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The population distribution of the sagittal abdominal diameter (SAD) and SAD/height ratio among Finnish adults

H. S. Kahn[1], **H. Rissanen**[2], **K. M. Bullard**[1], and **P. Knekt**[1]

[1]Division of Diabetes Translation, Centers for Disease Control and Prevention, Atlanta, GA, USA
[2]Population Health Unit, National Institute for Health and Welfare, Helsinki, Finland

Summary

Sagittal abdominal diameter (SAD; 'abdominal height' measured in supine position) may improve upon conventional anthropometry for predicting incident cardiometabolic diseases. However, the SAD is used infrequently by practitioners and epidemiologists. A representative survey of Finnish adults in 2000–2001 collected body measurements including SAD (by sliding-beam calliper) using standardized protocols. Sampled non-pregnant adults (ages 30+ years; 79% participation) provided 6123 SAD measurements from 80 health centre districts. Through stratified, complex survey design, these data represented 2.86 million adults at ages 30+ years. SAD ranged from 13.5 to 38.0 cm, with a population mean (standard error) of 21.7 (0.05) cm and median (interquartile range) of 21.0 (19.1–23.4). Median SAD was higher at ages 50+ years compared with ages 30–49 both for men (22.4 [20.5–24.6] vs. 20.8 [19.3–22.7]) and women (21.7 [19.6–23.9] vs. 19.4 [17.8–21.4]). The SAD/height ratio was similar (0.118) for both sexes at 30–39 years, rising more steeply with age for women than men. Attaining only a basic education, compared with a high level, was associated with increased mean (95% confidence interval) SADs for men (22.6 [22.3–22.8] vs. 22.0 [21.7–22.2]) and women (21.8 [21.5–22.0] vs. 20.6 [20.4–20.8]). Finland's early experience with nationally representative SAD measurements provides normative reference values and physiological insights useful for investigations of cardiometabolic risk.

Keywords

Abdominal height; adiposity; anthropometry; reference values

Address for correspondence: Dr HS Kahn, Division of Diabetes Translation, Centers for Disease Control and Prevention, Mail Stop F-73, 4770 Buford Highway, Atlanta, GA 30341, USA. hkahn@cdc.gov.

Conflict of Interest Statement
No conflict of interest was declared.

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Author contributions
PK and HR participated in the planning and execution of the *Health 2000* Survey. HSK proposed the collaborative report, reviewed the literature and drafted the first version of the manuscript. HR performed the data analyses and prepared the figures. All co-authors were involved in revising the manuscript and approving the final version.

Introduction

A quarter century ago Swedish investigators proposed that the volume of visceral adipose tissue (VAT) could be estimated better by measuring the external sagittal abdominal diameter (SAD) than by the waist circumference (WC) (1). They recommended that the sagittal dimension (back to front) of the abdomen be measured in the supine position, and thus the anthropometry literature sometimes describes SAD as the ‘abdominal height’. The external WC, however, has been studied by epidemiologists for more than 50 years (2) and by actuaries for more than a century (3). Although basic researchers may now quantify adipose tissue compartments through the use of costly imaging methods, clinicians and epidemiologists generally continue to depend on the less expensive measurement of WC for studying body fat distribution in relation to cardiometabolic disease risk or early mortality.

In the dozen years that followed the Swedish description of the SAD, independent reports confirmed that the SAD could be useful as a correlate of VAT (4–10) or as a marker of cardiometabolic and physiologic risk (5,11–19). Nevertheless, clinical and epidemiologic adoption of the SAD has come slowly in the 21st century.

One barrier to wider adoption is the variety of anthropometric protocols that claim to measure the SAD. Publications describing SAD in the supine position have used methods ranging from a carpenter’s level at the bedside (17,20,21) to cross-sectional abdominal imaging by magnetic resonance (4) or computerized tomography (22). External SAD measurements have been obtained variously at the level of the iliac crest (14), the umbilicus (23), the highest point (7) or the narrowest point between the last rib and iliac crest (24). A few reports have described SAD obtained in the standing position using different instruments and anatomic levels (25–27).

Another barrier to adoption has been the absence of community-based, normative reference values for the SAD. Whereas population distributions of the WC and body mass index (BMI, kg m^{-2}) have been readily available from several regions, population distributions of the supine SAD have been unavailable until very recently when the National Health and Nutrition Examination Survey (NHANES) of 2011–2012 reported its population SAD estimates for adults in the United States (28).

