Original Article

Obesity indices among infants and their parents, Shiraz, Iran

S.M.T. Ayatollahi, S.T. Heydari

Abstract

Background: Infantile obesity is becoming increasingly recognized as one of the public health problems in Iran.

Objective: Obesity charts of a cohort of 317 healthy infants and their parents living in Shiraz (Southern Iran) are presented and the familial pattern of infants' obesity with that of its parents explored.

Methods: An adjusted weight-for-height index was used to develop power type obesity indices, $I_p = W/H^p$. Polynomial modelling was used by applying the Healy-Rasbash-Yang (HRY) nonparametric method to estimate age-related smoothed centiles of obesity and dynamic obesity charts for infants and their parents are presented. Principal component analysis (PCA) was applied to the data as continuous variables to analyse familial pattern of parent-infant obesity structurally.

Results: The optimal value of p was found to be 2.5 for infants and 1 for their parents. Infants' obesity increases from birth to six months of age and decreases thereafter until the age of 21 months when it became stable. Obesity indices and circumferences sizes were reduced to two principal components interpreting infants as well as family obesity. The first principal component evaluates infants' obesity as a combination of obesity index as well as their arm, chest and head circumferences. Also the second principal component combines mothers' obesity and her arm circumference, while father obesity did not influence familial obesity structure significantly.

Conclusion: Obesity is an age related phenomenon and dynamic charts presented herein are appropriate practical tools to assess obesity in both infants less than two years of age and their parents.
Iran J Med Sci 2004; 29(4): 161-167.

Keywords ● Obesity chart ● infant ● parent ● age related

Departments of Biostatistics & Epidemiology,
School of Public Health,
Shiraz University of Medical Sciences,
 Shiraz, Iran

Correspondence:
SMT Ayatollahi PhD.
P.O. Box 71345-1874, Shiraz, Iran
Tel: +98 711 7251001
Fax: +98 711 7260225
E-mail: ayatolahim@sums.ac.ir

Introduction

Obesity is becoming increasingly recognized as one of the public health problems even in developed world[1-6] and also in recent decade in developing countries due to modernization, affluence, and increased food consumption.[7,10] Some studies have indicated that childhood obesity is predictable from their parents,[11,13] and more markedly was correlated with mother's obesity.[14]

Body Mass Index (BMI) is an indicator of obesity of school aged children as the subjects predominate in the most of these studies. Infantile obesity studies are few even in developed world.[15] Limited studies are carried out in the past decade, in Iran on preschool, school children and adolescents.[14,16,18]

However, at present no data are available on infants' obesity. BMI may not be an appropriate indicator for studying obesity in children less than two years. Hence a more appropriate index is needed to define infants' obesity. The value of dynamic charts, which take age into account, is of crucial importance for clinical works as well as public health strategies.

Therefore, the purpose of this paper was to (i) develop indices measuring the degree of fatness (obesity indices) in infants and their parents by scaling weight-for-height, (ii) present the pattern of change of these indices with age by fitting appropriate smooth curves and (iii) explore the familial pattern of infants' obesity with that of parents structurally in Shiraz, a major developed city in southern Iran.

Subjects and methods

Nearly all pregnant women in Shiraz (97.5%) give birth in hospitals. A cohort of 317 neonates (164 girls and 153 boys) were selected randomly using probability proportional to size scheme among those born at the 14 maternity clinics of Shiraz during two consecutive weeks from 7th to 20th of June 1996. Maternity clinics are scattered across the city and each formed a stratum. The selected subjects were healthy singleton neonates who were mothers conceived in Shiraz and their parents did not intend to migrate elsewhere during the study period. They were visited at homes at target ages of 1.5, 3, 4.5, 6, 8, 10, 12, 15, 18, 21 and 24 months as well as their supine lengths, weights, mid upper arm circumference (MUAC), head circumferences (HC) and chest circumferences (CHC) measured by the trained auxologists using techniques presented by Cameron.[19] Five trained auxologists observed infants in the first year of the study. Four of which were replaced by newly trained auxologists in the second year. All observers held a first university degree in the area of public health and/ or nursing and midwifery with distinction. In addition four community medicine experts monitored the subjects for three months from birth. If needed, infants were referred to a consultant pediatrician. A subject was considered as missing, if at least one of the following conditions was met: 1. were not available for any reasons when home visits were performed at least three times at that occasion. 2. Their family migrated elsewhere for unknown reasons. 3. The subject decided to leave the study. 4. The neonate expired. The selected cohort was a 2.5% sample of neonates born in 1996 in Shiraz.

