A Multivariate Multilevel Analysis of the Risk Factors Associated with Anthropometric Indices in Iranian mid-adolescents

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Abstract

Background The present study was conducted to assess some specific factors related to anthropometric indices in a representative sample of Iranian mid-adolescents. It also aimed to investigate the relationship between three anthropometric indices using a multivariate multilevel approach.Methods This study was conducted among 2538 students (1286 boys) aged 14 - 20 years old, who were randomly selected among 16 high schools by multi-stage random sampling procedure from 4 education districts of Shiraz, Iran. Data on demographic characteristics and anthropometric measures were collected. Anthropometric indices were estimated by the calibrated tools. A multivariate multilevel model was used to assess the predictor variables associated with obesity measures of the triceps (TST), abdominal (AST), and subscapular (SST) skinfold thickness.Results In this study, the prevalence of overweight and obesity was estimated to be 10.2 and 5.1%, respectively. Hierarchical models showed that, the outcome variables were correlated at the child and district levels. Positive associations were observed between the sex, family history of obesity, and moderate and high Socio-Economic Status (SES) with three anthropometric indices. Moreover, there were positive associations between moderate to vigorous physical activities with AST and SST, but they were not statistically significant at a significance level of 0.05.Conclusions Our findings revealed that, TST, AST, and SST could be useful indices for measuring the adiposity in mid-adolescents. In addition, the effect of the district level on the predictor variables highlights the important role of the environmental factors on the childhood obesity.

Introduction

In recent years, the rapid growth of obesity among children and adolescents has become a serious public health challenge in both developing and developed countries (1-3). The prevalence of childhood obesity has an arising trend in Iran, like other developing countries (4, 5). Obesity in early life, as an important metabolic problem leads to major health disorders such as hypertension (4), non-alcoholic fatty liver disease (6), obesity in the adulthood and more other nutrition -related chronic diseases such as type 1 diabetes, cardiovascular disease (7), some types of cancer (8) as well as a decrease in the life expectancy (9).

Among several approaches used to measure the obesity, Body Mass Index (BMI), Skinfold Thickness (ST) and waist circumference (WC) have been more frequently used in clinical setting (8). Although, BMI, as a simple and inexpensive parameter is used more than other approaches for measuring the obesity, it has several drawbacks as mentioned in the literature (10-12). ST is an easily obtained adiposity index, which is commonly used, and is an accurate estimate for measuring the subcutaneous body fat among children and adolescents (7, 13-16). It also can be easily applied in clinics, laboratories and schools because of its portable, low cost and non-invasive nature (17).

The mechanism of obesity development has remained unidentified, and the researchers characterize the obesity as a health disorder with multiple causes (18). Certainly, a lot of influential factors have been reported to be effective on childhood obesity. Individual factors such as physical and social functioning as well as environmental factors, lifestyle preferences, and cultural environment play an important role in increasing or decreasing the prevalence of childhood obesity (19, 20). A systematic review of the published studies in South Asian countries revealed that the lack of proper physical activities, prolonged TV watching or using different electronic media, unhealthy dietary patterns, family history of obesity, and the family socio-economic status are among the main factors found to be significantly associated with the obesity in children and adolescents (21). In fact, factors related to childhood obesity are a subset of multi-factorial etiology in three levels: family, school, and community. Therefore, it is necessary to consider effective strategies in order to prevent and control childhood obesity in different aspects.

Since anthropometric indices seemingly share common biological and environmental relationships, simultaneous evaluation of multiple outcomes and the influential covariates using multivariate approaches will lead to more accurate results than univariate approaches. Furthermore, when the data have a hierarchical structure, predictor variables in ordinary multivariate regression models with single level do not provide correct inferences for outcome variables, due to the dependency existing between the observations. Therefore, it is necessary to fit a model that can accurately estimate the parameters. The present study aimed to simultaneously investigate the relationship between the influential covariates and three anthropometric indices including triceps (TST), abdominal (AST), and sub-scapular (SST) skinfold thickness using multivariate multilevel analysis.

Materials And Methods

Subjects, Study Design, and Sampling Procedure

In this cross-sectional study, 2538 healthy subjects (1286 boys and 1252 girls) aged 14 - 20 years old were selected among 16 high schools by multi-stage random sampling procedure from the 4 education districts of Shiraz, the capital of Fars Province in southern Iran. In the first step, 4 schools were chosen from each district (two from boy's schools and two from girl's schools) using simple random sampling. In the next step, based on the school sample size, 2 or 3 classrooms were randomly selected from each school, and all the students in the classroom were studied. The study protocol was approved by the Ethics Committee of Shiraz University of Medical Sciences. Moreover, the permission was obtained from schools principal for collecting the data from the selected classrooms.