In this paper we address these barriers by documenting a simple anthropometric protocol that used a portable, sliding-beam calliper to measure SAD. The SADs analysed here were obtained in 2000–2001 from a large, representative, community-based survey of Finnish adults at ages 30+ years. This Finnish experience provides the earliest normative reference values by sex and age group for the adult, supine SAD published for an entire country.

Because of reports that the SAD/height ratio is associated with both cardiometabolic risk (13,16,29) and the cross-sectional area of VAT (identified by computed tomography) (30), we present here also the population distribution for this ratio, a derived adiposity indicator, by sex and decades of adulthood. We have calculated population means similarly for the SAD/WC ratio; this derived variable may improve the appreciation of how sex and age might influence adult changes in distinct compartments of abdominal tissue. Because body composition has been associated with an educational gradient among adult Finns (31), we present here as well our analyses comparing mean SAD among three levels of educational attainment.

Materials and methods

Study population and sampling

The Finnish *Health 2000* Survey was developed with a stratified, two-stage, cluster sampling design (32). Finland was divided into five geographical strata defined by the university hospital districts of Helsinki, Turku, Tampere, Kuopio and Oulu. In the first stage of sampling, 80 health centre districts (clusters) were selected out of 249 districts in mainland Finland. The second stage involved sampling individual persons from those districts. Altogether 8028 adults were drawn from a nationwide population register. Adults in each selected health centre district were sorted by age, and selection was carried out by a systematic random method. The sampling thus involved implicit stratification by age.

Field contacts with survey participants consisted of a home visit interview that was followed by a clinic-based health examination restricted to adults of age 30+ years. All in all, 79% of the age-eligible sample took part in the health examinations. After exclusion of women who were pregnant and persons with missing or implausible values for SAD, WC or BMI, our analytic sample included 6123 adults whose ages ranged from 30 to 97 years. Nearly all examined adults were of white, northern European ancestry and <2% were born outside of Finland.

Responses at the health interview were combined into a variable describing three levels of education: basic, middle and high (31). Persons who had no training beyond a vocational course or on-the-job training and who had not taken the matriculation examination were classified as having a basic level of education. Completion of vocational school was defined as a middle level of education. All those who had passed the matriculation examination, but who had no vocational training beyond a vocational course or on-the-job training, were also classified into this intermediate group. Individuals with high educational status comprised those with degrees from higher vocational institutions, polytechnics and universities. Written informed consent was obtained from all the participants. The study was approved by the Ethical Committee for Research in Epidemiology and Public Health at the Hospital District of Helsinki and Uusimaa in Finland.

Anthropometric protocols

Survey nurses were specially trained in the use of a sliding-beam calliper developed by the survey's technical unit for measurement of abdominal diameters. This portable anthropometric instrument reports the distance between two parallel wings to determine body dimensions (Fig. 1). Each participant at the health examination was asked to lie down with legs flat on the examination table. One wing of the calliper was placed under the participant's back at a position defined by the iliac crests. The participant was asked to relax and breathe regularly. The other wing of the calliper was then lowered gently onto the belly. Measurements were performed after normal expiration. The SAD was recorded to an accuracy of 0.5 cm from a scale fixed to the vertical calliper shaft (32).

Height was measured (without shoes) with the feet together, head up and back against the wall, and recorded to the nearest 0.5 cm. Weight was measured on digital scales to the nearest 0.1 kg. If appropriate measuring was impossible for any reason, weights and heights were self-reported (4% and 7%, respectively, in this analytic sample). The WC was obtained in standing position by tape measure at the level midway between the lowest rib and the high point of the iliac crest (33). Waist measurements were performed during light expiration and rounded up to the nearest 0.5 cm.

The quality of anthropometric measurements was maintained through occasional parallel measurements within the field teams and on a quality control day during which results by members of all five geographical teams were compared with those obtained by national reference measurers. In the measurements within the field teams, the intraclass correlation coefficients for agreement between measurers were 0.95 for WC and 0.88 for SAD. In the quality control day the agreement between a reference measurer and the geographical teams were 0.94–0.99 for WC and 0.89–0.95 for SAD.

