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UPPER-ARM ANTHROPOMETRY AS NUTRITIONAL ASSESSMENT IN PRESCHOOL CHILDREN IN LATVIAN POPULATION

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ABSTRACT

The World Health Organization (WHO) recommends the body mass index (BMI) for the evaluation of nutrition in children. However, BMI alone is insufficient to differentiate between the excess body-weight associated with the muscle-mass and/or fat-mass. Therefore upper-arm anthropometry can be used to determine the upper arm composition, related to the body composition.

The present study includes 54 children, age 5–7 years, without chronic medical conditions and in a normal weight range. Body height, body weight, upper-arm circumference (UAC) and triceps skinfold (TSF) were measured; the BMI, total upper-arm area (TUA), upper-arm muscle area (UMA), upper-arm fat area (UFA) and arm fat index (AFI) were calculated. Nutritional status was determined using the upper-arm muscle-area by height (UAMAH).

This study showed correlations between the BMI and UAC; BMI and UMA; the BMI and UFA both in boys and girls. According to the UMA and UAMAH scores, muscularity was found greater among boys than girls; according to UFA and AFI scores, girls have a greater fat-pattern than boys. There was no statistically significant correlation, positive or negative, between the UAMAH Z-scores and BMI Z-scores. Although only children with the BMI >5th percentile and <95th percentile were included in the present study, the results showed that 7.41% were ranked as wasted or highly muscular according to the UAMAH scores.

Conclusions. Upper-arm anthropometry is a valuable assessment of the nutritional status of preschool children in the Latvian population. The child's BMI within a normal range could rather be associated with the muscle mass than the fat mass. For a more complete nutritional assessment in preschool children in the Latvian population the BMI should be used in combination with upper-arm anthropometry and UAMAH scores to improve the screening

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of undernutrition. The present study is supposed to be continued, including a higher number of subjects for a better assessment.

Keywords: *Body mass index; nutrition; upper-arm muscle area; upper-arm muscle area by height*

INTRODUCTION

Evaluating the nutritional status in children is important because both overweight and underweight are associated with higher morbidity and premature mortality [5, 10, 25]. The World Health Organization (WHO) recommends the body mass index (BMI) for the evaluation of nutrition in children [1].

The BMI formula as first published by Adolphe Quetelet (1796–1874) was called the Quetelet Index until it was renamed to the Body Mass Index in 1972 [8]. The BMI does not measure body fat directly, but research has shown that the BMI is correlated with more direct measures of body fat, such as skinfold thickness measurements, bioelectrical impedance, densitometry (underwater weighing) and dual energy x-ray absorptiometry (DXA) [11, 14,37]. However, the BMI is not the most sensitive marker for detecting excess body fat and may therefore be inaccurate for detecting future risks [9].

Measuring skinfold (SF) thickness is a widely used, simple and inexpensive method of evaluating nutrition in children. Different studies suggest that SF measurements in children are superior to the BMI as a predictor of obesity and adult body fat [18,23, 38]. The problem with the BMI alone is its inability to differentiate between the excess body-weight associated with muscle-mass and/or fat-mass [32, 33].

SF measurements can be used as absolute values (in mm) or used in a group of the equation called upper-arm anthropometry, which is used to determine the upper-arm composition [13, 19, 21]. The necessary measurements are upper-arm circumference (UAC) and triceps skinfod thickness (TSF), which are used in calculations to assess the body composition by upper-arm muscle area (UMA), upper-arm fat area (UFA), arm-fat index (AFI), and upper-arm muscle-area by height (UAMAH) [7, 13, 27]. The credibility of upper arm anthropometry calculations has been approved by magnetic resonance imaging (MRI) investigations [27].

Several different studies suggest that the upper-arm composition in children is related to body composition [4, 15, 29]. Also, several studies show the direct association of changes in biochemical processes and the nutritional status with upper-arm composition [3, 17]. However, the upper-arm anthropometry for nutritional assessment in children is not the WHO recommended it as a standard procedure [26].

MATERIAL AND METHODS

The study includes 54 children, age 5–7 years, without chronic medical conditions and in a normal weight range.