Measurements

The collected data were classified into two groups: demographic characteristics and anthropometric measures; the former describing sex, age, screen time, family history of obesity, Physical Activities (PA), and Socio-Economic Status (SES). These data were collected through a survey. Screen time was defined as the times spent on watching TV and playing video games per week. Family history of obesity was assessed using a question, "Is there a history of obesity in your family?" PA was classified into three levels, namely mild, moderate, and vigorous activities using the number of times per week in which the students had been physically active. SES was calculated using principal component analysis by available variables used for SES measurement (19). Variables such as parents’ education level, parents’ occupation, as well as choice of car type and homeownership (Ownership or Rent) were included in the analysis to make one main component. The SES score calculated using the weighted averages of the variables was categorized into three levels (low, middle, and high) to define the SES.

The second data related to anthropometric measures included body weight and height, BMI, TST, AST and SST. Height and weight were measured in all students, while wearing light clothing and no shoes, with 0.1 cm and 0.1 kg accuracy, respectively using tape measure and a SECA digital scale (Germany). BMI was calculated by dividing weight (kg) by height squared (m^2) and was classified based on the WHOs growth charts (22). The subjects of the same sex and age with BMI less than 85th percentile, between 85th and 95th percentile and above 95th percentile were classified into three groups: normal, overweight and obese, respectively (23). A graded caliper was used to measure the ST in three sites of the body (triceps, abdominal, and subscapular). To measure the triceps, the technician bent the elbow to 90 degrees and marked the point midway between the top of the shoulder and elbow, and then measured a vertical fold by the caliper at a 90-degree angle on that midway point with the arm hanging naturally at the subject's side. For AST measurements, vertical folds were measured at 2 cm to the right and left of the navel. Finally, a diagonal fold (calipers held at a 45-degree angle) was taken across the back, just below the shoulder blade to measure the SST. ST was measured on both right and left sides of the body separately, and the average of two measurements was recorded to the nearest 0.5 mm (24). All anthropometric measurements of the students were done by two trained technicians. Measurement was repeated by another technician if there was a great difference in the right and left sides.

Statistical Analysis

Mean and standard deviation were calculated for quantitative data, and frequency and percentage were reported for qualitative variables. Pearson Correlation Coefficient, Chi-Square, and One-Way ANOVA tests were used to investigate the association between the variables at the child level. A P-value of less than 0.05 was considered as statistically significant. Since, in this study, the data had a hierarchical structure with multiple outcomes, multivariate multilevel analysis was used to depict the hierarchical structure of the data (25). The ability to model the correlation between response variables (in our case, at individual and district levels), increasing the power, performing a single test to avoid the risk of chance capitalization, which is inherent to carrying out a separate test for each dependent variable, and measuring the effect of any exploratory variable separately across multiple outcome variables are main advantages using multivariate hierarchical analysis (26). In this study, TST, AST, and SST as three multiple outcome variables were at the first level in the hierarchy. Therefore, for each subject, three quantitative measures were recorded simultaneously as units in level 1. The subjects included as units in the second level, and districts were considered at the third level in the hierarchy. These levels are shown in Figure 1. The multilevel structure makes it possible to evaluate whether the districts made a difference to individual anthropometric indices. Three outcome variables were regressed on a set of explanatory variables in the random intercept model, which were in levels 2 and 3. Primary analysis of the data was carried out using SPSS software (Ver. 18.0). The MLwiN software version 2.00 was used to analyze the hierarchical model.

Results

Table 1 shows the results of descriptive statistics (mean ± SD, and percentage) for the children in 4 districts. A total of 1286 (50.7%) subjects were boys and were roughly distributed equally in 4 districts. Mean age (SD) of the participants was equal to 15.99 (0.94) years old, which was not distributed equally in the districts (P-value <0.05). On average, more times on watching TV or using computer were recorded for students living in districts 4 and 1. About 44% of the participants were categorized into family history of obesity group. Having mild physical activities was reported by 76.6% of the students and only 3.1% of them had vigorous physical activities. Compared to other districts, more children from district 3 lived in a family with low SES. The results of Chi-Square test revealed that, the subjects were distributed differently with regard to physical activities and SES in four districts. However, there was not a statistically significant difference between the four groups with respect to gender and family history of obesity.

