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Laser beam measurement of abdominal sagittal diameter in obese children: a validation study

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Summary

Objectives—Sagittal diameter (SAD) has been reported to correlate to visceral fat and cardiovascular risk factors. SAD is measured with the individual lying down, halfway between the lower rib margin and the iliac crest; it represents the mid-height of the abdomen. The aim of this study was to validate SAD measured using a recently-developed laser beam device (SAD_{LDB}) against SAD measured using MRI (SAD_{MRI}).

Methods—Of 48 obese children (25 boys, 23 girls) aged 9–11 years on the waiting list for obesity treatment, 34 agreed to a baseline measurement, which was followed by repeated measurements 6 and 12 months later in 31 and 22 children respectively. MRI was used to examine SAD_{MRI} at 5 cm above ($SAD_{MRI,cra}$) and below ($SAD_{MRI,cau}$) the mid plane of the L4-5 intervertebral disc.

Results—Each of the differences $SAD_{LDB} - SAD_{MRI,cau}$ and $SAD_{LDB} - SAD_{MRI,cra}$ was subjected to a repeated-measurements ANOVA; the visit did not have a statistically significant effect in either case ($p = 0.19$ and $p = 0.72$, respectively). The difference $SAD_{LDB} - SAD_{MRI,cau}$ was 1.50 on average ($p < 0.0001$; CI 1.26–1.74) while the corresponding figure for $SAD_{LDB} - SAD_{MRI,cra}$ was 1.26 ($p < 0.0001$; CI 1.04–1.49). Regression of the difference on the mean gave slopes of -0.09 ($p = 0.25$) and -0.04 ($p = 0.57$) respectively. Prediction of SAD_{MRI} from SAD_{LDB} can be performed in different ways: by means of linear regression or by means of an additive correction.

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Conflict of Interest Statement

There are no other conflicts of interest.

Conclusions—Thus, this laser device can be used instead of MRI to estimate SAD by using a simple correction.

Keywords

Body composition; magnetic resonance imaging; sagittal diameter; visceral adipose tissue

Introduction

Regional distribution of adipose tissue was recognized as an important feature for evaluating health risks as early as the 1940s (1).

Body mass index (BMI) is recommended as a screening tool for identifying obese or overweight people at the population level. However, BMI does not distinguish between muscle mass and fat, and so risks misclassifying otherwise healthy individuals as obese (2,3). In adults, sagittal diameter (SAD) is highly correlated to the volume of visceral fat (4), which is thought to be an important component in metabolic syndrome (5). SAD is measured with the individual lying down, halfway between the lower rib and the iliac crest; it represents the mid-height of the abdomen. A derived measurement (SAD: mid-thigh circumference) has also been related to ischaemic heart disease in adult men hospitalized for ischaemic heart disease (6,7). Waist circumference (WC) and SAD are better risk indicators than the waist hip ratio (WHR) in both men and women (8). SAD is also a marker of insulin resistance (euglycaemic-hyperinsulinaemic clamp) in adults (9) and has been related to cardiovascular risk factors in both male and female young adults (10). It is therefore an important risk indicator in adults, but has not been used in children because of the technical problems in performing the measurement.

According to the experiences of the staff at the specialized childhood obesity unit at Skåne University Hospital, it is difficult to measure SAD during adolescence because of the psychological factors. The techniques used in adults require body contact, which is an unfavourable technique in children. Finally, there have been no validation studies comparing SAD measured with anthropometric tools (e.g. ruler) to measurements made with more exact devices such as magnetic resonance imaging (MRI).

MRI provides detailed and precise information regarding different fat depots (11). However, due to cost and availability constraints, it cannot be used in such a common condition as obesity. There is thus a need for a simpler but still reliable new method for estimating abdominal adiposity. We also wanted to develop a practical, applicable and child-friendly assessment to be used in clinical practice.