Anthropometric measurements

Body height, body weight, UAC and TSF were measured according to standard procedures, using the instruments of "SiberHegner&Co". Body height was measured using an anthropometer to the nearest 0.10 cm. The weight of the children wearing minimum clothing and with bare feet was measured using a portable digital weighing machine to the nearest 100g. The UAC was mesured at the midpoint of the upper-arm using a plastic non-stretchable measuring tape to the nearest 0.10 cm. The TSF was recorded using a skinfold caliper to the nearest 0.20 mm.

The BMI calculation

The BMI was calculated according to the Quetelet formula [1]: the BMI (kg/m^2) = weight (kg) / height (m^2). The BMI was expressed as a percentile and evaluated [20]. The children with the BMI above the 95^{th} percentile and below the 5^{th} percentile were excluded from the study.

Upper arm anthropometry calculations

The upper-arm composition was assessed using equations by Best and Kuhl [13]. TUA,UMA, UFAand AFI were calculated using the following formulas: $TUA = UAC\ (cm)^2 / (4 \times \pi)$; $UMA = [(UAC\ (cm) - (TSF\ (cm) \times \pi))^2] / (4 \times \pi)$; $UFA = TUA\ (cm^2) - UMA\ (cm^2)$; $AFI = UFA\ (cm^2) / [UAC\ (cm)^2 / (4 \times \pi)] \times 100\%$

The nutritional status was determined using the Z-score based classification for UAMAH by Frisancho and Tracer [13], depicted in Table 1.

Table 1. Anthropometric classification for the evaluation of the nutritional status based on age and gender-specific anthropometric distributions [13].

Nutrition status	UAMAH percentile	UAMAH category	Z-score
Wasted	0–5.0	Category I	<−1.60
Below Average	5.1–15.0	Category II	−1.60 to −1.00
Average	15.1–85.0	Category III	−1.00 to +1.00
Above Average	85.1–95.0	Category IV	+1.00 to +1.60
High Muscle	95.1–100	Category V	≥ +1.60

Data analysis

The data analysis was performed using MS Excel 2007 and IBM SPSS Statistics 21.0 programs. Descriptive statistics and the correlation analysisofseveral different values were determined gender specifically.

RESULTS

The anthropometric measurements, the BMI and upper-arm anthropometry values are displayed gender specifically in Table 2 and Table 3.

Table 2. Age-specific subject distribution, descriptive statistics of anthropometric, the BMI and upper-arm anthropometry variables among boys.

Age (years)	Number	Weight (kg)	Height (cm)	BMI (kg/m^2)	UAC (cm)	TSF (mm)	TUA (cm^2)	UMA (cm^2)	UFA (cm^2)	AFI (cm^2)
5	5	20.38 ±1.95	113.6 ±3.37	15.89 ±0.79	16.42 ±0.93	8.64 ±0.84	21.51 ±2.40	15.01 ±2.22	6.50 ±0.60	30.39 ±3.37
6	17	21.40 ±2.15	116.77 ±4.30	15.68 ±1.13	17.27 ±1.15	8.19 ±1.75	23.85 ±3.30	17.27 ±2.23	6.58 ±1.65	27.40 ±7.71
7	8	24.09 ±2.86	124.32 ±6.98	15.54 ±0.84	17.84 ±1.07	9.43 ±1.11	25.40 ±2.96	17.70 ±2.61	7.69 ±0.94	30.50 ±3.95

Table 3. Age-specific subject distribution, descriptive statistics of anthropometric, the BMI and upper-arm anthropometry variables among girls.

Age (years)	Number	Weight (kg)	Height (cm)	BMI (kg/m^2)	UAC (cm)	TSF (mm)	TUA (cm^2)	UMA (cm^2)	UFA (cm^2)	AFI (cm^2)
5	8	19.59 ±1.95	113.24 ±3.48	15.26 ± 1.24	16.73 ±0.95	11.02 ±2.02	22.35 ±2.50	14.09 ±2.10	8.26 ±1.50	36.99 ±5.71
6	10	22.03 ±2.08	119.53 ±5.58	15.40 ±0.77	17.87 ±1.02	10.76 ±1.83	25.48 ±2.90	16.75 ±1.81	8.74 ±1.71	34.09 ±4.36
7	6	22.80 ±2.66	121.83 ±6.17	15.38 ±1.53	17.35 ±1.31	10.81 ±1.49	24.07 ±3.59	15.66 ±3.69	8.40 ±0.90	35.53 ±5.90

Assessment of height, weight and the BMI

In both genders the height and weight correlated significantly with age ($p<0.01$), while there was no significant correlation between age and the BMI both in boys and girls.