Overall, in this study, the prevalence of overweight and obesity was equal to 10.2 and 5.1%, respectively, and there was no significant association in the gender groups (prevalence of overweight and obesity was equal to 10.0 and 5.2% for boys and 10.3 and 5.0% for girls, respectively, with P-value>0.05). The results of anthropometric measures in 4 districts are presented in Table 2. Generally, there were statistically significant differences in all anthropometric indices between four groups (P-values <0.01). The results of ANOVA tests revealed that, district 4 and 1 had the highest values of TST, AST, and SST. Furthermore, means in all anthropometric measures were significantly lower in the third district than those of other districts.

Table 3 illustrates the effect of the covariates on the outcomes in a multivariate multilevel model. As shown in Table 3, being girl, having a family history of obesity, and high SES were significantly associated with three anthropometric measures. Although boys had greater mean BMI than girls (p-value < 0.001), the subcutaneous adipose tissue was thicker in girls than that of boys. Furthermore, subjects who lived in a family with a history of obesity had more fat than others did. Results also showed that, high SES had a significant direct effect on all three indices of obesity. Moreover, the levels of physical activity had a positive relationship with individual outcomes, with significant associations between the moderate to vigorous physical activities with AST and SST. Moreover, screen time did not play an important role in three outcome variables.

-2loglikelihood statistic with Iterative Generalized Least Squares (IGLS) as an estimation method was obtained as 26653.0 with 42 estimated parameters in final model, so that compared to the null model (null model is a model having only intercepts with the -2loglikelihood of 47697.8 with 15 estimated parameters), the deviance was equal to 21044.8 with 27 degree of freedom and p-value<0.001. Moreover, high correlations between the outcome variables indicated that, the districts are properly positioned in the third level of the hierarchy. The results of the correlation between the outcomes showed that, the intra-district correlations were obtained as 0.49, 0.21, and 0.80 for the (TST, AST), (TST, SST), and (AST, SST), respectively.

Discussion

The present study was an attempt to jointly evaluate the relationships between three body fat measures with a set of covariates in Iranian mid-adolescents within different 4 districts, using a multivariate multilevel analysis. Measuring the body composition and body fat with ST has achieved satisfactory results for evaluating the risk factors of childhood obesity in clinical environment (8, 27). The use of these anthropometric indices is a more accurate and cost-effective way to measure the obesity than the measurement approaches (28).

The prevalence of childhood obesity has sharply increased from 1990 to 2010 in low- and middle-income countries compared to the developed countries (29), which can have undesirable effects on physical, mental, and psychosocial health in adolescents (30-32). Studies reported that, the prevalence of overweight and obesity in adolescents varies in different parts of Iran (4, 19, 33). People, who were living in the same region with the same habits were similar in terms of growth, development, and body shape, which might be due to their lifestyle, dietary patterns, and socio-cultural factors (19, 20). The results of this study revealed that, there were statistically significant differences between the anthropometric indices with respect to four districts. Therefore, the effect of individual level risk factors may vary according to the environment in which one lives.

Results of multivariate multilevel approach showed that, some risk factors associated with the obesity in adolescents were consistent with those reported in previous researches in Iran (19, 20, 34). Results indicated a statistically significant association between the sex, family history of obesity, and SES with the adiposity indices. Sex was positively and highly associated with three outcomes, proving that girls had higher TST, AST, and SST than the boys. These results were in line with the previous study which reported that, the percentage of subcutaneous adipose tissue was lower in males bodies than that of females (35). Although, an agreement has been proved between BMI and TST in some studies (24, 36), BMI may not be a useful parameter in measuring the subcutaneous body fat of children, because changing the body shape occurs in childhood. Furthermore, it fails to differentiate the fat from the muscle mass and may classify children with large muscle into obese children group (18). Shriraam et al explained that, BMI is a crude measure, which does not provide a precise assessment of body density (10).

A positive association was found between family history of obesity and adiposity indices similar to other studies (20, 37, 38). Khashayar et al. reported that, the odds of obesity in Iranian students with obese parents were about 2 times greater than the others (19). Previous findings showed that, environmental factors such as family lifestyle, eating habits and also becoming obese due to the genetic factors are considered as the subset of family history of obesity, and are the most important reasons influencing the persistence of obesity in adulthood (4, 39, 40). Therefore, modification of diet, having proper physical activities, and health care in the families could be an effective approach to decrease the risk of childhood and adulthood obesity.