To fulfil these criteria, we developed a laser beam device (LBD) to anthropometrically measure SAD (SAD_{LBD}), making it possible to estimate visceral adiposity in future studies. Anthropometric SAD measurement has been used before in adults, but with different definitions (9,12). The level chosen in this study is equivalent to the level used for WC (midway between the lower rib margin and the iliac crest), and is easier to measure than the level of iliac crest in obese adult patients, as used in another study (9,13).

The aim of this study was to validate SAD_{LDB} against sagittal diameter measured using MRI (SAD_{MRI}), and to compare it with WC.

Such a validation could provide a tool for measuring SAD that is less expensive than MRI, equally accurate and still easily available for screening purposes. Furthermore, previous devices are not ideal for children and lack comparison with more exact measurements such as MRI. Finally, SAD seems to be the best predictor of cardiovascular risk and also of more importance than WC (14,15).

Methods and procedures

Forty-eight children aged 9–11 years (25 boys and 23 girls) on the waiting list for family-based obesity treatment at a tertiary referral centre were asked to participate. Children with precocious puberty were excluded by self-reported signs of puberty, physical examination or reviewing of growth charts (one of the authors, CEF). The children were obese according to international definition (16). They had simple obesity (no endocrine disorder), were selected 6 months before the investigation and were given no instruction to reduce calories. Measurements were taken in 34 children at baseline, 31 at 6 months and 25 at the 1-year follow-up; a total of 22 children had a complete dataset. The examination took place early in the morning after an overnight fast and included anthropometric measurements of weight, height and WC, which were measured according to standard procedures (17). The patients were first measured with the LBD and then taken in groups to the MRI measurement at the same day. After the patients were measured with the LBD, all anthropometric measurements were performed by the same investigator. Body weight was measured using an electronic scale (Tanita BWB-800, Tokyo, Japan.) to the nearest 0.1 kg, with the subject wearing light clothing without shoes. Height was measured using a standardized stadiometer (Hyssna Measuring Equipment AB, Hyssna, Sweden) to the nearest 0.1 cm without shoes. BMI was calculated as weight (kg) divided by the square of height (m). Imaging was performed on a clinical MRI system, Siemens Magnetom Sonata 1.5 T (Erlangen, Germany). An axial T1 weighted spin-echo sequence with the following parameters was used: TR/TE 210/12 ms, FoV 400 mm, Matrix 256 × 256, slice thickness 10 mm, 1 slice with a total acquisition time of 20 s. Two slices were acquired, 5.0 cm above and 5.0 cm below the intervertebral disc L4-L5, respectively.

Sagittal abdominal parameter

SAD_{LBD} was measured with the individual lying down, using a LBD (fig. 1). SAD_{LBD} was measured after normal expiration while in the supine position on a firm examination table and without clothes in the measurement area. The laser beam was placed halfway between the lower rib and the iliac crest. The laser was read against a measurement scale placed on the wall adjacent to the examination table. The laser source was placed on a tripod, making it simple to adjust the height where the laser beam disappeared from the measurement scale when lowered below the body contour. The device was assembled using a high-quality camera tripod and a laser device from building construction. The device has been further developed since (Innovator AB Skåne, patent pending 0900360-9 and 0950859-9).

Imaging analysis was performed at the Image Reading Center at the St. Luke's-Roosevelt Hospital of Columbia University, New York, USA. SAD_{MRI} was measured on cross-sectional MRI scans. The L4-5 level was examined both 5.0 cm above (with MRI cranially situated 5.0 cm above the L4-5 level, $SAD_{MRI,cra}$) and 5.0 cm below (MRI caudally situated 5.0 cm below the L4-5 level, $SAD_{MRI,cau}$) the midplane of the vertebrae (18–20). L5 was chosen since it is a traditional clinical landmark which is easy for an experienced doctor to find. The levels above and below L5 were chosen to find the best single MRI slice for this purpose. Slices above L5 have previously shown to give the best correlation to visceral adipose tissue and those below L5 to give the best correlation to subcutaneous adipose tissue (18–20).

