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Construction of Growth Charts of Body Mass Index for Adults in Pakistan: A Quantile Regression Approach

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Abstract: Available literature explores that having knowledge about an individual's body weight status, namely about the body mass index (BMI), remains helpful to overcome the problem of obesity. BMI growth chart may be taken as a useful tool in order to know an individual's obesity status in terms of BMI. In the present article, we construct growth charts of BMI for males and females, separately using quantile regression approach. Cross-sectional data comprising of 2000 adult (aged 14 years or more) individuals, both males and females were taken from Multan city as a case study. Following some available studies, we take six powers of the variable age as covariates while running the quantile regression with logarithm of BMI as dependent variable. Thus, obtained plots of BMI against different ages for different quantile settings, are the resultant growth charts. Referring the constructed BMI growth charts, it is reported that BMI for females is quite sensitive to age and the females gradually continue to put on their weights as compared to male especially, for middle ages of 30-45. BMI growth norms, expressed as 5th, 50th and 95th centiles are also discussed and males are reported to be heavier than those of females in their teen-ages.

Key words: BMI, growth charts, growth norms, obesity, quantile regression

INTRODUCTION

Obesity, an excessive accumulation of fat in the body, has acquired the status of a global epidemic (WHO, 1998). It has been related to numerous health risks, both physical and psychological. According to International Diabetes Federation (2004), 1.1 billion people in the world are estimated to be overweight and 320 million are calculated to be obese. More than 2.5 million deaths each year are attributed to obesity, a figure expected to double by 2030 (see also McLellan, 2002; WHO, 2004; Jawad, 2005).

There is a colossal medical and epidemiological literature on obesity exposing the association between obesity and adverse health effects (see, for example, Bray *et al*., 1998; Marion and Jacobson, 2000; Ferris, 2007). Further details can also be found by Aslam *et al.* (2010a,b).

Hollingsworth and Hauck (2005) note that, in addition to just health concerns, the medical and epidemiological literature on obesity reveals that the probable public health consequences of this epidemic are also potentially disastrous in economic terms. They further debate, "the most developed countries accept that universal provision of health care is the most efficient and equitable means of providing the population with the best possible life expectancy and quality of life. The increase in obesity makes us question how society can change the way it behaves, to avoid an overall fall in life expectancy and quality of life". According to Kan and Tsai (1993), the possession of knowledge on obesity's health risks prevents an individual from being overweight. So it becomes indispensable to know about obesity level of individuals.

There are many ways to determine if a person is obese, namely Body Mass Index (BMI), waist circumference, life insurance tables and absorptiometry etc. But a person's BMI (weight in kilograms divided by the square of height in meters) is the most widely accepted means of assessing obesity (Deurenberg *et al*., 1998). According to WHO's standards, a person is overweight if BMI $\geq$ 25 and obese if BMI $\geq$ 30.

A considerable literature can be found exploring the overweight/obesity status in Pakistan, see for example, Bharmal (2000), Pappas *et al.* (2001), Nanan (2002), Rehman *et al.* (2003), Afridi and Khan (2004), Khan *et al.* (2008) etc. and recently, Aslam *et al.* (2010a). The common point in these studies, is that all of them rely on just computing BMI and percentiles. However, Aslam *et al.* (2010b) extend the work presented by Aslam *et al.* (2010a) taking different covariates, responsible for obesity, into account. Following Chen (2005) and Ruhm (2006), Aslam *et al.* (2010b) make use of median regression, a special case of quantile regression, for studying the effects of different covariates on BMI. The significant covariates are gender, age, marital status, daily working hours, daily exercise routine and the number of meat-eaten days per week. But no efforts, in the all mentioned studies, have been made to construct growth charts of BMI for Pakistan. It is very pragmatic to use some percentiles representing an individual's

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standing according to his/her status of obesity at a given age and for this, growth chart of BMI can be thought as an adaptable tool. For the construction of such charts, BMI percentiles are required. However, according to Chen (2005), the empirical percentiles of BMI with grouped age provide a discrete approximation for the population percentile so it is more plausible to employ some regression methods to study the effects of different factors on obesity prevalence. Furthermore, the conventional regression methods are useful for estimating how covariates are related to mean values of the dependent variable but, without strong parametric assumptions, will not accurately indicate changes at other points in the distribution. Such assumptions are unlikely to be justified since BMI increases more over time at the high than the low end of the distribution. As an alternative, quantile regression methods proposed by Koenker and Bassett (1978), are used. The purpose of the quantile regression is to estimate conditional quantile functions, where quantiles of a response variable's distribution are specified as functions of observed covariates minimizes the weighted sum of the absolute deviations of the error term, unlike regression models that minimize the sum of the squared residuals (Koenker and Hallock (2001).