Statistical analyses

The complex sampling design and the post-stratification weights, which recognized oversampling and non-response (32), were accounted for using linearized variance estimates (34) implemented in the program package SUDAAN (RTI International, Research Triangle Park, NC, USA; release 10). To produce descriptive box plots of SAD, sex- and age-specific percentiles were calculated using PROC DESCRIPT.

Population estimates for the means of each adiposity indicator (SAD, SAD/height ratio or SAD/WC ratio) were calculated from linear regression models (PROC REGRESS) using predictive margins (35). An adiposity indicator was the dependent variable, and age group (30–39, 40–49, 50–59, 60–69 and ≥70 years) was the independent variable. The primary model also included an interaction term between age and sex to obtain separate estimates for men and women by age. For calculation of mean SAD/WC ratios, this model was further adjusted for categorical BMI (<25, 25 to <30, 30 to <35, ≥35 kg m^{-2}). An additional model estimated the strength of association between educational attainment (basic, middle or high) and SAD, controlling for age and sex. *P*-values <0.05 were considered statistically significant.

Results

Distributions of sagittal abdominal diameter by sex

From a sample of 6123 adults at ages 30+ years we estimated the population's SAD mean (standard error) to be 21.7 (0.05) cm. This estimate represented 1.375 million men with SAD mean of 22.3 (0.06) cm and 1.483 million non-pregnant women with SAD mean of 21.3 (0.06) cm (Table 1). For both sexes together, the SAD population median (interquartile range) was 21.0 (19.1–23.4) cm. The SAD median for men was 21.6 (19.8–23.8) cm, and for women was 20.6 (18.6–23.1) cm. SAD medians (percentile p50) by sex and age group are presented in Table 2 along with values for p5, p25, p75 and p95.

Among SAD measurements in the examined sample, the overall range of values for men was 15.5–38.0 cm and for women was 13.5–36.0 cm.

Distributions of sagittal abdominal diameter and sagittal abdominal diameter ratios by age

For both sexes we noted a tendency to larger SAD with increasing age. Mean values of SAD were larger at least through the 50s (years) for men and at least through the 60s for women (Table 1). In comparing the median SAD values of an older segment (ages 50+ years) with a younger segment (ages 30–49 years), the older segment's median (95% confidence interval) SAD was higher both for men (22.4 [22.2–22.6] vs. 20.8 [20.6–21.0]) and for women (21.7 [21.5–21.8] vs. 19.4 [19.2–19.6]). The increased SAD values for the older segment may be seen also in sex-specific box plots (SAD percentiles 5, 25, 50, 75, 95) stratified according to four BMI categories (Fig. 2).

The SAD/height ratios were similar for men (0.1181) and women (0.1185) in the 30s age group (Table 1). Within both sexes, the observed SAD/height ratios were greater across each of the next four age groups. For women, the increase in SAD/height ratios was greatest between the 30s and 40s. The increase for men was more modest between the 30s and 40s, and there was a plateau of the SAD/height ratio for men who were measured beyond the 60s. Selected percentile values by sex and age group for the SAD/height ratio are presented in Table 2. The range of SAD/height ratio values in the examined sample for men was 0.086–0.221 and for women 0.087–0.225.

The SAD/WC ratios demonstrated limited increases in relation to age. For both sexes, the mean SAD/WC ratio changed very little from the 30s to 40s, then rose from 40s to 50s (Table 1). With continued ageing, the men's SAD/WC ratio increased again through the 60s, but then ceased to rise. The women's SAD/WC ratio did not rise significantly from the 50s to 60s, nor did it rise between the 60s and the oldest age group.

Sagittal abdominal diameter distributions by educational attainment

Educational attainment to only a basic level, compared with attainment at a high level, was associated with increased mean SAD for all men (22.6 vs. 22.0 cm) and all women (21.8 vs. 20.6 cm). Our analysis of this relationship within strata of age was limited especially by the small number of elderly adults who had completed more than a basic education (Table 3). However, among adults at ages 30–49 or 50–69 years, mean SAD values showed a consistent pattern of increasing SAD values as the educational level declined from high to middle to basic.