Ethical approval

Signed informed consent was obtained from both children and parents. Ethical approval was obtained from the regional ethical review board at Lund University (Nos. 117/04 and 118/05). The procedure was in accordance with the Helsinki Declaration.

Statistical analysis

Repeated-measurements analysis of variance (ANOVA) was used to assess the influence of having the same child measured on several occasions. The relation between LBD and MRI measurements was investigated with linear regression of the difference in the mean ('Bland–Altman analysis') and also through assessment of prediction success, in terms of root mean squared errors (RMSEs), when predicting MRI results from LBD results. Comparisons between two estimates were performed using two-sided *t*-tests.

Results

The children had a mean age of 10.6 years (range 8.4–12.6) at baseline and 11.7 (range 9.7–13.8) at the final follow-up. BMI was 27.9 (standard deviation [SD] 2.4) at baseline and 30.2 (SD 3.0) at the final follow-up. The cut-off for obesity according to an international proposed standard is 24.6 and 24.8 (for boys and girls, respectively) at the age of 10.5 years and 25.6–26.0 at the age of 11.5 (16). According to this standard, all children were obese when they gave their informed consent. At baseline, three children had reduced their BMI (to 22.3, 24.2 and 23.9) and went from obese to overweight, and two of these returned to being obese at the next measurement.

$SAD_{MRI,cau}$ vs. $SAD_{MRI,cra}$

Repeated-measurements ANOVA of the differences $SAD_{MRI,cra} - SAD_{MRI,cau}$ did not show the visits to have a statistically significant effect ($P = 0.10$). Thus, we pooled data from all three visits and found the difference to be positive on average: 0.24 ($P = 0.0029$, confidence interval [CI] 0.08–0.39). Regression of the difference in the mean of the two measurements produced a slightly negative slope: -0.04 ($P = 0.39$).

SAD_{LBD} vs. SAD_{MRI}

Each of the differences $SAD_{LBD} - SAD_{MRI,cau}$ and $SAD_{LBD} - SAD_{MRI,cra}$ was subjected to a repeatedmeasurements ANOVA; the visits did not have a statistically significant effect in

either case ($P = 0.19$ and $P = 0.72$, respectively). The difference $SAD_{LBD} - SAD_{MRI,cau}$ was 1.50 on average ($P < 0.0001$, CI 1.26–1.74), while the corresponding figure for $SAD_{LBD} - SAD_{MRI,cra}$ was 1.26 ($P < 0.0001$, CI 1.04–1.49). Regression of the difference in the mean gave slopes of -0.09 ($P = 0.25$) and -0.04 ($P = 0.57$), respectively. Prediction of SAD_{MRI} from SAD_{LBD} can be performed in different ways: by means of linear regression or by means of an additive correction. Table 1 presents results on prediction success, as measured by RMSE. Table 2 shows data included in the calculations.

Discussion

The results of this first longitudinal study comparing SAD_{LBD} and SAD_{MRI} in obese children show the potential of using a practical anthropometric method. The possibility to predict SAD_{MRI} from SAD_{LBD} indicates that this method could be used in daily clinical practice. The SAD_{LBD} measurement is simpler to perform than WC, and also more comfortable for the patient as it does not involve physical contact. Previous techniques for measuring SAD required physical contact with the patient; e.g., using a ruler and a water level (21) or a caliper touching the patient's back and top of abdomen (22). The studied device reduces skin touching to a minimum compared with the use of water level or caliper but also when compared with the waist measurement process. In very sensitive patients, they could even indicate crista iliaca and the lower rib margin themselves, although this was not done in the present study. The disadvantage of such techniques is that physiological characteristics correlated with BMI indicate that obese subjects are more sensitive to skin discomfort (23). Furthermore, they have not been validated against more exact techniques such as MRI.

It has also been shown that SAD is a better indicator of cardiovascular risk than WC, visceral fat area measured with MRI, and abdominal fat compartment measured with CT (14,24,25). Notably, SAD is not likely to measure an increase in the transverse diameter.

A simple additive correction, independent of the level, seems appropriate for transformation between SAD_{MRI} and SAD_{LBD} , as indicated by the results given in Table 1.