Recently, following Chen's (2005) approach of quantile regression, Aslam and Altaf (2011) draw growth charts for Body Surface Area (BSA), separately for males and females, taking Multan city as a case study and using the same data set as used by Aslam *et al.* (2010a,b). Similar approach motivates us to construct BMI growth charts also and same is the objective of the present article.

MATERIALS AND METHODS

A cross-sectional data comprising of 2000 adult (aged 14 years or more) individuals, both males and females, except pregnant women, were taken from Multan city as a case study of Pakistan (see, Aslam *et al.*, 2010a,b for more details about the data).

For the present study, the variables of interest (with their respective codes) are Gender (GENDER: 1 = male and 2 = female), Age in years (AGE, rounded to next year), Weight in kg (WT), Height in inches (HT). While BMI of the individuals are calculated as weight in kilograms divided by height in meters squared.

When covariates X are considered, the linear conditional quantile function, $Q(\tau|X = x) = x'\beta(\tau)$, can be estimated by solving,

$$\hat{\beta}(\tau) = \operatorname{argmin} \sum_{i=1}^{n} \rho_\tau(y_i - x'_i \beta) \quad (1)$$

for any $\tau \varepsilon (0,1)$. The quantity $\hat{\beta}(\tau)$ is called the regression quantile. Further details of quantile regression have been skipped here and can be found by Chen (2005), Chen and Wei (2005), Stife and Averett (2009), Aslam *et al.* (2010b) and Aslam and Altaf (2011).

For the construction of BMI growth charts using quantile regression, we take natural logarithm of BMI (logBMI) as a dependent variable y in (1). Although the logarithm transformation might not help the quantile regression but, it might help the statistical inference on regression quantiles (Chen, 2005). It has been established to involves six powers of AGE as covariates for the quantile regression and they are INVAGE (AGE^{-1}), SQRTAGE ($\sqrt{AGE}$), AGE, AGE^2 (AGE*AGE) and AGE^3 (AGE*AGE*AGE) (see Chen, 2005, for details). We take τ = 0.05, 0.10, 0.25, 0.50, 0.75, 0.85, 0.90 and 0.95 for computation of 5th, 10th, 25th , 50th, 75th, 90th and 95th BMI percentiles, respectively, using the quantile regression. The BMI growth charts are constructed for both, males and females plotting BMI percentiles against age of the respondents. We use EViews 7.0 (Quantitative Micro Software, 2009) to run the quantile regression for the BMI percentiles.

RESULTS AND DISCUSSION

In our data set of 2000 individuals, 1123 are males (56.2%) and 877 are females (43.8%). Since the data set under study has already been used and discussed by Aslam *et al.* (2010a,b) and Aslam and Altaf (2011), therefore, the details of summary statistics about the age, weight, height, BMI and obesity status can be had from Aslam *et al.* (2010a,b). However, for the interest of readers, we reproduce few results about weight, height and BMI alongwith respective standard deviations given in parentheses. The mean weight for males is 62.0 (10.64) while for females is 48.4 (9.69), respectively. Similarly, the mean height and the mean BMI are 65.0 (3.02) and 20.91 (3.63) for males, respectively and the same are 61.0 (2.63) and 19.33 (3.92) for females.

To explore the growth pattern of BMI, BMI growth norms (see Cacciari *et al.*, 2002, for details) expressed as 5th, 50th and 95th centiles, are given in the following Table 1. The table presents a comparison between males and females for different BMI percentiles at different cut-offs of age like, 15, 20, 25, 30, 35, 40, 45, 50 and 55. From the table, it can be concluded that if there are 100 boys at age of 15 years, 5 of them will be seriously underweight (BMI = 15.01) and the situation is more severe for girls of the same age. Even at this age, more than 50% boys and girls remain underweight in Multan. The BMI level improves a little bit at age 20 for both the genders while considering 5th centiles. At this age, the 95th percentile shows an overweight status with BMI, 28.39 and 27.53 for males and females, respectively. A moderate difference emerges in the median values males and females, till age 25 and males seem to be heavier than females. But after 45, females become substantially heavier than males with respect to median values of BMI while during middle ages (30 to 35), there is no considerable difference in the median values of BMI.