The infant's lengths were measured to unit millimetre using portable length tables designed by the principal author. Their weights were measured to the last ten grams on sophisticated balance scales calibrated at each home. The MUAC, HC and CHC were measured to unit millimetre using a non extensible strip. The auxologists were instructed to weigh the infants naked. When due to baby's conditions this was not possible the type of clothing recorded in the analysis. Weight data were adjusted for average baby clothing weight, giving the real infant weight.

Ages on each occasion were precisely recorded, based on the difference between date of visit and date of birth in days and then converted to months subsequently.

Infants' age was corrected for gestational age (GA) if GA < 38 weeks. In this case the infant's age was calculated as:
AGE from Expected Date of Delivery (EDD) =AGE (from birth)-40+GA where EDD stands for expected date of delivery (i.e. 40 weeks). Observations were included only if AGE from EDD was equal to or greater than zero.

Choice of obesity indices
To adjust weight (kg) for height (m), indices of the form $I_p=(weight)/(height)^p$ were used, where p is a constant as indicated by Cole.[20] It is assumed that the distribution of obesity is independent of height, thus a 'good' value of p is one whose obesity index is uncorrelated with height. A good obesity index will also be highly correlated with weight. A model of the form of weight = C× $height^p$ (C is a constant) was fitted to search for appropriate values of p. log transformation led to log (weight) = C+p×log (height). Thus the value of p then can be estimated (with 95% confidence interval) by ordinary regression analysis.

Parent-infant age-related obesity centile charts
In order to fit appropriate models for obesity, HRY method[21] was used to estimate age related smoothed centiles. This method makes no assumption about the nature of the measurement. It first assumes that the 50th measurement centiles can be expressed as a polynomial of degree q (q=1,2) in age represented by t (in case of weight for height t is taken as height). The smoothed value of the 50th measurement centile, y_{50}, might be: y_{50} = $a_1t + a_2t^2 + a_3t^3$ +… Second, at any given age

the other measurement centiles may be expressed in polynomials of standard normal deviate, z, in relation to the 50th centile, i.e. $y_i = y_{50} + b_0 + b_1 z + b_2 z^2 + b_3 z^3 + ...$ where y_i is the qth smoothed centile of the measurement and z is the corresponding normal equivalent deviate (NED). In the second equation we see that if the measurements were exactly normally distributed with standard deviation of SD(y), then $b_2 = b_3 = ... = 0$ and $b_1 = SD(y)$. A term in z^2 can account for skewness and in z^3 for kurtosis. The HRY method does not assume that the coefficients b_1, b_2, b_3, are fixed but allows them to vary with age (t), so that the whole model after collecting together terms t^0, t^1, t^2, etc. from the two equations, and may be written as:

$$y_{it} = a_0 + b_{01}z + b_{02}z^2 + (a_1 + b_{11}z + b_{12}z^2 + ...)t + (a_2 + b_{21}z + b_{22}z^2 + ...)t^2 + ...$$