In line with previous studies in Iran (19, 20), Our findings showed positive relationships between SES with three anthropometric measures, especially at high levels, which revealed that higher risk of overweight/obesity is related to the social environment. Bahreynian et al study reported that the prevalence of overweight was greater in areas with high SES, whereas underweight and short stature were more prevalent in areas with low SES (41). In the current study, students with higher anthropometric measures were living in families with higher SES, as confirmed in some other studies conducted in Iran and some other countries, in which positive significant associations were found between SES and adiposity among children and adolescents in developing countries (20, 42, 43). It is noteworthy that, the means of body fat, height, and weight were lower in the students living in district 3 than other children (Table 2). Only 1.5% of families living in this district had a relatively high SES level and about 77% of them were classified as families with low income, educational and occupational levels. These findings highlight the need for planning to increase the level of awareness in the families in order to improve their lifestyle, nutrition and try to have more physical activities.

Several studies have reported time spent in watching TV or playing video games increased the risk of overweight/obesity in children (20, 42, 44, 45). Moreover, the results obtained in some studies revealed a negative correlation between inactivity/sedentary behavior and physical activities in children and adolescents (46-48). In our study, however, there was no statistically significant association between screen time and physical activities with adiposity indices. The results of Table 2 revealed that, the subjects living in districts one and four were more likely to be at risk of obesity with respect to body fat measures and BMI indices than other groups. Adolescents living in these two districts had more physical activities and also spent more time in watching TV or playing computer games compared to other two groups (Table 1). Watching TV and other sedentary behaviors increases the consumption of the most advertised goods, including sweetened cereals, sweets, salty snacks, and sweetened beverages leading to increased appetite, energy intake, thus affecting the body weight in children (49, 50). These findings highlight that; the presence of one behavior may be so strong that it cannot compensate for the presence of the other.

One of the strengths of the study was concerned with the results obtained in the random effects section. The response variables were correlated at the districts and the subject levels, confirming the appropriateness of classifying the individual and district in the second and third hierarchical levels. The major portion of the total variance in TST (97.1%), AST (97.7%), and SST (97.5%) was found at the child level, meaning that children with higher TST tend to have high AST and SST. Results also highlighted the importance of clustering in assessing the relationships between demographic characteristics and anthropometric indices.

The cross-sectional nature of the study could be considered as a limitation in this study, because, it is not clear how response variables are influenced by the covariates. Further studies could take a prospective and time-based approach to obtain more accurate results. The lack of other predictor variables related to adolescent obesity such as eating habits, biological measures, as well as the selection of the district as the only variable in the third hierarchical level were also regarded as the second limitation of the study.

Conclusion

The findings of this study showed that, TST, AST, and SST could be useful indices for measuring the adiposity in adolescents. The results of multivariate multilevel analysis showed that, anthropometric indices were significantly associated with the sex, family history of obesity, and SES. Furthermore, these indices were more prevalent among the students living in districts 1 and 4 than other two districts. Therefore, it is suggested to develop effective interventions to prevent the effects of individual and environmental undesirable factors on childhood obesity in both family and community levels, especially in these two districts.

List Of Abbreviations

BMI: body mass index; ST: skinfold thickness; WC: waist circumference; TST: triceps skinfold thickness; AST: abdominal skinfold thickness; SST: subscapular skinfold thickness; PA: physical activity; SES: socio-economic status; IGLS: iterative generalized least squares

Declarations

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Ethics approval and consent to participate

This study was approved by the ethics committee of Shiraz University of Medical Sciences.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

MA contributed in analyzed the data, and interpreted the results, wrote the manuscript drafting. **ST** contributed in designed the study, analysis of data, interpretation the results. **SMT** contributed in interpretation the results and designed the study. RT and **MA** contributed in interpretation the results wrote the manuscript drafting. The final version was confirmed by all authors for submission