Discussion

This review of survey data from *Health 2000* describes possibly the first collection of SAD measurements obtained from a nationally representative sample. The portable calliper and anthropometric protocol used in Finland were similar to those employed by smaller studies of non-representative research participants in Europe, Asia and the Americas. With the exception of positioning legs flat on the examination table, the Finnish protocol was identical to that employed recently by the US NHANES. Thus, the *Health 2000* Survey established early the feasibility and utility of low-cost SAD measurements using a standardized method. With the publication of these population-based SAD distributions, the growing literature on how SAD relates to cardiometabolic risk factors and medical outcomes should be easier to evaluate, interpret and replicate.

Although *Health 2000* did not include SAD measurements on persons younger than 30 years, it covered an age range in which the major chronic conditions of adulthood become increasingly prevalent. These cross-sectional data demonstrate that the SAD rises through the years of middle adulthood until an older age where SAD increments level off, perhaps in association with reduced survival (differential attrition) among abdominally obese persons. Because the SAD is strongly correlated with VAT (1,10,36), this pattern is consistent with computerized tomography studies of non-European adults in which imaging showed that VAT increases with age more than the subcutaneous adipose depot (37,38).

Given the associations between VAT and multiple pathways that contribute to chronic disease (39,40), the SAD may be substantially associated with future disease outcomes. An 8-year longitudinal follow-up of non-diabetic adults in the *Health 2000* Survey recently reported that in the presence of BMI information, the addition of SAD information enhanced the prediction of incident type 2 diabetes more than did the addition of information on WC or waist/hip ratio (41). An 11-year longitudinal Swedish study reported on SAD and incident cardiovascular disease. For participants with baseline BMI ≥25 kg m^{-2}, the prediction by SAD was greater than by WC for both sexes, greater than by waist/hip ratio for women, but less than by waist/hip ratio for men (42).Without stratification by baseline BMI, the prediction by the SAD/height ratio was greater than by WC or BMI for both sexes, greater than by waist/hip ratio for women, but less than by waist/hip ratio for men (29).

Our presentation of the SAD/height ratio suggests that after the 30s, SAD increases more rapidly among women than among men. The women's accelerated increase of this ratio could be driven in part by women having a greater decrease in height as they age. Alternatively, the women's greater increase in SAD could reflect a relatively greater expansion (compared with men) of their subcutaneous abdominal adipose tissue that accompanies their increase of VAT. There are distinct deep and superficial sub-depots of subcutaneous adipose tissue that have contrasting associations with cardiometabolic risk (43). When the quantity of VAT is enlarged, men may experience parallel expansion only of their deep subcutaneous adipose tissue, the sub-depot that is most closely linked to cardiometabolic risk variables. By contrast, women demonstrate comparable expansions of both the deep (adverse risk) and superficial (relatively benign) sub-depots (44).

Our analysis of the SAD/WC ratio, likewise, is consistent with the observation that women may expand their subcutaneous adipose tissue relatively more than men during the advancing decades of adulthood. Table 1 shows that between the 30s and 40s the mean SAD (a dimension focused primarily on VAT) increased by 1.0 cm for each sex. However, across the same age interval the men's SAD/WC ratio trended towards a modest increase while the women's SAD/WC ratio trended towards a decline. We infer from this that women had a relatively greater enlargement of their WC, a dimension that incorporates both visceral and subcutaneous adipose tissue. Similarly, across the age interval from the 30s to the 60s, we found that while men's SAD increased slightly less than women's SAD, the men's

SAD/WC ratio increased more than twice as much than the women's SAD/WC ratio. This contrast in subcutaneous accumulation between the sexes is consistent with men's relatively restricted increase in WC as they age, a limitation that possibly reflects men's inability to expand their superficial sub-depots of the subcutaneous adipose tissue.

The finding of an inverse association between SAD and educational attainment is in accordance with an earlier report from the *Health 2000* Survey that found low educational status was associated with overall and abdominal adiposity but only weakly associated with fat-free mass (31). This inverse association between SAD and education was present in men and women 30–69 years of age and also for older women. As suggested in the earlier Finnish analysis, it is possible that the desire to be thin among the highest educated women lasts throughout their entire lives whereas obesity was a more acceptable characteristic for men. A similar association of increased SAD with low educational level was noted in a large study of patients in California, but their SAD was obtained in the standing position rather than supine (45). Among elderly Americans, baseline depressive symptoms were associated with a 5-year increase in supine SAD (determined by consecutive computerized tomography images of the abdomen) (46). These similar observations based on the SAD may facilitate the future study of pathways by which socio-economic disadvantages or psychological stressors are associated with abdominal adiposity.