Considering the precision to which measurements are made, we suggest that 1.5 cm should be added to an SAD_{LBD} value in order to obtain the corresponding SAD_{MRI} value; although there is a small systematic difference between the results from the two modes of obtaining MRI values, we do not deem it necessary to utilize different corrections. It is also relevant to mention that the variation among the differences is no larger in the part of the data where the SAD values are high than in the part where these values are low (data not provided). The reason for this difference could be that a softer bed was used together with the LBD than was used in the MRI machine. A constant correction was not chosen from the beginning, as it was not known how this would reflect on the results. However, our data indicate that all children compressed the softer bed to a similar extent. The instructions regarding respiration were the same using the LBD and the MRI machine.

Study limitations

A study limitation is the lack of puberty data. However, the aim of this study was to validate a new device for easily measuring SAD in children. Although the measurements of SAD, WC, WHR and BMI z -score might be influenced by puberty stages for group comparisons, in this study no such comparisons are made and each individual is investigated the same day with two different devices, and thus the influence of puberty is the same for each measurement. Furthermore, one study showed that puberty had no significant influence on WC, WHR (WC/hip) and BMI z -score (26).

Measurement advantages

The laser beam measurement is easier to perform than the WC and is probably more comfortable for the patient. Furthermore, it does not expose the patient to a close physical contact with the investigator and is thus probably better tolerated, particularly in obese adolescents.

This device is less expensive than MRI, equally accurate and still easily available for screening purposes. Furthermore, previous devices are not ideal for children and lack comparison with more exact measurements such as MRI. SAD seems to be the best predictor of cardiovascular risk and is also of more importance than WC (14,22). It also seems to be a better predictor of an adverse metabolic profile than visceral adipose tissue (25). Finally, SAD has been shown to have a stronger correlation to visceral adipose tissue than WC, BMI and transverse abdominal diameter in both sexes (27). All these studies support the necessity to measure SAD in the future, where this new accurate child-friendly device might be of importance. However, more research is needed to further evaluate the measurement principle.

Conclusions

Several studies have shown the increasing importance of SAD over both WC and visceral adipose tissue in estimating cardiovascular risk.

This is the first study to validate a measurement device for SAD against MRI. A study limitation is the lack of puberty data. However, the LBD is not likely to be affected by puberty status itself as the individual was in the same puberty status at the day of the measurement using two different devices (LBD and MRI). More research is needed to further evaluate the measurement principle.

This LBD gives as precise and accurate SAD measurements as does MRI. There is a need for more research regarding the appropriate level of the MRI slice as well as how the age of the subjects influences the results. Furthermore, the LBD needs to be validated on a larger group of differently sized children.

This new reliable method to investigate SAD in children without using radiation or expensive equipment will make future large epidemiological studies possible. However, the reliability for body sizes other than obese and overweight children needs further study.