Table 1: Correlation coefficients of obesity of the form I^p with height and weight. The best obesity index is given in bold.			
Subjects	**Index**	**Height**	**Weight**
Children N=317	I_1	0.803*	0.978*
	$I_{1.5}$	0.689*	0.926*
	I_2	0.468*	0.789*
	$I_{2.5}$	**0.078**	**0.484***
	I_3	-0.375*	0.047
	$I_{3.5}$	-0.681*	-0.307*
	I_4	-0.832*	-0.515*
Fathers N=260	**I_1**	**0.082**	**0.962***
	$I_{1.5}$	-0.064	0.909*
	I_2	-0.206*	0.835*
	$I_{2.5}$	-0.334*	0.747*
	I_3	-0.441*	0.654*
	$I_{3.5}$	-0.525*	0.562*
	I_4	-0.528*	0.478*
Mothers N=301	**I_1**	**0.039**	**0.980***
	$I_{1.5}$	-0.062	0.954*
	I_2	-0.160*	0.919*
	$I_{2.5}$	-0.253*	0.877*
	I_3	-0.338*	0.829*
	$I_{3.5}$	-0.342*	0.777*
	I_4	-0.483*	0.725*

* $p < 0.001$

This method has been implemented for the World Health Organisation in the GROSTAT computer package.[22] First goodness of fit was assessed both graphically and numerically. Second Z-scores (SD scores) of the measurements were calculated upon fitting smoothed aged related centiles. We adopted 5th, 85th and 95th centiles as cut off points for thin, overweight and obese infants respectively, as generally accepted for children and adults.[6, 23, 25]

A structural principal component analysis (PCA) is used for an exploration of familial pattern of obesity. This sophisticated technique analyses the data as a whole. It is a suitable projection method for viewing a high dimensional set of quantitative data in a few dimensions in order to clarify the structure of the data.

The analysis used eight variables of obesity for each family. These were infants obesity index (IOI), infants arm circumference (IAC), infants chest circumference (ICC), infants head circumference (IHC), fathers obesity index (FOI), fathers arm circumference (FAC), mothers obesity index (MOI) and mothers arm circumference (MAC). As the eight sets of data are inter-related, some of the variability between families are explained by one variable, i.e. infant's OI, could also be explained by another variable, e.g. mothers obesity index. It is advantageous if the new variables are not correlated, so that the variability explained by one new variable is not explained in part by another. Variables such as these are called principal components (PC). The linear combination of the original variables which explains most of the variability between families than any other linear combination is called the first principal component. The second principal component is that linear combination which is uncorrelated with first principal component, and explains more of the residual variability between families than any other linear combination etc. In this analysis the principal components of the correlation matrix were computed using SAS software.

Results

Birth weights of 9 subjects (2.8%) were under 2500 grams (ranges 2050 to 2450 grams). No failure to thrive subjects was observed. A total number of 34 subjects (10.7%) left the study by age of six months, another 14 subjects (4.4%) by age of one year and 22 subjects (6.9%) by the end of the study period, giving 70 dropouts (22.0%) totally. Migration of parents to other cities due to occupational reasons was the main reason for missing values. No significant differences were seen between dropouts and other subjects with

Table 2: Correlation matrix of obesity indices and anthropometric circumferences.								
Index	IOI	IAC	ICC	IHC	FOI	FAC	MOI	MAC
Infant Obesity Index (IOI)	1							
Infant Arm Circ. (IAC)	0.69*	1						
Infant Chest Circ. (ICC)	0.47*	0.85*	1					
Infant Head Circ. (IHC)	0.40*	0.70*	0.82*	1				
Father Obesity Index (FOI)	-0.03	0.02	0.06	0.04	1			
Father Arm Circ. (FAC)	-0.12	-0.01	0.03	-0.06	-0.01	1		
Mother Obesity Index (MOI)	-0.05	-0.01	-0.07	-0.10	0.16*	0.06	1	
Mother Arm Circ. (MAC)	-0.06	-0.02	-0.06	-0.10	0.08	0.05	0.85*	1

* $p < 0.01$

respect to sociodemographic as well as behavioural and anthropometric characteristics. Therefore, dropouts were probably not selective.