More generally, the availability of a standardized SAD measurement protocol and population distributions for adult SAD should enable future investigators to make better use of this inexpensive anthropometric tool. The SAD information in US NHANES 2011–2012 was collected using a very similar protocol, and these NHANES data, including SAD measurements on participants as young as 8 years old, are available for public use (47). Comparisons of adult population distributions of SAD and SAD/height ratio from Finland (in 2000–2001) and from the ancestrally diverse United States (in 2011–2012) could stimulate productive discussions about how abdominal adiposity may vary according to culture, geographical contexts and among ancestral subpopulations.

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References

1. Sjostrom L, Kvist H. Regional body fat measurements with CT-scan and evaluation of anthropometric predictions. Acta Med Scand Suppl. 1988; 723:169–177. [PubMed: 3164964]
2. Morris JN, Heady JA, Raffle PA. Physique of London busmen - epidemiology of uniforms. Lancet. 1956; 271:569–570. [PubMed: 13368467]
3. Kahn HS, Williamson DF. Abdominal obesity and mortality risk among men in nineteenth-century North America. Int J Obes Relat Metab Disord. 1994; 18:686–691. [PubMed: 7866464]
4. van der Kooy K, Leenen R, Seidell J, 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. [PubMed: 8399118]

5. Pouliot MC, Despres 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]
6. Jensen MD, Kanaley JA, Reed JE, Sheedy PF. Measurement of abdominal and visceral fat with computed tomography and dual-energy x-ray absorptiometry. Am J Clin Nutr. 1995; 61:274–278. [PubMed: 7840063]
7. Zamboni M, Turcato E, Armellini F, et al. Sagittal abdominal diameter as a practical predictor of visceral fat. Int J Obes Relat Metab Disord. 1998; 22:655–660. [PubMed: 9705025]
8. Keller C, Chintapalli K, Lancaster J. Correlation of anthropometry with CT in Mexican–American women. Res Nurs Health. 1999; 22:145–153. [PubMed: 10094299]
9. Owens S, Litaker M, Allison J, et al. Prediction of visceral adipose tissue from simple anthropometric measurements in youths with obesity. Obes Res. 1999; 7:16–22. [PubMed: 10023726]
10. Bertin E, Marcus C, Ruiz JC, Eschard JP, Leutenegger M. Measurement of visceral adipose tissue by DXA combined with anthropometry in obese humans. Int J Obes Relat Metab Disord. 2000; 24:263–270. [PubMed: 10757618]
11. Ohrvall M, Tengblad S, Vessby B. Lower tocopherol serum levels in subjects with abdominal adiposity. J Intern Med. 1993; 234:53–60. [PubMed: 8326290]
12. Houmard JA, McCulley C, Roy LK, et al. Effects of exercise training on absolute and relative measurements of regional adiposity. Int J Obes Relat Metab Disord. 1994; 18:243–248. [PubMed: 8044198]
13. Richelsen B, Pedersen SB. Associations between different anthropometric measurements of fatness and metabolic risk parameters in non-obese, healthy, middle-aged men. Int J Obes Relat Metab Disord. 1995; 19:169–174. [PubMed: 7780492]
14. 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]
15. Stokic E, Ivkovic-Lazar T. [Relation between the abdominal sagittal diameter, fat tissue distribution and metabolic complications]. Med Pregl. 1996; 49:365–368. [PubMed: 8999292]
16. Kumlin L, Dimberg L, Marin P. Ratio of abdominal sagittal diameter to height is strong indicator of coronary risk. BMJ. 1997; 314:830. [PubMed: 9081022]
17. Sugerman H, Windsor A, Bessos M, Wolfe L. Intra-abdominal pressure, sagittal abdominal diameter and obesity comorbidity. J Intern Med. 1997; 241:71–79. [PubMed: 9042096]
18. Rosmond R, Dallman MF, Bjorntorp P. Stress-related cortisol secretion in men: relationships with abdominal obesity and endocrine, metabolic and hemodynamic abnormalities. J Clin Endocrinol Metab. 1998; 83:1853–1859. [PubMed: 9626108]
19. Gustat 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; 151:885–891. [PubMed: 10791561]
20. Tornaghi G, Raiteri R, Pozzato C, et al. Anthropometric or ultrasonic measurements in assessment of visceral fat? A comparative study. Int J Obes Relat Metab Disord. 1994; 18:771–775. [PubMed: 7866479]
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; 2010:757939. [PubMed: 20798888]
22. Hill JO, Sidney S, Lewis CE, et al. Racial differences in amounts of visceral adipose tissue in young adults: the CARDIA (Coronary Artery Risk Development in Young Adults) study. Am J Clin Nutr. 1999; 69:381–387. [PubMed: 10075320]
23. Paula HA, Ribeiro Rde C, Rosado LE, Abranches MV, Franceschini Sdo C. Relationship between waist circumference and supine abdominal height measured at different anatomical sites and cardiometabolic risk factors in older women. J Hum Nutr Diet. 2012; 25:563–568. [PubMed: 23173640]
24. Anunciacao PC, Ribeiro RC, Pereira MQ, Comunian M. Different measurements of waist circumference and sagittal abdominal diameter and their relationship with cardiometabolic risk factors in elderly men. J Hum Nutr Diet. 2014; 27:162–167. [PubMed: 24387274]