The BMI was expressed to percentile according to the WHO data. It was established that 53.3% of boys were in between the 5th and 50th percentile, while 46.7% were in between the 50th and 95th percentile. 37.5% of girls were in between the 5th and 50th percentile, and 62.5% were in between the 50th and 95th percentile. The percentage of boys with the BMI less than 50th percentile grew significantly with age (from 20% in the age of 5 years to 75% in the age of 7 years); there was a similar tendency observed in girls (from 25% in the age of 5 years to 50% in the age of 7 years).

Assessment of upper arm anthropometry.

In boys there was a medium correlation between the age and UAC ($r=0.39$; $p<0.05$). There was no statistically significant correlation between age and TSF both in boys and girls.

In boys there was a medium correlation between age and UMA ($r=0.33$; $p<0.05$) and age. However, in girls there was no statistically significant correlation.

There was also no statistically significant correlation between age and TSF or AFI in boys and girls.

Comparison of upper arm anthropometry and the BMI

There was a medium-high correlation between the BMI and UAC in both boys ($r=0.54$; $p<0.01$) and girls ($r=0.61$; $p<0.01$).

A medium correlation was found between the BMI and UMA in boys ($r=0.53$; $p<0.01$) and girls ($r=0.48$ $p<0.01$). A medium correlation was also found between the BMI and UFA in boys ($r=0.35$; $p<0.05$) and girls ($r=0.41$; $p<0.05$).

Both in boys and girls there was no statistically significant correlation between the BMI andAFI.

The nutritional assessment

Nutritional status was determined using the proposed Z-score based UAMAH classification (Table 1). The results are shown in Table 4.

Table 4. Assessment of the nutritional status using UAMAH.

Gender	UAMAH Category I	UAMAH Category II	UAMAH Category III	UAMAH Category IV	UAMAH Category V
Boys	1 (3.33%)	2 (6.67%)	21 (70%)	5 (16.67%)	1 (3.33%)
Girls	0	2 (8.33%)	19 (79.17%)	1 (4.17%)	2 (8.33%)
Total	1 (1.85%)	4 (7.41%)	40 (74.07%)	6 (11.1%)	3 (5.56%)

The overall prevalence of wasting (<−1.60 Z-score) and below average (−1.60 to −1.00 Z-score) were found in 1.85% and 7.41%. There is a little prevalence of high muscle mass (5.56% overall).

There was no statistically significant correlation between the BMI and UAMAH Z-score in both boys and girls.

DISCUSSION

The body composition and the nutritional status assessment based on anthropometry is still an important technique for providing important epidemiological and clinical investigation. The upper-arm composition can provide good assessment of muscularity and adiposity compared to the conventional anthropometric measure [28, 30].

The widely used and the WHO recommended BMI has a few imperfections in evaluating nutrition in children. For example, a low BMI can be an indicator of malnutrition, which is characterized by a decrease in both fat and muscle tissue. However, a tall and normally lean child can also have a low BMI. Similarly, an obese child usually has a high BMI; but a muscular and large-framed child can also have a high BMI. Therefore the high BMI is not always associated with excess fat, and a low BMI does not necessarily mean malnutrition[13].

During the study it was established that the BMI correlates with UAC and UMA in both genders; in 2015 similar results were shown in a study by Ma et al. [22].The present study concludes that the BMI correlates also with UFA in both genders, which confirms the BMI being associated with both fat and muscle mass. However, it was also found that both boys and girls have no statistically significant correlation between the BMI and AFI. This suggests that the BMI within a normal range in preschool children could rather be associated with the amount of muscle mass.