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References

1. Vague J. La différenciation sexuelle, facteur déterminant des formes de l'obésité. *Presse Méd.* 1947; 30:339–340. [PubMed: 18918084]
2. Okorodudu DO, Jumeau MF, Montori VM, et al. Diagnostic performance of body mass index to identify obesity as defined by body adiposity: a systematic review and meta-analysis. *Int J Obes (Lond)*. 2010; 34:791–799. [PubMed: 20125098]
3. Sakuragi S, Abhayaratna K, Gravenmaker KJ, et al. Influence of adiposity and physical activity on arterial stiffness in healthy children: the lifestyle of our kids study. *Hypertension*. 2009; 53:611–616. [PubMed: 19273744]
4. Sjöström L. A computer-tomography based multicompartiment body composition technique and anthropometric predictions of lean body mass, total and subcutaneous adipose tissue. *Int J Obes*. 1991; 15(Suppl. 2):19–30. [PubMed: 1794934]
5. Björntorp P. Abdominal fat distribution and the metabolic syndrome. *J Cardiovasc Pharmacol*. 1992; 20(Suppl. 8):S26–S28. [PubMed: 1283766]
6. Kahn HS, Austin H, Williamson DF, Arensberg D. Simple anthropometric indices associated with ischemic heart disease. *J Clin Epidemiol*. 1996; 49:1017–1024. [PubMed: 8780611]
7. Kahn HS, Simoes EJ, Koponen M, Hanzlick R. The abdominal diameter index and sudden coronary death in men. *Am J Cardiol*. 1996; 78:961–964. [PubMed: 8888678]
8. Pouliot MC, Després JP, Lemieux S, et al. Waist circumference and abdominal sagittal diameter: best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. *Am J Cardiol*. 1994; 73:460–468. [PubMed: 8141087]
9. Riserus U, Arnlov J, Brismar K, Zethelius B, Berglund L, Vessby B. Sagittal abdominal diameter is a strong anthropometric marker of insulin resistance and hyperproinsulinemia in obese men. *Diabetes Care*. 2004; 27:2041–2046. [PubMed: 15277437]
10. Ohrvall M, Berglund L, Vessby B. Sagittal abdominal diameter compared with other anthropometric measurements in relation to cardiovascular risk. *Int J Obes Relat Metab Disord*. 2000; 24:497–501. [PubMed: 10805508]
11. Heymsfield SB, Wang Z, Baumgartner RN, Ross R. Human body composition: advances in models and methods. *Annu Rev Nutr*. 1997; 17:527–558. [PubMed: 9240939]
12. Schoen RE, Thaete FL, Sankey SS, Weissfeld JL, Kuller LH. Sagittal diameter in comparison with single slice CT as a predictor of total visceral adipose tissue volume. *Int J Obes Relat Metab Disord*. 1998; 22:338–342. [PubMed: 9578239]
13. Riserus U, Arnlov J, Berglund L. Long-term predictors of insulin resistance: role of lifestyle and metabolic factors in middle-aged men. *Diabetes Care*. 2007; 30:2928–2933. [PubMed: 17644620]
14. Guzzaloni G, Minocci A, Marzullo P, Liuzzi A. Sagittal abdominal diameter is more predictive of cardiovascular risk than abdominal fat compartments in severe obesity. *Int J Obes (Lond)*. 2009; 33:233–238. [PubMed: 19139755]
15. Sakuragi S, Abhayaratna WP. Arterial stiffness: methods of measurement, physiologic determinants and prediction of cardiovascular outcomes. *Int J Cardiol*. 2010; 138:112–118. [PubMed: 19473713]
16. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000; 320:1240–1243. [PubMed: 10797032]

17. Pietrobelli A, Boner AL, Tatò L. Adipose tissue and metabolic effects: new insight into measurements. *Int J Obes (Lond)*. 2005; 29(Suppl. 2):S97–S100. [PubMed: 16385759]
18. Shen W, Punyanitya M, Chen J, et al. Visceral adipose tissue: relationships between single slice areas at different locations and obesity-related health risks. *Int J Obes (Lond)*. 2007; 31:763–769. [PubMed: 17060927]
19. Shen W, Punyanitya M, Wang Z, et al. Total body skeletal muscle and adipose tissue volumes: estimation from a single abdominal cross-sectional image. *J Appl Physiol*. 2004; 97:2333–2338. [PubMed: 15310748]
20. Shen W, Punyanitya M, Wang Z, et al. Visceral adipose tissue: relations between single-slice areas and total volume. *Am J Clin Nutr*. 2004; 80:271–278. [PubMed: 15277145]
21. Riserus U, de Faire U, Berglund L, Hellenius ML. Sagittal abdominal diameter as a screening tool in clinical research: cutoffs for cardiometabolic risk. *J Obes*. 2010;1–7. Article ID 757939.
22. Nakata K, Choo J, Hopson MJ, et al. Stronger associations of sagittal abdominal diameter with atherogenic lipoprotein subfractions than waist circumference in middle-aged US white and Japanese men. *Metabolism*. 2010; 59:1742–1751. [PubMed: 20580038]
23. Loffler H, Aramaki JU, Effendy I. The influence of body mass index on skin susceptibility to sodium lauryl sulphate. *Skin Res Technol*. 2002; 8:19–22. [PubMed: 12005116]
24. Hoenig MR. MRI sagittal abdominal diameter is a stronger predictor of metabolic syndrome than visceral fat area or waist circumference in a high-risk vascular cohort. *Vasc Health Risk Manag*. 2010; 6:629–633. [PubMed: 20730019]
25. Valsamakis G, Jones A, Chetty R, et al. MRI total sagittal abdominal diameter as a predictor of metabolic syndrome compared to visceral fat at L4-L5 level. *Curr Med Res Opin*. 2008; 24:1853–1860. [PubMed: 18507894]
26. Schwandt P, Kelishadi R, Haas GM. First reference curves of waist circumference for German children in comparison to international values: the PEP Family Heart Study. *World J Pediatr*. 2008; 4:259–266. [PubMed: 19104889]
27. Yim JY, Kim D, Lim SH, et al. Sagittal abdominal diameter is a strong anthropometric measure of visceral adipose tissue in the asian general population. *Diabetes Care*. 2010; 33:2665–2670. [PubMed: 20843976]

