By definition, obesity is a disproportionate buildup of energy in the form of body fat, which impairs health. The degree of health impairment is determined by the amount and distribution of fat, and the presence of other risk factors. Among the mentioned factors, it is the distribution of fat that serves as key to understanding the relationship between obesity and disease.1 The significance of body fat distribution in relation to various metabolic diseases is not a new concept. Studies carried out by the late Dr. Jean Vague showed that insulin resistance and hyperinsulinism are the metabolic bases for accelerated atherosclerosis, diabetes, gout, and uric calculi in the android type of obesity.2 These insights have imposed a need to determine body composition, and the mass and fat tissue distribution.

Body mass index (BMI) and waist-hip ratio (WHR) are two of the most commonly used indices for obesity. In terms of their relation to adverse coronary outcomes, however, WHR is more consistent as an index of abdominal obesity and a stronger predictor of atherosclerotic events compared to BMI3 in both men4 and women.5 A particularly important anthropometric parameter which has been increasingly applied in the recent years is the sagittal abdominal diameter (SAD) (also called abdominal height) measured by calipers constructed by Kahn.6 It has recently gained attention because of its stronger correlation to cardiovascular diseases compared to the other anthropometric measures.7 In a recent study by Sampaio et al, SAD was considered to be a valid predictor of visceral abdominal fat with very high reliability (interclass coefficient, 0.99).8 Although this anthropometric indicator measures only the visceral fat tissue, it gives a very good estimate of metabolic risks because of the type of fat tissue involved.

Few studies have actually linked SAD to other metabolic abnormalities. A recent study by Mukuddem-
Petersen and colleagues concluded that the use of SAD had no advantages over simpler and more commonly used anthropometric measures such as the waist circumference in older men and women. On the other hand, Petersson and colleagues emphasized that SAD identifies insulin resistance, subclinical inflammation, and hyperlipidemia, at least among Swedish women and women of Middle eastern descent. No such study has been undertaken in the Middle East, particularly in Saudi Arabia, where the incidence of obesity, including childhood obesity, and other metabolic risk factors are high. Furthermore, very few studies have been undertaken with regards to SAD among children. Hence, this study aims to establish cut-off points for SAD (values below the cut-off are considered abnormal) among Arab youth and to determine the relationship of SAD to conventional markers of obesity such as BMI, waist, hip circumference, and WHR.

**METHODS**

This cross-sectional study was conducted at the Diabetes and Endocrinology Research Laboratory of King Saud University, Riyadh Kingdom of Saudi Arabia from January 2008 to December 2008. The subjects were Saudi children aged 5-17 years who were recruited randomly by primary care physicians through door-to-door interviews within Riyadh, Saudi Arabia. Recruitment was part of the ongoing biomarker screening of the Ministry of Health in collaboration with King Saud University. Written and informed assent from the children and parental consent were obtained. Ethical approval was obtained from the Ethics Committee of the College of Medicine and Research Center, King Saud University Riyadh, Kingdom of Saudi Arabia.

The 964 subjects included 365 prepubertal (146 boys and 219 girls), 249 pubertal (125 boys and 124 girls), and 350 postpubertal (198 boys and 152 girls) children. Tanner staging was used to assess the pubertal stage of boys and girls by trained physicians during their physical exam. Subjects within stage 1 were assigned to the prepubertal stage, subjects within stages 2-4 to the pubertal stage, and subjects in stage 5 to the post-pubertal stage. Children with acute or chronic medical conditions as well as those with diabetes and/or asthma were not included in the study. A generalized datasheet containing demographic information and consent was given to the subjects with their parents’ assistance along with a sheet for anthropometric measurements.