Reliable weight data were available for only and heights were recorded only for 260 (82.0%) fathers and 303 (95.6%) mothers. Therefore, obesity indices based on the reliable measurements could only be computed for 260 (82.0%) fathers and 301 (95.0%) mothers. As a result, only 260 (82.0%) families had a complete set of joint measurements. Any analysis in this paper involving joint distribution of measurements is based on these numbers. Family data were 296 (93.1%) complete for < 6 months infants; 287 (90.4%) complete for 6-12 months infants, and 259 (81.6%) complete for older infants aged > 12 months.

Choice of obesity index
P was calculated as 1 with 95% confidence intervals (0.64-1.77) and (0.89-1.80) for mothers and fathers respectively and 2.5 with 95% confidence interval (2.42-2.72) for infants. The value of p for different age groups was examined and a power p > 1 for parents and a power > 2.5 for infants were not necessary. Therefore, p=1 and p=2.5, were chosen as the best powers for estimating an index of obesity for parents and infants respectively. For more validation a searching approach was applied using p=1, 1.5... 4. Table 1 shows that the only indices with minimal acceptable correlations with height are I_1 and $I_{2.5}$ for parents and infants respectively. These indices are significantly correlated with weight. Thus, I_1 and $I_{2.5}$ represent obesity better than any other indices in the Table. The correlation in Table 1 also shows that for the chosen indices, the correlation with height are 0.039, 0.082, 0.078 so that at most less than 1% of variation in the indices is associated with height and vice versa.

Table 1 also shows that the correlations with weight are 0.962 and 0.980 for fathers and mothers respectively, so that they can explain more than 86% of the variation in the weight. We have introduced arm circumference of mothers and fathers as complementary indicator of obesity in our analysis. The

correlation with weight is 0.484 for infants, which explains only 23.3% of variability in weight. Therefore, we have introduced arm, chest and head circumferences of infants in our analysis as complementary indicators of obesity. These measurements provide useful indication of growth, giving information paralleling body weight and have the advantage of operational simplicity.
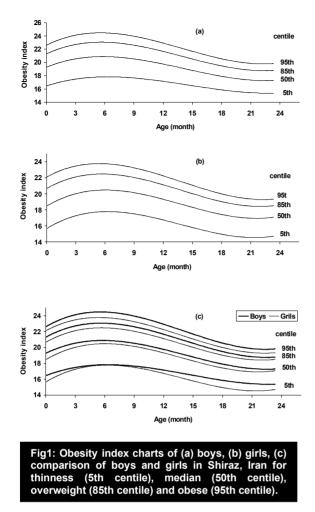
Obesity index charts
Obesity index charts of boys and girls are presented in Figs 1a and 1b respectively. A comparison of obesity index of both sexes is shown in Fig 1c. Obesity tends to increase with age in both sexes up to the age of 6 months and then decreases to age 21 months where it becomes stable. Girls' obesity centiles lie below boys. Parents' obesity index charts are displayed in figures 2a and 2b respectively, which are nearly age independent. No more than cubic and quadratic polynomials were needed to fit obesity-for-age smoothly for infants and their parents respectively.

The graphical procedures for assessing goodness of fit of the models were examined for all the measurements under the study to validate the age-related obesity models presented in Figs 1 and 2.

Parent-Infant Obesity
Table 2 shows the correlation matrix of obesity indices and anthropometric circumferences. Those measurements which had a significant correlation were employed in further structural analysis that followed by using only the first two principal components, the data can be plotted and the resulting diagram examined for clusters. The total variances explained by the first and second factors are 40.7% and 26.7% so that together they accounted for 67.4%. Thus, in these data, family obesity could be attributed to two factors and the data can be simplified as and after adopting the first two PCs communalities were calculated and as the proportion of variance explained by common factors.

Fig1: Obesity index charts of (a) boys, (b) girls, (c) comparison of boys and girls in Shiraz, Iran for thinness (5th centile), median (50th centile), overweight (85th centile) and obese (95th centile).