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References

1. Wijnhoven TM, van Raaij JM, Spinelli A, Starc G, Hassapidou M, Spiroski I, et al. WHO European Childhood Obesity Surveillance Initiative: body mass index and level of overweight among 6–9-year-old children from school year 2007/2008 to school year 2009/2010. BMC public health. 2014;14(1):806.
2. Ogden CL, Fryar CD, Hales CM, Carroll MD, Aoki Y, Freedman DS. Differences in obesity prevalence by demographics and urbanization in US children and adolescents, 2013-2016. Jama. 2018;319(23):2410-8.
3. Rahmani A, Sayehmiri K, Asadollahi K, Sarokhani D, Islami F, Sarokhani M. Investigation of the prevalence of obesity in Iran: a systematic review and meta-analysis study. Acta Medica Iranica. 2015:596-607.
4. Rashidi H, Erfanifar A, Latifi SM, Payami SP, Aleali AM. Incidence of obesity, overweight and hypertension in children and adolescents in Ahvaz southwest of IRAN: Five-years study. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2019;13(1):201-5.
5. Djalalinia S, Kelishadi R, Qorbani M, Peykari N, Kasaeian A, Nasli-Esfahani E, et al. A systematic review on the prevalence of overweight and obesity, in iranian children and adolescents. Iranian journal of pediatrics. 2016;26(3).
6. Ahad Eshraghian M, EshraghianMD H, OmraniMD GR. Nonalcoholic fatty liver disease in a cluster of Iranian popula-tion: thyroid status and metabolic risk factors. Archives of Iranian medicine. 2013;16(10):584.
7. Freedman DS, Ogden CL, Kit BK. Interrelationships between BMI, skinfold thicknesses, percent body fat, and cardiovascular disease risk factors among US children and adolescents. BMC pediatrics. 2015;15(1):188.
8. Sahoo K, Sahoo B, Choudhury AK, Sofi NY, Kumar R, Bhadoria AS. Childhood obesity: causes and consequences. Journal of family medicine and primary care. 2015;4(2):187.
9. Fontaine KR, Redden DT, Wang C, Westfall AO, Allison DB. Years of life lost due to obesity. Jama. 2003;289(2):187-93.
10. Mahadevan S, Ali I. Is body mass index a good indicator of obesity? : Springer; 2016.

11. Neovius M, Rasmussen F. Evaluation of BMI-based classification of adolescent overweight and obesity: choice of percentage body fat cutoffs exerts a large influence. The COMPASS study. European journal of clinical nutrition. 2008;62(10):1201.
12. Daniels SR. The use of BMI in the clinical setting. Pediatrics. 2009;124(Supplement 1):S35-S41.
13. Heydari ST, Ayatollahi SMT, Zare N. Diagnostic value of bioelectrical impedance analysis versus body mass index for detection of obesity among students. Asian J Sports Med. 2011; 2(2): 68–74.
14. Jiménez EG. Body composition: assessment and clinical value. Endocrinología y Nutrición (English Edition). 2013;60(2):69-75.
15. Addo OY, Himes JH. Reference curves for triceps and subscapular skinfold thicknesses in US children and adolescents. The American journal of clinical nutrition. 2010;91(3):635-42.
16. Ayatollahi SMT, Mostajabi F. Triceps skinfold thickness centile charts in primary school children in Shiraz, Iran. Archives of Iranian medicine. 2008;11(2):210-3.
17. Yeung DC-s, Hui SS-c. Validity and reliability of skinfold measurement in assessing body fatness of Chinese children. Asia Pacific journal of clinical nutrition. 2010;19(3):350-7.
18. Dehghan M, Akhtar-Danesh N, Merchant AT. Childhood obesity, prevalence and prevention. Heart Views. 2006;7(2):74.
19. Khashayar P, Kasaeian A, Heshmat R, Motlagh ME, Gorabi AM, Noroozi M, et al. Childhood overweight and obesity and associated factors in iranian children and adolescents: A multilevel analysis; the CASPIAN-IV study. Frontiers in pediatrics. 2018;6.
20. Kelishadi R, Heidari Z, Kazemi I, Jafari-Koshki T, Mansourian M, Motlagh M-E, et al. A hierarchical Bayesian tri-variate analysis on factors associated with anthropometric measures in a large sample of children and adolescents: the CASPIAN-IV study. Journal of Pediatric Endocrinology and Metabolism. 2018;31(4):443-9.
21. Mistry SK, Puthussery S. Risk factors of overweight and obesity in childhood and adolescence in South Asian countries: a systematic review of the evidence. Public health. 2015;129(3):200-9.
22. Group WMGRS. WHO Child Growth Standards based on length/height, weight and age. Acta paediatrica (Oslo, Norway: 1992) Supplement. 2006;450:76.
23. Onis Md, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World health Organization. 2007;85:660-7.
24. Ayatollahi SMT, Bagheri Z, Heydari ST. Agreement analysis among measures of thinness and obesity assessment in Iranian school children and adolescents. Asian J Sports Med. 2013;4(4):272-80.
25. Goldstein H. Multilevel statistical models: John Wiley & Sons; 2011.
26. Hox JJ, Moerbeek M, van de Schoot R. Multilevel Analysis: Techniques and Applications (Quantitative Methodology). New York: Taylor & Francis; 2010.
27. Jeddi M, Dabbaghmanesh MH, Omrani GR, Bakhshayeshkaram M. Body composition reference percentiles of healthy Iranian children and adolescents in southern Iran. Archives of Iranian medicine.