Trained research nurses were assigned to record anthropometric indices. A measurement called percentile of BMI was used to identify overweight and obesity in children and adolescents. The BMI used for this study was gender- and age-specific for children. Measurements included height, weight, waist circumference, hip circumference, and SAD. Body weight in light clothes was measured to the nearest 0.1 kg using a standardized Detecto balance beam scale (Detecto Scale Inc, Brooklyn, NY, USA). Height was assessed to the nearest 0.5 cm using standardized stadiometers (Detecto Scale Inc, Brooklyn, NY, USA). Subjects were asked to stand upright on a flat surface without shoes, with the back of their heels and the occiput on the stadiometer. BMI was calculated as weight (kg) divided by height in squared meters. Waist circumference was measured using a standardized measuring tape to the nearest centimeter, taken midway between the lowest rib and iliac crest, whereas hip circumference was measured at the level of the greater trochanters. Holtain Khan abdomi-
nal calipers (Holtain Ltd, Crymych, UK) were used to measure SAD. Each subject was examined in the supine position on a firm examination table. Using sliding calipers with parallel blades, a direct reading could be made between the lower arm (touching the subject’s back) and the sliding upper arm (touching the front of the subject’s abdomen). The measurement was taken after normal expiration (as instructed by the research nurse) with the subject in a relaxed position, and the caliper not indenting the subject’s skin. Systolic and diastolic blood pressure readings were also measured using an aneroid sphygmomanometer (Omron with pediatric cuffs by Kappa Medical LLC, AZ, USA).

The data were analyzed using the Statistical Package for the Social Sciences (SPSS for Windows version 11.5). Data are expressed as mean (standard deviation) or as median and range if not normally distributed. Group comparisons were done using the t test or by the Mann-Whitney U-test if not normally distributed. Frequencies were expressed in percentages. Normalization of BMI was done to calculate z scores. BMI z scores were plotted according to the SAD percentiles of boys and girls that had been stratified to pubertal stage. In essence, the z score represents the number of SD units by which a given score deviates above or below the mean score. As zero corresponds to the mean BMI, the percentile SAD value nearest to a z score of zero was deemed to be the cut-off value. Simple and partial correlation coefficients were determined and regression analysis done to determine relationships between variables of interest. Significance was set at \( P < .05 \).

**RESULTS**

As expected, all parameters of postpubertal subjects were significantly higher compared to their pubertal and prepubertal counterparts, regardless of gender (Table 1). The cut-off values for SAD are shown in red in Table 2, which shows BMI z scores relative to SAD percentiles (Table 2). Although there was a significant correlation between SAD and the indices of obesity, regardless of gender, also noteworthy was the very strong association of SAD with BMI as well as waist and hip circumference of pubertal boys ( \( R \) values: 0.77, 0.75, 0.74; \( P < .001 \) respectively). Furthermore, there was a weak association between systolic blood pressure and SAD ( \( R = 0.18; P < .05 \) ) among pubertal boys that was not present in other subgroups (Table 3). This association was lost after adjusting for BMI, waist, and hip circumference. The strongest association of SAD was with BMI, regardless of gender, during the pubertal stage ( \( R^2 = 0.45; P < .001 \) ) (Figure 1). Neither BMI nor SAD values of postpubertal subjects showed a Gaussian distribution (Figure 2), which probably explains why the cut-off points established for both boys and girls in this age group were beyond the 50th percentile. The prevalence of overweight and obesity in both boys and girls which was most evident in the postpubertal group (Figure 3).

**DISCUSSION**

Anthropometric measures are clinically useful because their collection is noninvasive and cheap. Measures such as BMI are highly associated with cardiovascular disease. On the other hand, measures of abdominal obesity