Fig 2: Obesityindex charts of (a) fathers and (b) mothers in Shiraz, Iran for thinness (5th centile), median (50th centile), overweight (85th centile) and obese (95th centile)

As a result of the analysis, the first and second principal components (PC1 and PC2) of the standardized variables were found to be approximately:
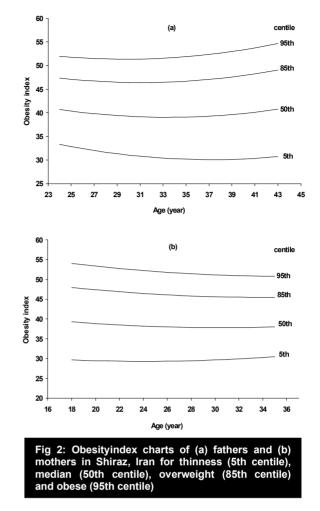
PC1=0.2×IOI+0.3×IAC+0.3×ICC+0.3×HC
PC2=0.5×MOI+0.5×MAC

PC1 presents infantile obesity which is a linear combination of infants' obesity index, arm, chest and head circumferences, PC2 evaluates family obesity as a linear combination of mothers' obesity as well as her arm circumference. Fathers' obesity did not show any significant influence on family obesity structure.

Discussion

This study displays a picture of obesity in a birth cohort of infants who were followed for two years as well as their parents in a defined population.

The reference values of infantile obesity are presented in this paper which due to the basis of sampling scheme used and structural socio-demographic consistency with the general population of less than two years infants is likely to be applied to urban populations of Iran's infants.

Most obesity studies in the world are either based on school children attending schools or those attending clinics.[8,9,16,26] Cole and Roede presented reference values for body mass index of Dutch children aged 0-20 years,[15] whereas our study focussed exclusively on children less than 2 years old, a very sensitive age.[6] However, these studies used body mass index as obesity index which may not be appropriate as far as the main purpose of an obesity index is concerned. One can see from Table 1 that BMI (I_2) was highly correlated with height for infants and their parents, which did not satisfy the fundamental definition of obesity. In addition, PCA analysis showed that obesity index of any kind is not enough to assess obesity; rather other related anthropometric measurements are needed for this purpose. This paper presented new indices for evaluating obesity which overcome the above mentioned drawbacks in definition of obesity using BMI. Obesity study should take into account the dynamic aspect inherent in the phenomenon and this study achieved the goal successfully

by presenting the age-related charts and the PCA.

Girls' obesity lies below boys and obesity age dependency for both genders was explored. A weak but non significant correlation exists between the obesity of parents and their infants, which concurs with our previous study.[14]

The first principal component comprising the infants' obesity index plus arm, chest and head circumferences may be a good way to summarize infants' obesity. This accord with our previous study on school children, which found that obesity in children was not described solely by an adjusted weight-for-height index, but also by arm circumference too.[14] The second principal component evaluated family obesity with more weights going to the mothers' obesity index and arm circumference. The principal component analysis proves to be an efficient tool for summarizing obesity in infants and their parents.

Acknowledgments

References

1 Kalies H, Lens J, Von Kries R. Prevalence of overweight and obesity and trends in body mass index in German pre-school children, 1982-1997. *Int J Obes Relat Metab Disord* 2002; **26**: 1211-7.

2 Zimmermann MB, Hess SY, Hurrell RF. A national study of the prevalence of overweight and obesity in 6-12 y-old Swiss children: body mass index, body-weight perceptions. *Eur J Clin Nutr* 2000; **54**: 568-72.

3 Rolland-cachera MF, Castetbon K, Arnault N, et al. Body mass index in 7-9-y-old French children: frequency of obesity, overweight and thinness. *Int J Metab DIsord* 2002; **26**: 1610-6.

4 Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth Charts: United States. *Adv Data* 2000; **8:** 1-27.

5 Kuskowska-Wolk A, Bergtrom R. Trends in body mass index and prevalence of obesity in Swedish women 1980-89. *J Epidemiol Community Health* 1993; **47**: 195-9.