What is already known about this subject

- Sagittal diameter (SAD), i.e. the mid height of the abdomen when lying down, has been reported to correlate to visceral fat, insulin resistance and cardiovascular risk factors in adults.
- SAD seems to be the best anthropometric predictor of cardiovascular risk, and also of more importance than waist circumference (WC) in adults.
- There has been no validation studies comparing SAD measured with anthropometric tools (e.g. ruler) to measurements made with more exact devices such as magnetic resonance imaging (MRI) in pediatric age.

What this study adds

- This new reliable method is ideal for children due to limited body contact and no radiation.
- It is accurate, less expensive than MRI, and also easier to perform than measuring WC.
- It is easily available for screening purposes making future epidemiological studies possible evaluating health risks related to regional distribution of abdominal tissue.

Table 1Root mean squared errors (cm) in prediction of SAD_{MRI} from SAD_{LBD}

	$SAD_{MRI,cau}$	$SAD_{MRI,cra}$
Linear regression	1.0	1.0
Additive constants 1.50 (cau); 1.26 (cra)	1.1	1.0

MRI, magnetic resonance imaging; SAD, sagittal diameter.

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Table 2

Data used in the analysis for all included subjects

	Sex (G = girl, B = boy)	Age at baseline	Age at follow-up	SAD LBD at baseline	SAD LBD at 6 months	SAD LBD at 12 months	SAD MRI, cra baseline	SAD MRI, cra at 6 months	SAD MRI, cra at 12 months	SAD MRI, cau at baseline	SAD MRI, cau at 6 months	SAD MRI, cau at 12 months	BMI at baseline	BMI at 6 months	BMI at 12 months
1.	G	10.6	11.9	19.5	19.0	-	19.9	19.8	20.9	19.7	19.3	20.7	25.8	27.4	28.2
2.	B	11.2	11.9	24.0	25.0	-	24.2	24.9	-	23.1	25.4	-	34.2	34.7	35.0
3.	G	9.1	9.8	19.5	21.5	-	20.6	20.4	-	20.1	20.7	-	27.6	27.7	31.0
4.	B	8.4	9.7	23.5	23.5	23.5	23.2	-	25.6	22.6	-	25.1	29.5	31.5	32.7
5.	G	10.1	10.9	19.5	19.0	-	21.7	20.9	-	21.1	20.5	-	26.7	25.3	-
6.	B	9.4	10.6	21.0	22.5	21.5	24.1	-	22.9	24.2	-	23.7	27.0	27.8	27.1
7.	G	9.5	10.1	21.0	22.5	-	21.9	22.1	-	21.7	22.2	-	28.3	29.2	30.8