| Table 2. Percentiles of sagittal abdominal diameter (SAD) and corresponding body mass index (BMI) z scores of subjects according to pubertal stage. |
| SAD (cm) percentile | Prepubertal | BMI z scores | Postpubertal |
|---------------------|------------|--------------|--------------|
|                     | Girls      | Boys         | Girls        | Boys         | Girls        | Boys         |
| 10                  | 11 (-0.15) | 11 (0.03)    | 13 (-0.1)    | 12.7 (-1.07) | 14 (-0.46)  | 14.1 (-0.39) |
| 20                  | 12 (-0.08) | 11 (0.03)    | 14 (-0.24)   | 14 (-0.45)   | 15.9 (-0.63) | 16 (-0.46)   |
| 30                  | 12 (-0.08) | 12 (-0.09)   | 15 (0.03)    | 15 (-0.25)   | 17 (-0.04)  | 17 (-0.33)   |
| 40                  | 13 (-0.45) | 13 (-0.05)   | 15.7 (-0.71) | 15.2 (-0.56) | 18 (-0.13)  | 18 (0.66)    |
| 50                  | 14 (-0.01) | 13.6 (-0.49) | 17 (-0.3)    | 16 (-0.04)   | 19 (-0.4)   | 19 (0.57)    |
| 60                  | 14.7 (-0.68)| 14 (-0.02)  | 18 (0.3)     | 17 (-0.26)   | 20 (0.33)   | 20 (0.51)    |
| 70                  | 15.4 (-0.19)| 15 (-0.17)  | 19 (-0.36)   | 18 (-0.25)   | 21.5 (0.02) | 21 (0.48)    |
| 80                  | 16.5 (0.14)| 16 (-0.05)   | 20.6 (-0.05) | 19.5 (0.63)  | 23 (0.26)   | 22 (0.14)    |
| 90                  | 18.3 (1.38)| 18 (-0.2)    | 24 (1.44)    | 22 (2.08)    | 25 91.3     | 28 (3.9)     |

Data are SAD (z score). Cut-off values for SAD in red.
Table 3. Pearson correlation coefficients using SAD as a dependent variable among subjects in different pubertal stages.

| Parameter                        | Prepubertal | Pubertal | Postpubertal |
|----------------------------------|-------------|----------|--------------|
|                                  | Girls       | Boys     | Girls        | Boys       | Girls   | Boys   |
| Age (years)                      | 0.18        | 0.27     | 0.06         | -0.05      | 0.12    | 0.23   |
| BMI (kg/m²)                      | 0.24        | 0.22     | 0.32         | 0.77       | 0.50    | 0.44   |
| Waist (cm)                       | 0.23        | 0.33     | 0.33         | 0.75       | 0.39    | 0.41   |
| Hips (cm)                        | 0.30        | 0.44     | 0.31         | 0.74       | 0.34    | 0.12   |
| Systolic blood pressure (mm Hg)  | 0.11        | 0.01     | 0.03         | 0.18       | 0.06    | -0.02  |
| Diastolic blood pressure (mm Hg) | 0.12        | 0.02     | -0.01        | 0.13       | 0.05    | -0.03  |

*a P<.05; *b P<.001

**Figure 1.** Association of SAD with BMI z scores according to pubertal stage: a) prepubertal, b) pubertal and c) postpubertal.

**Figure 2.** Histograms of selected anthropometric measurements according to pubertal stage: a) SDI prepubertal vs postpubertal, b) BMI prepubertal vs postpubertal and c) waist circumference distribution vs postpubertal.
such as the waist-hip ratio could be more clinically useful than BMI to predict diabetes and cardiovascular disease.10 SAD has recently gained attention because of its stronger correlation with cardiovascular diseases compared to other anthropometric measures.13 In a study done by Anjana and colleagues, both waist circumference and SAD were found to correlate well with visceral and abdominal obesity, both of which are strongly correlated to the development of diabetes.12 In another recent study by Oppert et al, SAD was found to be the only significant predictor of cardiac death compared to other measures of obesity.13 Krist et al were the first to demonstrate that the sagittal diameter measured by CT scan was closely related to the volume of visceral fat.14 The correlation of the sagittal diameter was 0.94 in 19 women and 0.92 in 24 men, with subjects presenting a wide range of BMI. The correlations between the waist circumference and visceral fat were found to be 0.85 and 0.88, respectively. These correlations are considerably higher than those observed between anthropometric variables and the visceral fat area measured at the level of the umbilicus in obese men and women.15

To the best of our knowledge, no study has been conducted to determine SAD cut-offs and their relationship to other measures of obesity among Arab youth. This is particularly important as childhood obesity that persists into adulthood is an inevitable factor for the growing incidence of noncommunicable chronic diseases. Furthermore, there is still no existing consensus as to the definition of pediatric metabolic syndrome.16 Compared to other studies, our postpubertal cut-offs were relatively higher compared to those found in Brazilians (19.3 cm and 20.5 cm as the threshold values for SAD in women and men),8 suggesting probable ethnic variation or other factors such as choice of the cohort.