6 Massa G. Body mass index measurements and prevalence of overweight and obesityy in school-children living in the province of Belgian Limburg. *Eur J Pediatr* 2002; **161**: 343-6.

7 Kordy MN, el-Gamal FM. A study of pattern of body mass index (BMI) and prevalence of obesity in Saudi population. *Asia Pac J Public Health* 1995; **8**: 59-65.

8 El-Hazmi MA, Warsy AS. A comparative study of prevalence of overweight and obesity in children in different provinces of Saudi Arabia. *J Trop Pediatr* 2002; **48**: 172-7.

9 Musaiger AO, Gregory WB. Profile of body composition of school children (6-18yrs) in Bahrain. *Int J Obes Relat Metab Disord* 2000; **24**: 1093-6.

10 al-Isa AN. Changes in body mass index (BMI) and prevalence of obesity among Kuwaitis 1980-1994. *Int J Obes Relat Metab Disord* 1997; **21**: 1093-9.

11 Guo SS, Wu W, Chumlea WC, et al. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *Am J Clin Nutr* 2002; **76**: 653-8.

12 Lake JK, Power C, Cole TJ. Child to adult body mass index in the 1958 British birth cohot: associations with parental obesity. *Arch Dis Child* 1997; **77**: 376-81.

13 Quek CM, Koh K, Lee J. Parental body mass index: a Predictor of childhood obesity? *Ann Acad Med Singapore* 1993; **22**: 342-7.

14 Ayatollahi SMT. Obesity in school children and their parents in southern Iran. *Int J Obes Relat Metab Disord* 1992; **16**: 845-50.

15 Cole TJ, Roede MJ. Centiles of body mass index for Ductch children aged 0-20 years in 1980- a baseline to assess recent trends in obesity. *Annals of Human Biology* 1999; **26**: 303-8.

16 Dorosty AR, Siassi F, Reilly JJ. Obesity in Iranian children. *Arch Dis Child* 2002; **87**: 388-91.

17 Ayatollahi SMT, Carpenter RG: Height, weight BMI and weight-for-height of adults in southern Iran: how obesity should be defined? Annals of Human Biology 1993; **20**: 13-9.

18 Ayatollahi SMT. Sizes and obesity pattern of South Iranian adolescent females. *Annals of Human Biology* 2003; **30**: 191-202.

19 Cameron N: The Measurement of Human Growth. Bristol: Biddle Ltd, Guildford and King's Lynn, 1984.

20 Cole TJ. Weight/height^p compared to Weight/height^2 for assessing adiposity in childhood: influence of age and bone on p during puberty. *Annals of Human Biol* 1986; **13**: 433-51

21 Healy MJR, Rasbash J, Yang M. Distribution-free estimation of age-related

centiles. *Annals of Human Biol* 1988; **15**: 17-22.

22 GROSTAT. A Programme for Estimating Age Related Distribution Free Centiles (London: London School of Hygiene and Tropical Medicine) 1988.

23 Barlow SE, Dietz WH. Obesity evaluation and treatment: Expert Committee recommendations. The Maternal and Child Health Bureau, Health Resources and Services Administration and the Department of Health and Human Services. *Pediatr* 1998; **102**:E29.

24 Must A, Dallal GE, Dietz WH. Reference data for obesity: 85th and 95th percentiles of body mass index (wt/ht^2) and triceps

skin folds thickness. *Am J Clin Nutr* 1991; **53**: 839-46.

25 Himes JH, Diets WH. Guidelines foroverweight in adolescent preventive services: recommendations from an expert committee. The Expert Committee on Clinical Guidelines for Overweight in Adolescent Preventive Services. *Am J Clin Nutr* 1994; **59**: 307-316.

26 Wang Z, Patterson CM, Hills AP. Association between overweight obesity and household income and parental body mass index in Australian youth: analysis of the Australian National Nutrition Survey, 1995. *Asia Pac J Clin Nutr* 2002; **11**: 200-5.