During the study it was also established that UAC and UMA correlated with age in boys. There was no statistically significant correlation in girls; however, it could be explained by insufficient amount of data for confirming or disclaiming correlation. Different studies suggest that although UMA correlates positively with age in both genders, the UAC and UMA increase significantly during puberty from Tanner stage 1 to 5 [4, 6,28]. In the present study Tanner scores were not evaluated due to the mean age of puberty onset being 10.5 years in girls and 11.5 years in boys [16, 35].

Several authors suggest the high value of UAC in nutritional assessment. In 2015 Sultana et al. suggests that UAC could replace the BMI as an assessment of undernutrition [31]. Moreover, a study by Ma et al. (2015) suggests that UAC is equivalent to the BMI and waist circumference as a screening test for hypertension in children [22].

The upper-arm composition can provide a better assessment of muscularity and adiposity, but it has some flaws, like beingrather insensitive to short-term changes in the body composition. The UAMAH is considered to be a valuable index used to identify the risk factors of undernutrition when both muscle-mass and fat-mass are decreased [2, 30].

According to the UMA and UAMAH scores, muscularity was found greater among boys than girls; the results also showed that girls tend to have a greater fat-pattern than boys, according to UFA and AFI scores. Similar results were shown in the children's population studies in Turkey [24], Argentina [2] and India [4, 30]. These differences can be explained by several factors such as sexual dimorphism, genotype, birth weight, catch-up growth, breastfeeding, diet and eating habits, physical activity, socioeconomic status and environmental conditions [34, 36]. It is suggested that the greater muscularity would reflect a greater protein reserve and the lowest musculature is related to the lowest height in children [12, 13].

Only children with BMI >5th percentile and <95th percentile (category II to category IV) were included in the present study. However, the results show that out of 54 children 1 (1.85%) was ranked in UAMAH category I. On the contrary, the number of subjects in category V was 3 (5.56%). There was no statistically significant correlation, positive or negative, between the UAMAH Z-scores and BMI Z-scores. This again suggests that the BMI alone cannot be a sufficient method to evaluate nutrition, specifically undernutrition or high muscularity. A study by Frisancho et al. (1987) suggests that if a child with BMI below the 5th percentile also possesses UAMAH score below the 5th percentile, it can be inferred that the child is undernutrified (or wasted) [13]. The organism's first response to malnutrition first affects nutritionally labile tissues, such as fat and muscle, which then are depleted first and, as malnutrition continues, growth retardation occurs. Therefore, it is advised that the BMI and UAMAH should be used in conjunction for a more complete evaluation of the body composition, the growth and nutritional status [13, 30]. The use of UAMAH has improved the accuracy of detectionof undernutrition and may be a more appropriate indicator of it [30, 32]. This could allow for an objective, systematic and early screening and promote rational and early treatment, therefore reducing morbidity, mortality, worsening of the quality of life and global healthcare costs [26, 30, 32].

CONCLUSIONS

1. Upper-arm anthropometry is a valuable assessment of the nutritional status of preschool children in the Latvian population.
2. In the Latvian preschool children's population a child's BMI within a normal range could rather be associated with the muscle mass than the fat mass.
3. For a more complete nutritional assessment in preschool children in the Latvian population the BMI should be used in combination with upper-arm anthropometry and UAMAH scores to improve the screening of undernutrition.
4. The present study is supposed to be continued, including a higher number of subjects for a better assessment.

ABBREVIATIONS

Arm-fat index (AFI); Body mass index (BMI); Dual energy x-ray absorptiometry (DXA); Magnetic resonance imaging (MRI); Skinfold (SF); Upper-arm circumference (UAC); Upper-arm fat area (UFA); Upper-arm muscle area (UMA);Upper-arm muscle-area by height (UAMAH); Triceps skinfold thickness (TSF); World Health Organization (WHO).