2014;17(10):661.

28. Hingorjo MR, Syed S, Qureshi MA. Overweight and obesity in students of a dental college of Karachi: lifestyle influence and measurement by an appropriate anthropometric index. JPMA The Journal of the Pakistan Medical Association. 2009;59(8):528.
29. De Onis M, Borghi E, Arimond M, Webb P, Croft T, Saha K, et al. Prevalence thresholds for wasting, overweight and stunting in children under 5 years. Public health nutrition. 2019;22(1):175-9.
30. Pulgaron ER. Childhood obesity: a review of increased risk for physical and psychological comorbidities. Clinical therapeutics. 2013;35(1):A18-A32.
31. Sanders RH, Han A, Baker JS, Cobley S. Childhood obesity and its physical and psychological co-morbidities: a systematic review of Australian children and adolescents. European journal of pediatrics. 2015;174(6):715-46.
32. Rankin J, Matthews L, Cobley S, Han A, Sanders R, Wiltshire HD, et al. Psychological consequences of childhood obesity: psychiatric comorbidity and prevention. Adolescent health, medicine and therapeutics. 2016;7:125.
33. Kelishadi R, Haghdoost A-A, Sadeghirad B, Khajehkazemi R. Trend in the prevalence of obesity and overweight among Iranian children and adolescents: a systematic review and meta-analysis. Nutrition (Burbank, Los Angeles County, Calif). 2014;30(4):393-400.
34. Baygi F, Dorosty AR, Kelishadi R, Qorbani M, Asayesh H, Mansourian M, et al. Determinants of childhood obesity in representative sample of children in North East of Iran. Cholesterol. 2012;2012.
35. Blaak E. Gender differences in fat metabolism. Current Opinion in Clinical Nutrition & Metabolic Care. 2001;4(6):499-502.
36. Selvi A, Naaraayan SA, Priyadharishini D, Begum NS. Comparison of various body fat indices in early and mid-adolescents of South India: School-based cross-sectional study. Indian Journal of Child Health. 2018:124-7.
37. Chung AE, Skinner AC, Steiner MJ, Perrin EM. Physical activity and BMI in a nationally representative sample of children and adolescents. Clinical pediatrics. 2012;51(2):122-9.
38. Hands B, Parker H. Pedometer-determined physical activity, BMI, and waist girth in 7-to 16-year-old children and adolescents. Journal of Physical Activity and Health. 2008;5(s1):S153-S65.
39. Li L, Yin J, Cheng H, Wang Y, Gao S, Li M, et al. Identification of genetic and environmental factors predicting metabolically healthy obesity in children: data from the BCAMS study. The Journal of Clinical Endocrinology & Metabolism. 2016;101(4):1816-25.
40. Portela DS, Vieira TO, Matos SM, de Oliveira NF, Vieira GO. Maternal obesity, environmental factors, cesarean delivery and breastfeeding as determinants of overweight and obesity in children: results from a cohort. BMC pregnancy and childbirth. 2015;15(1):94.
41. Bahreynian M, Motlagh ME, Qorbani M, Heshmat R, Ardalan G, Kelishadi R. Prevalence of growth disorders in a nationally representative sample of Iranian adolescents according to socioeconomic status: the CASPIAN-III Study. Pediatrics & Neonatology. 2015;56(4):242-7.