25. Seidell JC, Andres R, Sorkin JD, Muller DC. The sagittal waist diameter and mortality in men: the Baltimore Longitudinal Study on Aging. Int J Obes Relat Metab Disord. 1994; 18:61–67. [PubMed: 8130817]

26. Iribarren C, Darbinian JA, Lo JC, Fireman BH, Go AS. Value of the sagittal abdominal diameter in coronary heart disease risk assessment: cohort study in a large, multiethnic population. Am J Epidemiol. 2006; 164:1150–1159. [PubMed: 17041127]

27. Empana JP, Ducimetiere P, Charles MA, Jouven X. Sagittal abdominal diameter and risk of sudden death in asymptomatic middle-aged men: the Paris Prospective Study I. Circulation. 2004; 110:2781–2785. [PubMed: 15492315]

28. Kahn HS, Gu Q, Bullard KM, et al. Population distribution of the sagittal abdominal diameter (SAD) from a representative sample of US adults: comparison of SAD, waist circumference and body mass index for identifying dysglycemia. PLoS ONE. 2014; 9:e108707. [PubMed: 25272003]

29. Carlsson AC, Riserus U, Engstrom G, et al. Novel and established anthropometric measures and the prediction of incident cardiovascular disease: a cohort study. Int J Obes (Lond). 2013; 37:1579–1585. [PubMed: 23609935]

30. Carneiro Roriz AK, Santana Passos LC, Cunha de Oliveira C, et al. Discriminatory power of indicators predictors of visceral adiposity evaluated by computed tomography in adults and elderly individuals. Nutr Hosp. 2014; 29:1401–1407. [PubMed: 24972481]

31. Seppanen-Nuijten E, Lahti-Koski M, Mannisto S, et al. Fat free mass and obesity in relation to educational level. BMC Public Health. 2009; 9:448. [PubMed: 19961589]

32. Heistaro S. Methodology report - Health 2000 survey. [WWW document]. URL http://urn.fi/URN:NBN:fi-fe201204193320.

33. World Health Organization. Geneva: 2008 Dec. Waist circumference and waist–hip ratio: report of a WHO expert consultation; p. 8-11.[WWW document]. URL http://apps.who.int/iris/bitstream/10665/44583/1/9789241501491_eng.pdf [accessed August 2014]

34. Lehtonen, R.; Pahkinen, E. Practical Methods for Design and Analysis of Complex Surveys. 2nd edn.. John Wiley & Sons: Chichester; 2004.

35. Lee J. Covariance adjustment of rates based on the multiple logistic regression model. J Chronic Dis. 1981; 34:415–426. [PubMed: 7263831]

36. Kullberg J, von Below C, Lonn L, et al. Practical approach for estimation of subcutaneous and visceral adipose tissue. Clin Physiol Funct Imaging. 2007; 27:148–153. [PubMed: 17445065]

37. Kotani K, Tokunaga K, Fujioka S, et al. Sexual dimorphism of age-related changes in whole-body fat distribution in the obese. Int J Obes Relat Metab Disord. 1994; 18:207–212. [PubMed: 8044194]

38. Lara-Castro C, Weinsier RL, Hunter GR, Desmond R. Visceral adipose tissue in women: longitudinal study of the effects of fat gain, time, and race. Obes Res. 2002; 10:868–874. [PubMed: 12226134]

