childhood in order to 1) control the persistence of the obesity in adulthood, 2) prevent subsequent physical health problems, 3) improve the awareness of healthy weight in Saudi children, 4) emphasize the importance of following the WHO recommendations on the physical activity level of children aged 5 to 17 years old,[31] and 5) minimize the cost and expenses of healthcare services for childhood obesity. The findings of this study should alert clinicians and patients to the physical health problems that might be influenced by obesity such as postural balance and musculoskeletal flexibility.

## REFERENCES

**1.** Bradford NF, Bradford NF. Overweight and Obesity in Children and Adolescents. Primary care. 2009;36(2):319-39.
**2.** WHO. Obesity and overweight 2016 [updated June 2016. Available from: http://www.who.int/mediacentre/factsheets/fs311/en.
**3.** Cunha M, Aparicio G, Duarte J, Pereira A, Albuquerque C, Oliveira A. Genetic heritage as a risk factor enabling childhood obesity. Aten Primaria. 2013;45 Suppl 2:201-7.
**4.** Gurnani M, Birken C, Hamilton J. Childhood obesity: causes, consequences, and management. Pediatric Clinics of North America. 2015;62(4):821-40.
**5.** Shabana, Hasnain S. The p. N103K mutation of leptin (LEP) gene and severe early-onset obesity in Pakistan. Biol Res. 2016;49:23.
**6.** Del Porto H, Pechak C, Smith D, Reed-Jones R. Biomechanical effects of obesity on balance. International Journal of Exercise Science. 2012;5(4):1.
**7.** El-Basatiny HMYM, El-Kafy EMA. Assessment of Dynamic Postural Balance among Saudi Adolescent Girls in Al-Khobar-Saudi Arabia. Indian Journal of Physiotherapy and Occupational Therapy. 2014;8(1):248.
**8.** B?aszczyk JW, Cie?linska-?wider J, Plewa M, Zahorska-Markiewicz B, Markiewicz A. Effects of excessive body weight on postural control. Journal of Biomechanics. 2009;42(9):1295-300.7.
**9.** Shultz SP, Sitler MR, Tierney RT, Hillstrom HJ, Song J. Consequences of pediatric obesity on the foot and ankle complex. J. Am. Podiatric Med. Assoc. 2012;102(1):5-12.
**10.** Fayed EE, Khallaf ME, Epuru S. Association of obesity and physical activity with lung capacity in adult women. Int. J. Med. Res. Health Sci. 2014;3(2):314-21.
**11.** de Melo Barcelar J, Aliverti A, de Barros Melo TLL, Dornelas CS, Lima CSFR, Reinaux CMA, et al. Chest wall regional volumes in obese women. Respiratory physiology & neurobiology. 2013;189(1):167-73.
**12.** Boucher F, Handrigan GA, Mackrous I, Hue O. Childhood obesity affects postural control and aiming performance during an upper limb movement. Gait Posture. 2015;42:116-21.
**13.** Simmonds M, Llewellyn A, Owen C, Woolacott N. Predicting adult obesity from childhood obesity: a systematic review and meta?analysis. Obesity Rev. 2016;17(2):95-107.
**14.** Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. Pediatrics. 2007;120 Suppl 4:S164-92.
**15.** Azzeh FS, Kensara OA, Helal OF, El-Kafy EMA. Association of the body mass index with the overall stability index in young adult Saudi males. J. Taibah University Medical Sciences. 2017;12(2):157-63.
**16.** Alahmari KA, Marchetti GF, Sparto PJ, Furman JM, Whitney SL. Estimating postural control with the balance rehabilitation unit: measurement consistency, accuracy, validity, and comparison with dynamic posturography. Archives Phys. Med. Rehab. 2014;95(1):65-73.
**17.** Ibrahim AI, Muaidi QI, Abdelsalam MS, Hawamdeh ZM, Alhusaini AA. Association of postural balance and isometric muscle strength in early- and middle-school-age boys. J. Manipu. Phys. Ther. 2013;36(9):633-43.
**18.** Hall EA, Docherty CL. Validity of clinical outcome measures to evaluate ankle range of motion during the weight-bearing lunge test. J. Sci. Med. Sport. 2016.
**19.** Debouche S, Pitance L, Robert A, Liistro G, Reychler G. Reliability and reproducibility of chest wall expansion measurement in young healthy adults. J. Manipu. Phys. Ther. 2016;39(6):443-9.
**20.** D D. Introduction to Inferential Statistics Digital Textbook, BOLD Educational Software [Online]. Available from: http://www.bold-ed.com. Published 2012. Accessed 10/5 2017, 2017.
**21.** Simoneau M, Teasdale N. Balance control impairment in obese individuals is caused by larger balance motor commands variability. Gait Posture. 2015;41(1):203-8.
**22.** Gilleard W, Smith T. Effect of obesity on posture and hip joint moments during a standing task, and trunk forward flexion motion. Int. J. Obesity. 2007;31(2):267.
**23.** Corbeil P, Simoneau M, Rancourt D, Tremblay A, Teasdale N. Increased risk for falling associated with obesity: mathematical modeling of postural control. IEEE Transactions Neur. Sys. Rehab. Eng. 2001;9(2):126-36.
**24.** Ou X, Andres A, Pivik RT, Cleves MA, Badger TM. Brain gray and white matter differences in healthy normal weight and obese children. J. MRI. 2015;42(5):1205-13.
**25.** Garcia-Vicencio S, Martin V, Kluka V, Cardenoux C, Jegu AG, Fourot AV, et al. Obesity-related differences in neuromuscular fatigue in adolescent girls. Eur. J. Appl. Phys. 2015;115(11):2421-32.
**26.** Mueller S, Carlsohn A, Mueller J, Baur H, Mayer F. Influence of obesity on foot loading characteristics in gait for children aged 1 to 12 years. PloS one. 2016;11(2): e0149924.
**27.** Song Q, Yu B, Zhang C, Sun W, Mao D. Effects of backpack weight on posture, gait patterns and ground reaction forces of male children with obesity during stair descent. Res. Sports. Med. (Print). 2014;22(2):172-84.
**28.** Jespersen E, Verhagen E, Holst R, Klakk H, Heidemann M, Rexen C, et al. Total body fat percentage and body mass index and the association with lower extremity injuries in children: a 2.5-year longitudinal study. Brit. J. Sports Med. 2014;48(20):1497-502.
**29.** Matrangola SL, Madigan ML. The effects of obesity on balance recovery using an ankle strategy. Human Mov. Sci. 2011;30(3):584-95.
**30.** Shultz SP DHE, Fink PW, Lenoir M, Hills AP. The effects of pediatric obesity on dynamic joint malalignment during gait. Clinical Biomechanics. 2014;29(7):8-835.
**31.** WHO. Global Recommendations on Physical activity for Health [Online]. Available: http://www.who.int/dietphysicalactivity/publications/physical-activity-recommendations-5-17years.pdf-ua=1. Published 2011. Accessed 3/11/2018, 2018.