42. Gomes T, Katzmarzyk P, Santos F, de Chaves R, Santos D, Pereira S, et al. Are BMI and sedentariness correlated? a multilevel study in children. Nutrients. 2015;7(7):5889-904.
43. Yusefzadeh H, Rahimi B, Rashidi A. Economic burden of obesity: A systematic review. Soc Health Behav. 2019;2:7-12.
44. Schmidt ME, Haines J, O'brien A, McDonald J, Price S, Sherry B, et al. Systematic review of effective strategies for reducing screen time among young children. Obesity. 2012;20(7):1338-54.
45. Tremblay MS, LeBlanc AG, Kho ME, Saunders TJ, Larouche R, Colley RC, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. International journal of behavioral nutrition and physical activity. 2011;8(1):98.
46. Gomes T, Hedeker D, dos Santos F, Souza M, Santos D, Pereira S, et al. Relationship between sedentariness and moderate-to-vigorous physical activity in youth: a multivariate multilevel study. International journal of environmental research and public health. 2017;14(2):148.
47. Marshall SJ, Biddle SJ, Sallis JF, McKenzie TL, Conway TL. Clustering of sedentary behaviors and physical activity among youth: a cross-national study. Pediatric exercise science. 2002;14(4):401-17.
48. Leech RM, McNaughton SA, Timperio A. The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review. International Journal of Behavioral Nutrition and Physical Activity. 2014;11(1):4.
49. Carandente F, Roveda E, Montaruli A, Pizzini G. Nutrition, activity behavior and body constitution in primary school children. Biology of Sport. 2009;26(4).
50. Story M, Neumark-Sztainer D, French S. Individual and environmental influences on adolescent eating behaviors. Journal of the American Dietetic association. 2002;102(3):S40-S51.

Tables

Table 1. Descriptive statistics among individuals by districts

Variables	Descriptor	District 1 (n=699)	District 2 (n=601)	District 3 (n=609)	District 4 (n=629)	Total (n=2538)	P-value
Screen time (min per week)							
	Mean (SD)	268.01 (137.70)	263.46 (127.50)	261.42 (151.12)	283.45 (151.05)	269.61 (141.44)	0.07[a]
Sex							
Boy	N (%)	359 (51.4)	309 (51.4)	295 (48.4)	323 (51.4)	1286 (50.7)	0.66[b]
Girl	N (%)	340 (48.6)	292 (48.6)	314 (51.6)	306 (48.6)	1252 (49.3)	
Age groups (year)							
[14-16)	N (%)	362(51.9)	347(57.8)	320(52.6)	347(55.2)	1376(54.3)	0.00[b]
[16-18)	N (%)	328(47.0)	252(42.0)	254(41.8)	260(41.3)	1094(43.2)	
[18-20]	N (%)	8(1.1)	1(0.2)	34(5.6)	22(3.5)	65(2.6)	
Family history of obesity							
Yes	N (%)	296 (42.6)	261 (43.8)	270 (44.6)	286 (45.9)	1113 (44.2)	0.67[b]
No	N (%)	399 (57.4)	335 (56.2)	336 (55.4)	337 (54.1)	1407 (55.8)	
Physical activity							
Mild	N (%)	431 (75.0)	315 (72.9)	355 (82.2)	379 (76.7)	1480 (76.6)	0.02[b]
Moderate	N (%)	124 (21.6)	99 (22.9)	65 (15.0)	105 (21.3)	393 (20.3)	
Vigorous	N (%)	20 (3.5)	18 (4.2)	12 (2.8)	10 (2.0)	60 (3.1)	
SES status							
Low	N (%)	124 (26.1)	48 (11.3)	349 (76.9)	191(44.3)	712 (39.9)	0.00[b]
Med	N (%)	303 (63.8)	307 (72.1)	98 (21.6)	227 (52.7)	935 (52.4)	
High	N (%)	48 (10.1)	71 (16.7)	7 (1.5)	13 (3.0)	139 (7.8)	

SES socio-economic status

a P-values are derived from ANOVA test

b P-value are derived from Chi squared tests

Table 2. Anthropometric measurement of individual at district level

	District 1	District 2	District 3	District 4	P-value
TST (mm)	16.36 (7.33)	15.65 (7.02)	13.08 (5.93)	16.71 (8.25)	0.00
AST (mm)	17.49 (9.34)	16.49 (7.78)	14.61 (8.83)	17.57 (9.36)	0.00
SST (mm)	16.60 (8.14)	16.10 (7.83)	13.85 (6.71)	17.91 (8.84)	0.00
Height (cm)	165.88 (8.69)	167.28 (8.08)	163.62 (8.37)	165.48 (8.60)	0.00
Weight (kg)	60.50 (13.99)	60.79 (13.43)	56.47 (12.12)	59.32 (13.97)	0.00
BMI (kg/m^2)	21.86 (4.22)	21.61 (3.85)	21.01 (3.69)	21.59 (4.33)	0.00