In our study, SAD was strongly associated with several components of the metabolic syndrome (BMI and systolic blood pressure) although this does not apply to all ages. This age-wise difference reflects the body’s evolution through childhood and puberty and the associated changes in metabolic and clinical characteristics.16 Nevertheless, SAD remains a promising alternative measure of central obesity among children as it is superior to other anthropometric measures in terms of visceral fat estimation.17 This is because when a person with enlarged intraabdominal adipose tissue is standing, all fat tissue is pulled downwards. Hence, waist or hip circumference measurements may not be as accurate in assessing the intraabdominal fat, especially among children who are very obese. When the same person lies supine, the mass shifts cranially, causing anterior projection of the abdomen which is measured by the sagittal diameter. Thus, it is the anteroposterior fat that seems to be important for the prediction of the metabolic syndrome.18

Our results showed gender differences in terms of the strength of SAD’s association with other measures of obesity, which was more evident in the pubertal group as compared to the prepubertal group. This confirms the findings of Arfai and colleagues at least in terms of visceral fat.19 Furthermore, in our results, boys and girls showed no difference in SAD values, indicating a monomorphic trend in values for intraabdominal adipose tissue at least during childhood. In contrast, visceral fat is more predominant in males due to considerable gender differences in fat topography among adults.18

Epidemiological studies conducted in Saudi Arabia point to an increased incidence of overweight and obese Saudi children.20-24 Given that obesity is an influential risk factor for certain cancers and chronic diseases such as atherosclerosis, hypertension, and most especially, diabetes mellitus (prevalence of 23.7% in 2004 alone25), it is imperative to address childhood obesity as critically as one would address its co-morbidities. The use of SAD therefore offers a cheap but reliable index of how close a child is to developing insulin-resistance-related diseases. Establishing SAD cut-offs that are specific to gender and age, is imperative to develop meaningful and evidence-based strategies aimed at reducing risk factors through parental education, school programs, and child-
hood training.

Although the sample size was large enough to elicit the needed associations, a bigger sample size with the inclusion of rural children would have distinguished the impact of SAD on various age groups as well as establishing more reliable cut-offs that would have been age- and gender-specific. Furthermore, as this study was confined only to anthropometric measurements, further studies which will include other components of the metabolic syndrome such as lipid profile and glucose levels besides other laboratory measurements, are necessary to strengthen the clinical relevance of SAD among the obese pediatric population. A prospective approach is also suggested to determine whether variations in SAD translate to changes in the metabolic profiles of children.

In conclusion, SAD can be used as a reliable indicator of visceral obesity among children and adolescents in particular. Further studies should be done to prospectively compare its association to harder measures such as cardiometabolic risk factors, components of metabolic syndrome, and indices of insulin resistance to determine whether SAD can be a promising risk factor for diabetes mellitus and coronary heart disease.