REFERENCES

1. BMI Classification (2006). Global Database on Body Mass Index. World Health Organization.
2. Bolzan A., Guimarey L., Frisancho A.R. (1999). Study of growth in rural school children from Buenos Aires, Argentina using upper arm muscle area by height and other anthropometric dimensions of body composition. Ann Hum Biol, 26(2), 185–193.
3. Chomtho S., Fewtrell M.S., Jaffe A., Williams J.E., Wells J.C. (2006). Evaluation of arm anthropometry for assessing pediatric body composition: evidence from healthy and sick children. Pediatr Res, 59(6), 860–865.
4. Chowdhury S.D., Ghosh T. (2009). The upper arm muscle and fat area of Santal children: an evaluation of nutritional status. ActaPaediatr, 98, 103.
5. Corsi D.J., Mejía-Guevara I., Subramanian S.V. (2016). Risk factors for chronic undernutrition among children in India: Estimating relative importance, population attributable risk and fractions. SocSci Med, 157, 165–185.
6. Derman O., Yalcin S.S., Kanbur N.O., Kinik E. (2002). The influence of the sexual stages of adolescent boys on the circumference of the arm, muscle area and skinfold measurements. Int J Adolesc Med Health, 14(1), 19–26.
7. Derman O., Yalcin S.S., Kanbur N.O., Kinik E. (2002). The importance of the measurement of the circumference of arm, arm muscle area and skinfold thickness during puberty. Int J Adolesc Med Health, 14 (3), 193–197.
8. Eknoya G. (2007). AdolpheQuetelet (1796–1874) – the average man and indices of obesity. Nephr Dial Transpl, 23(1), 47–51.
9. Franzosi M.G. (2006). Should we continue to use BMI as a cardiovascular risk factor? Lancet, 368, 624–625.
10. Fentahun N., Belachew T., Lachat C. (2016). Determinants and morbidities of multiple anthropometric deficits in southwest rural Ethiopia. Nutrition, 2016 Apr 8,pii, S0899-9007(16)30038-7. doi:10.1016/j.nut.2016.03.023. (Epub ahead of print)
11. Freedman D.S., Wang J., Ogden C.L., Thornton J.C., Mei Z., Pierson R.N., Sopher A.B., Dietz W.H., Horlick M. (2009). Classification of Body Fatness by Body Mass Index-for-Age Categories Among Children. Arch Pediatr Adolesc Med, 163(9), 805–811.
12. Frisancho A.R. (1981). New norms of upper limb fat and muscle areas for assessment of nutritional status. Am J Clin Nutr, 34(11), 2540–2545.
13. Frisancho A., Tracer D.P. (1987). Standards of Arm Muscle by Stature for the Assessment of Nutritional Status of Children. American Journal of Physical Anthropology, 73, 459–465.
14. Garrow J.S., Webster J. (1985). Quetelet's Index (W/H2) as a Measure of Fatness. Int J Obes, 9(2), 147–153.