P-values are derived from ANOVA tests (p-value < 0.05 was statistical significant), All measurement are presented as mean (standard deviation)

Abbreviation: TST triceps skinfold thickness, AST abdominal skinfold thickness , SST subscapular skinfold thickness, BMI body mass index

Table 3. associated factors with three anthropometric indices in hierarchical model

Fixed Effects						
	TST		AST		SST	
	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	10.49**	1.17	11.11**	1.55	10.60**	1.34
Sex						
girls/boy	3.02**	0.37	2.33**	0.49	2.17**	0.42
Family history of obesity						
yes/no	2.25**	0.34	3.30**	0.45	3.49**	0.39
Physical activity						
mild /vigorous	0.81	1.16	1.67	1.52	1.27	1.32
moderate/ vigorous	1.51	1.04	2.54*	1.40	2.24*	1.20
SES status						
moderate/low	0.81**	0.39	1.01*	0.52	0.80*	0.45
high/low	1.70**	0.66	2.25**	0.90	2.48**	0.77
Age groups						
group2/group1	-0.67*	0.34	-0.09	0.46	0.54	0.39
group3/group1	0.30	1.30	-1.09	1.76	1.75	1.51
Screen time(min per week)						
watching TV or video games	0.06	0.08	0.15	0.10	0.11	0.09

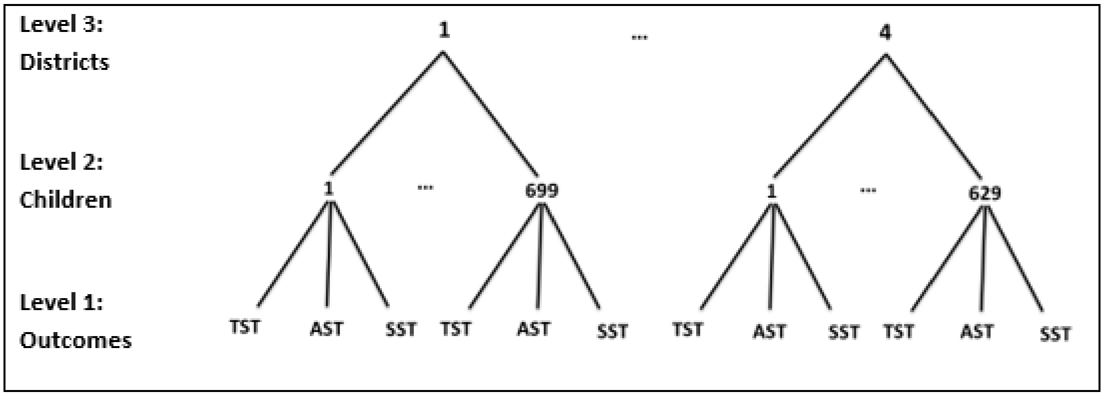
Random Effects						
	TST		AST		SST	
Variance	Estimate	SE	Estimate	SE	Estimate	SE
Child-level	38.85	1.46	70.82	2.66	52.32	1.97
District-level	1.18	0.62	1.63	0.94	1.33	0.74
	TST, AST	**SE**	**TST, SST**	**SE**	**AST, SST**	**SE**
Covariance						
Child-level	35.85	1.69	32.41	1.47	48.71	2.07
District-level	0.68	0.62	0.27	0.51	1.18	0.76
Correlation						
Child-level	0.68	-	0.72	-	0.80	-
District-level	0.49	-	0.21	-	0.80	-

Abbreviation: **TST** triceps skinfold thickness, **AST** abdominal skinfold thickness , **SST** subscapular skinfold thickness, **SES** socio-economic status

Age groups: **group1** [14-16), **group2** [16-18) and **group 3** [18-20]

**p-value < 0.05 , *p-value< 0.1

Figures



TST triceps skinfold thickness; **AST** abdominal skinfold thickness; **SST** subscapular skinfold thickness

Figure 1

Multivariate multilevel structures of anthropometric indices (TST, AST and SST) at level one nested within children at level 2, nested within districts at level 3