39. Wong SL, Janssen I, Ross R. Abdominal adipose tissue distribution and metabolic risk. Sports Med. 2003; 33:709–726. [PubMed: 12895129]

40. Tchernof A, Despres JP. Pathophysiology of human visceral obesity: an update. Physiol Rev. 2013; 93:359–404. [PubMed: 23303913]

41. Pajunen P, Rissanen H, Laaksonen MA, et al. Sagittal abdominal diameter as a new predictor for incident diabetes. Diabetes Care. 2013; 36:283–288. [PubMed: 22961578]

42. Carlsson AC, Riserus U, Arnlov J, et al. Prediction of cardiovascular disease by abdominal obesity measures is dependent on body weight and sex - results from two community based cohort studies. Nutr Metab Cardiovasc Dis. 2014; 24:891–899. [PubMed: 24680224]

43. Golan R, Shelef I, Rudich A, et al. Abdominal superficial subcutaneous fat - a putative distinct protective fat subdepot in type 2 diabetes. Diabetes Care. 2012; 35:640–647. [PubMed: 22344612]

44. Marinou K, Hodson L, Vasan SK, et al. Structural and functional properties of deep abdominal subcutaneous adipose tissue explain its association with insulin resistance and cardiovascular risk in men. Diabetes Care. 2014; 37:821–829. [PubMed: 24186879]

45. Whitmer RA, Gustafson DR, Barrett-Connor E, et al. Central obesity and increased risk of dementia more than three decades later. Neurology. 2008; 71:1057–1064. [PubMed: 18367704]

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46. Vogelzangs N, Kritchevsky SB, Beekman AT, et al. Depressive symptoms and change in abdominal obesity in older persons. Arch Gen Psychiatry. 2008; 65:1386–1393. [PubMed: 19047525]

47. National Center for Health Statistics. NHANES 2011–2012 data documentation, codebook, and frequencies, body measures (BMX_G). [WWW document]. URL http://wwwn.cdc.gov/nchs/nhanes/2011-2012/BMX_G.htm.

What is already known about this subject

- The sagittal abdominal diameter (SAD) has previously been measured with methods ranging from the bedside application of a carpenter's level to cross-sectional abdominal imaging by computed tomography or magnetic resonance imaging.
- Irrespective of anthropometric protocol, the SAD generally has demonstrated associations with visceral adipose tissue volume and cardiometabolic risk that could be useful for clinical practice and community-level research.
- Adoption of the SAD measurement has been impeded by lack of methodological consistency and the absence of published reference values.

What this study adds

- The use of a low-cost, sliding-beam, portable calliper to measure sagittal abdominal diameter (SAD) can be standardized and applied to large populations.
- For adults in the age range vulnerable to type 2 diabetes and cardiovascular events there now are community-based, normative, reference values of SAD and the SAD/height ratio from Finland, which could help characterize cardiometabolic risk and how it might be related to socio-economic disadvantage.

Figure 1.
Sliding-beam calliper used to measure sagittal abdominal diameter (SAD) in Finland's *Health 2000* Survey.