15. Gultekin T., Ozer B.K., Katayama K., Akin G. (2006). Age-related patterns of upper arm muscle and fat area in Turkish children and assessment of nutritional status. Int J Anthropol, 21, 231–239.
16. Herman-Giddens M.E.,Kaplowitz P.B., Wasserman R. (2004). Navigating the Recent Articles on Girls Puberty in Pediatrics: What Do We Know and Where Do We Go from Here? Pediatrics, 133(4), 911–917.
17. Hurtado-López E.F., Larrosa-Haro A., Vásquez-Garibay E.M., Macías-Rosales R., Troyo-Sanromán R., Bojórquez-Ramos M.C. (2007). Liver function test results predict nutritional status evaluated by arm anthropometric indicators. J Pediatr Gastroenterol Nutr, 45(4), 451–457.
18. Kriemler S., Puder J., Zahner L., Roth R., Meyer U., Bedogni G. (2010). Estimation of percentage body fat in 6- to 13-year-old children by skinfold thickness, body mass index and waist circumference. Br J Nutr, 104(10), 1565–1572.
19. Kromeyer-Hauschild K., Glasser N., Zellner K. (2012). Percentile curves for skinfold thickness in 7- to 14-year-old children and adolescents from Jena, Germany. Eur J Clin Nutr, 66, 613–621.
20. Kuczmarski R.J. (2002). CDC Growth Charts for the United States: methods and development. Vital Health Stat, 11(246), 1–190.
21. Lohman T.G., Going S.B. (2006). Body composition assessment for development of an international growth standard for preadolescent and adolescent children. Food Nutr Bull, 27(4), S314–325.
22. Ma C.M., Li Y., Gao G.Q., Yin F.Z., Wang R., Liu X.L., Lu Q. (2015). Mid-upper arm circumference as a screening measure for identifying children with hypertension. Blood Press Monit, 20(4), 189–193.
23. Nooyens A.C., Koppes L.L., Visscher T.L., Twisk J.W., Kemper H.C., Schuit A.J. (2007). Adolescent skinfold thickness is a better predictor of high body fatness in adults than is body mass index: the Amsterdam Growth and Health Longitudinal Study. Am J Clin Nutr, 85(6), 1533–1539.
24. Ozturk A., Budak N., Cicek B., Mazicioglu M.M., Bayram F., Kurtoglu S. (2009). Cross-sectional reference values for mid-upper arm circumference, triceps skinfold thickness and arm fat area of Turkish children and adolescents.Int J Food Sci Nutr, 60(4), 267–81.
25. Reilly J.J., Kelly J. (2011). Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes, 35, 891–898.
26. Report of a WHO Expert Committee (1995). Physical status: the use and interpretation of anthropometry. World Health Organ Tech Rep Ser, 854, 1–452.
27. Rolland-Cachera M.F., Brambilla P., Manzoni P., Akrout M., Sironi S., Del Maschio A., Chiumello G. (1997). Body composition assessed on the basis of arm circumference and triceps skinfold thickness: a new index validated in children by magnetic resonance imaging. Am J Clin Nutr, 65(6), 1709–1713.
28. Sen J., Mondal N. (2013). Fat mass and fat-free mass as indicators of body composition among Bengalee Muslim children.Ann Hum Biol, 40(3), 286–293.

29. Sen J., Mondal N., Dey S. (2011). Assessment of the nutritional status of children aged 5–12 years using upper arm composition. Ann Hum Biol, 38(6), 752–759.
30. Singh J. Mondal N. (2014). Use of Upper-Arm Anthropometry as Measure of Body-Composition and Nutritional Assessment in Children and Adolescents (6–20 Years) of Assam, Northeast India. Ethiop J Health Sci, 24(3), 243–252.
31. Sultana T., Karim M.N., Ahmed T., Hossain M.I. (2015). Assessment of under nutrition of Bangladeshi adults using anthropometry: can body mass index be replaced by mid-upper-arm-circumference? PLoS One, 10(4), e0121456.
32. Thibault R., Genton L., Pichard C. (2012). Body composition: why, when and for who? Clin Nutr, 31(4), 435–447.
33. Thibault R., Pichard C. (2012). The evaluation of body composition: a useful tool for clinical practice. Ann Nutr Metab, 60(1), 6–16.
34. Ulijaszek S.J. (2006). The international growth standard for children and adolescents project: environmental influences on preadolescent and adolescent growth in weight and height. Food Nutr Bull, 27(4 Suppl Growth Standard), 279–294.
35. Wang Y. (2002). Is obesity associated with early sexual maturation? A comparison of the association in American boys versus girls. Pediatrics, 110(5), 903–910.
36. Wells J.C. (2007). Sexual dimorphism of body composition.Best Pract Res ClinEndocrinolMetab, 21(3), 415–430.
37. Wohlfahrt-Veje C., Tinggaard J., Winther K., Mouritsen A., Hagen C.P., Mieritz M.G., de Renzy-Martin K.T., Boas M., Petersen J.H., Main K.M. (2014). Body fat throughout childhood in 2647 healthy Danish children: agreement of BMI, waist circumference, skinfolds with dual X-ray absorptiometry. Eur J Clin Nutr, 68(6), 664–670.
38. Zimmermann M.B., Gubeli C., Puntener C., Molinari L. (2004). Detection of overweight and obesity in a national sample of 6–12-y-old Swiss children: accuracy and validity of reference values for body mass index from the US Centers for Disease Control and Prevention and the International Obesity Task Force. Am J Clin Nutr, 79(5), 838–843.

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