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REFERENCES
1. Larsson I. Human body composition: Reference data and anthropometric equations, the metabolic syndrome and risk. Scand J Nutr 2005; 49: 133-4.
2. Vague J. The degree of masculine differentiation of obesity: A risk factor for determining predisposition to diabetes, atherosclerosis, gout, and uric calculous disease. Am J Clin Nutr 1996; 64: 20-34.
3. Canoy D., Boekholdt SM, Wareham N, Luben R, Welch A, Bingham S, et al. Body fat distribution and risk of coronary heart disease in men and women in the European Prospective Investigation into Cancer and Nutrition in Norfolk cohort: A population-based prospective study. Circulation 2007; 115: 2933-43.
4. Rexrode KM, Buring JE, Manson JE. Abdominal and total adiposity and risk of coronary heart disease in men. Int J Obes Relat Metab Disord 2001; 25: 1047-56.
5. Rexrode KM, Carey VJ, Hennekens CH, Walters EE, Colditz GA, Stampfer MJ, et al. Abdominal adiposity and coronary heart disease in women. JAMA 1998; 280: 1843-8.
6. Gustaf J, Elkasabany A, Srinivasan S, Berenson GS. Relation of abdominal height to cardiovascular risk factors in young adults: The Bogalusa Heart Study. Am J Epidemiol 2000; 151: 885-91.
7. Ivens LA. Recent diagnostic methods of the specific distribution of adipose tissue. Med Prir 2000; 33: 184-7.
8. Sampaoi LR, Simões EJ, Assis AM, Ramos LR. Validity and reliability of the sagittal abdominal diameter as a predictor of visceral abdominal fat. Arq Bras Endocrinol Metabol 2007; 51: 980-6.
9. Mukaddem-Petersen J, Snijder MB, van Dam HM, Dekker JM, Bouter LM, Stehouwer CD, et al. Sagittal abdominal diameter: No advantage compared with other anthropometric measures as a correlate of components of the metabolic syndrome in elderly from the Hoorn Study. Am J Clin Nutr 2006; 84: 995-1002.
10. Petersson H, Daryani A, Riisér U. Sagittal abdominal diameter as a marker of inflammation and insulin resistance among immigrant women from the Middle East and native Swedish women: A cross-sectional study. Cardiovasc Diabetol 2007; 6: 10.
11. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: International survey. BMJ 2000; 320: 1246-8.
12. Anjana M, Sandeep S, Deepa R, Vimalanathan KS, Farooq S, Mohan V. Visceral and central abdominal fat and anthropometry in relation to diabetes in Indian Indians. Diabetes Care 2004; 27: 2494-8.
13. Oppert JM, Charles MA, Thibault N, Guy-Grand B, Eschwege E, Ducimetière P. Anthropometric estimates of muscle and fat mass in relation to cardiac and cancer mortality in men: The Paris prospective study. Am J Clin Nutr 2002; 76: 1107-13.
14. Krist H, Chowdhury B, Grangård U, Tylén U, Sjöström L. Total and visceral adipose tissue volumes derived from measurements with computed tomography in adult men and women: Predictive equations. Am J Clin Nutr 1998; 68: 1351-61.
15. van den Kooi K, Leenen R, Seidell JC, Deurenberg P, Visser M. Abdominal diameters as indicators of visceral fat: Comparison between magnetic resonance imaging and anthropometry. Br J Nutr 1993; 70: 47-58.
16. Pietrobelli A, Malovoliti M, Battistini NC, Fuiano N. Metabolic syndrome: A child is not a small adult. Int J Pediatr Obes 2008; 3: 57-71.
17. Asayama K, Dobashi K, Hayashibe H, Kodera K, Uchida N, Nakane T, et al. Threshold values of visceral fat measures and their anthropometric alternatives for metabolic derangement in Japanese obese boys. Int J Obes Relat Metab Disord 2002; 26: 208-13.
18. Valsamakis G, Chetty R, Anwar A, Banerjee AK, Barnett A, Kumar S. Association of simple anthropometric measures of obesity with visceral fat and the metabolic syndrome in male Caucasian and Indo-Asian subjects. Diabet Med 2004; 21: 1339-45.
19. Afzal K, Pitsilopoulou E, Dziadzio S, Tancredi L, Di Tommaso L, Coviello A, et al. Waist circumference, body mass index and waist-to-hip ratio are better determinants of visceral fat than BMI in a large sample of healthy Mexican-American adults. Obes Rev 2007; 8: 215-21.
20. El-Hazmi MA, Warsy AS. The prevalence of obesity and overweight in 1-18-year-old Saudi children. Ann Saudi Med 2002; 22: 303-7.
21. Al-Almaie SM, Al-Saeed WY, Al-Dawood KM, Bukhari IA, Bahnassy A. Prevalence and socio-economic risk factors of obesity among urban female students in Al-Khobar City, Eastern Saudi Arabia. Obes Rev 2003; 4: 91-9.
22. Al-Ruban MO. Obesity among Saudi male adolescents in Riyadh, Saudi Arabia. Saudi Med J 2003; 24: 27-33.
23. Al-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.
24. Al-Nozha MM, Al-Maatouq MA, Al-Mazrou YY, Al-Harthi SS, Arafah MR, Khalil MZ, et al. Diabetes Mellitus in Saudi Arabia. Saudi Med J 2005; 26: 1633-10.