Table 1: BMI growth norms, expressed as 5th, 50th and 95th centiles

	Males			Females		
Age	5th	50th	95th	5th	50th	95th
15	15.01	18.72	25.42	14.43	17.32	23.10
20	17.59	21.93	28.39	16.24	21.48	27.53
25	19.14	24.06	29.95	18.84	23.06	30.04
30	19.99	24.86	30.03	19.86	24.88	32.14
35	20.10	24.77	30.39	20.20	25.12	32.50
40	20.17	25.16	30.31	21.88	27.03	32.94
45	20.28	26.22	30.24	22.81	27.26	33.52
50	20.34	27.56	32.40	24.77	31.62	34.94
55	20.52	28.62	36.67	26.14	33.27	35.84

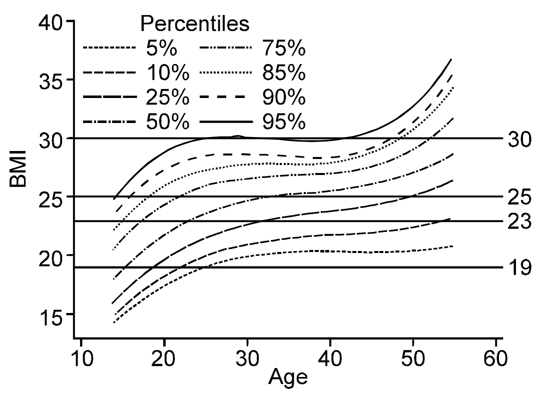

Fig. 1: BMI growth chart for males. BMI percentiles for males of aged 14 years and above

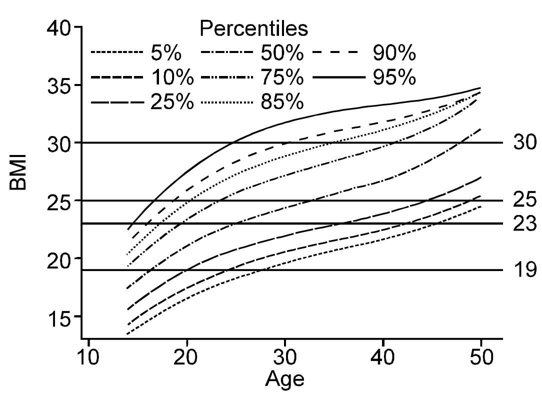

Fig. 2: BMI growth chart for females. BMI percentiles for women of aged 14 years and above

Eight percentile (5th, 10th, 25th, 50th, 75th, 85th, 90th and 95th) curves of BMI for males and females are shown by Fig. 1 and Fig. 2, respectively. Three standard BMI-cutoff points, 19, 25 and 30 mentioned in the both figures. According to the WHO's recommendations (2000), one additional cutoff at BMI = 23, is also given. According to these recommendations, a person will be underweight (if BMI < 19), normal (if 20 $\leq$ BMI < 23), overweight (if 23 $\leq$ BMI < 25) and obese (BMI $\geq$ 25) (see, also Nanan, 2002; Leung *et al.*, 2008; Jaleel, 2009; Aslam *et al.*, 2010a).

For males, starting from age 14, BMI has a cogent drop followed by a gradual growth until age 25 but for females the BMI drop and growth are relatively small with the increase for all ages. For males, BMI remains stable after age 30, while for females, the growth continues till the recorded ages. Beginning from age 14, boys show, as compared to girls, a faster growth rate of BMI for all the quantiles and the same has been discussed earlier with reference to Table 1. But during ages between 30 and 40, the situation converses, namely for the upper percentiles. Again after 40s, males seem to be heavier than females in terms of high BMI growth rate. Two obvious concavities are noted in the percentile curves for males; one between age 20 and 30 and the other for age 45 and above but for upper percentiles. On the other hand, only a weaker concavity can be observed for females between ages 20 and 30.

Unfortunately, our data set do not contain sufficient observation for higher ages, 55 and above, therefore the behaviour of the curves for higher ages cannot be exposed.

If we focus on 50th percentiles for both males and females, it is clear that the growth pattern is same for the both genders. But for upper percentiles (85%, 90%, and 95%), females show more growth in their BMI as compared to their counterparts. Five percent of the females become obese after age of just 25 while males attain the same percentage after age 45. Similarly, 10% of males become overweighed after age 18 but this percentage is attained by females at age 21.

Conclusion: Following some available studies (Chen, 2005; Aslam and Altaf, 2011), we use the quantile regression to construct growth charts of BMI for males and females, separately. Since, it is not common practice to use BMI growth charts for males and females, separately so our findings were not directly comparable with the available studies in Pakistan. Any how, when BMI growth charts for males and females is compared, it is concluded that the males remain relatively stable in gaining weight as compared to the females. On the other hand, the females gradually continue to put on their weights with the increase in age. With the similar approach of quantile regression, we can construct growth charts for other age-related variables of medical measurements for the population of Pakistan. Such growth charts may be used as reference growth charts if a suitable size of relevant data are collected for all the ages.

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