8.	B	10.7	12.0	23.0	21.5	22.5	23.9	22.0	22.8	24.5	22.8	23.6	27.6	26.0	27.7
9.	G	11.2	12.4	21.5	23.0	23.5	22.7	25.9	25.7	23.3	26.3	26.0	28.2	31.8	32.1
10.	G	12.6	13.3	21.0	23.5	22.5	23.5	23.5	-	23.4	22.9	-	31.3	33.3	34.2
11.	G	10.8	12.1	21.5	20.5	20.5	23.2	22.3	22.8	23.3	22.6	22.5	28.1	26.8	27.9
12.	G	11.8	12.5	18.5	19.5	-	21.7	21.3	-	21.2	20.6	-	25.2	26.5	27.1
13.	B	9.5	10.8	20.0	18.5	20.0	20.7	20.6	23.4	20.3	20.5	21.6	27.6	26.9	30.8
14.	G	9.6	10.9	18.0	19.5	20.0	20.4	20.2	22.1	18.7	19.7	22.4	24.2	25.5	26.8
15.	G	10.6	11.9	20.5	21.0	21.5	21.2	21.6	22.7	20.5	21.0	22.0	25.7	27.0	28.1
16.	G	11.2	12.4	22.5	24.5	22.0	23.5	24.0	23.2	23.1	23.3	22.8	26.6	28.0	27.1
17.	G	9.3	9.9	19.0	20.5	-	-	21.1	-	-	21.2	-	25.4	27.4	29.3
18.	B	9.8	11.0	16.5	17.5	20.0	23.1	19.8	19.8	20.1	20.6	22.0	25.2	24.2	26.4
19.	B	11.8	13.2	20.5	23.0	26.0	22.5	24.2	26.3	22.8	24.2	25.9	27.8	30.7	35.0
20.	G	11.3	12.6	22.0	23.5	23.5	23.1	24.5	25.6	22.8	24.4	25.6	30.6	32.4	33.2
21.	G	11.3	12.0	20.0	21.0	-	20.6	21.7	-	20.1	21.5	-	25.8	26.7	25.8
22.	G	9.6	10.8	20.5	20.0	19.5	21.6	21.6	22.5	20.8	22.0	22.4	25.6	26.9	26.7
23.	G	12.6	13.8	20.5	21.5	22.5	22.1	23.5	23.2	22.2	23.9	22.6	28.2	28.4	30.7
24.	G	11.7	13.0	19.0	21.0	-	20.9	21.6	22.8	20.5	21.8	22.6	29.1	31.2	32.4
25.	G	10.0	11.3	21.5	23.0	23.5	23.3	23.8	25.5	23.5	22.9	24.6	29.9	30.9	34.1
26.	G	9.0	10.3	18.5	18.5	21.0	20.2	20.7	21.4	19.2	20.5	22.5	23.9	25.5	26.5
27.	B	9.6	11.0	21.5	-	22.5	23.0	23.0	24.8	22.9	23.0	25.2	27.9	29.5	30.6
28.	G	10.4	11.6	21.5	21.0	-	23.0	23.7	22.9	22.4	22.5	22.3	27.0	28.4	28.7
29.	G	11.6	12.8	21.5	24.5	23.5	24.3	26.1	25.8	23.7	25.3	24.5	30.3	34.1	34.9
30.	B	11.6	-	23.0	-	-	25.0	-	-	24.8	-	-	33.0	34.0	34.0
31.	B	9.4	10.0	21.5	21.5	-	22.7	22.6	-	23.3	23.5	-	30.8	31.0	31.4
32.	B	11.9	13.1	22.5	21.5	23.0	24.0	22.6	24.9	23.7	22.7	24.6	28.6	27.5	29.5
33.	G	11.8	13.0	20.0	22.5	22.0	21.9	23.5	24.7	21.2	23.8	22.6	28.9	32.0	33.4
34.	B	9.9	11.1	19.5	20.5	20.5	22.6	23.5	22.7	20.7	23.4	23.0	25.9	27.8	27.4

LBD, laser beam device; MRI, magnetic resonance imaging; SAD, sagittal diameter.

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