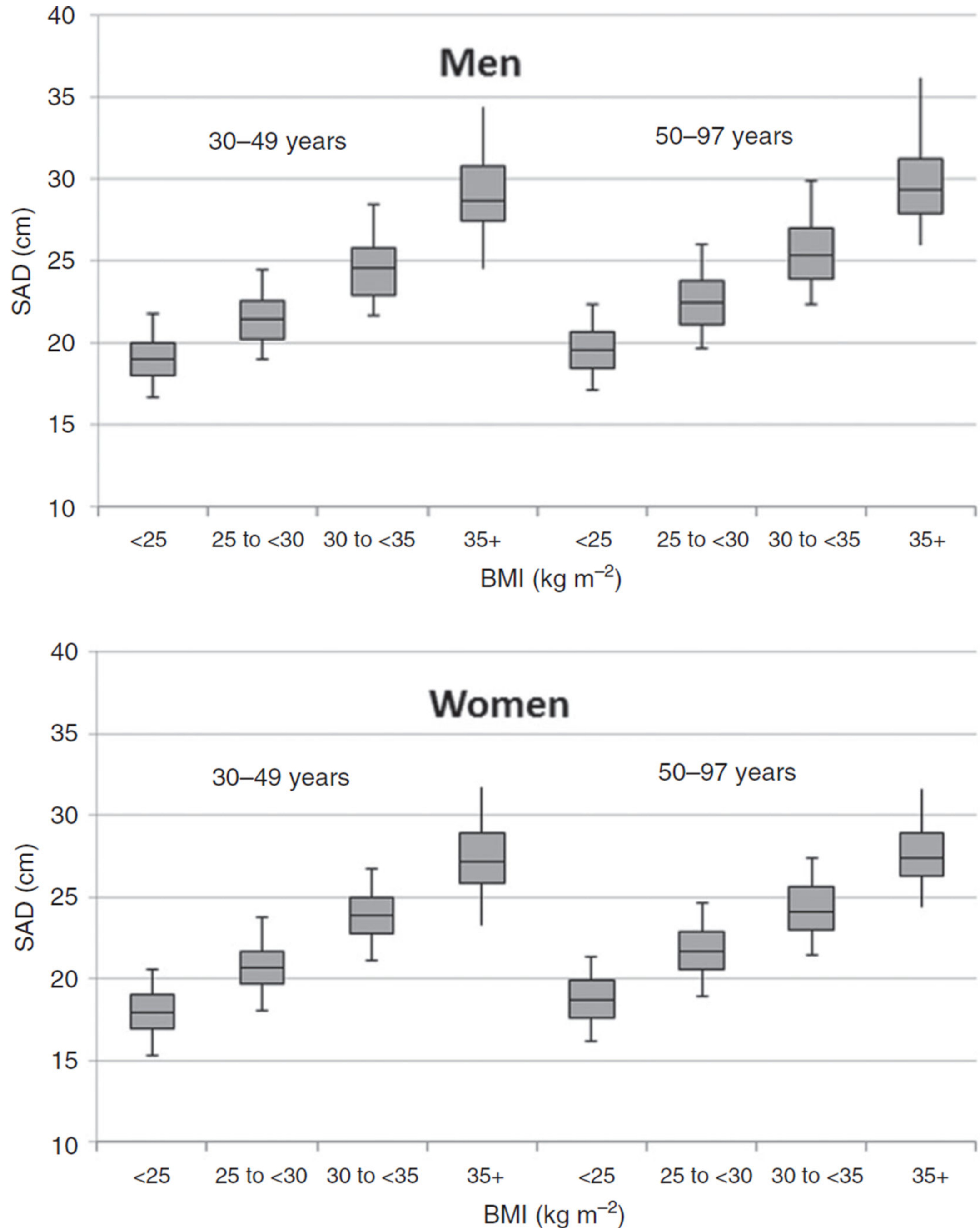

Figure 2.

Sex-specific population distributions of the sagittal abdominal diameter (SAD) in Finnish adults stratified by age group and categories of body mass index. Box plots denote median values and interquartile ranges (p25–p75); values of p5 and p95 are denoted by caps on the ‘whiskers’ except where the sample size is inadequate for confident estimation.

Table 1

Population means (SE) of SAD, SAD/height ratio and SAD/WC ratio for men and women in five age groups

	Age (years)					
	30–39	40–49	50–59	60–69	70+	Total
Men (represented population, 1000)	333	355	333	202	151	1375
Mean SAD	21.0 (0.1)	22.0 (0.1)	22.9 (0.1)[a]	23.2 (0.1)[a]	23.0 (0.2)[a]	22.3 (0.1)
Mean SAD/height ratio	0.118 (0.0007)	0.123 (0.0006)	0.130 (0.0007)	0.133 (0.0008)[a]	0.135 (0.0010)[a]	0.127 (0.0004)
Mean SAD/WC ratio*	0.226 (0.0006)[a]	0.226 (0.0006)[a]	0.227 (0.0006)	0.231 (0.0007)[b]	0.231 (0.0009)[b]	0.228 (0.0004)
Women (represented population, 1000)	308	357	345	233	241	1483
Mean SAD	19.6 (0.1)	20.6 (0.1)	21.7 (0.1)	22.4 (0.1)[a]	22.6 (0.1)[a]	21.3 (0.1)
Mean SAD/height ratio	0.119 (0.0007)	0.129 (0.0007)	0.133 (0.0009)	0.140 (0.0009)	0.144 (0.0008)	0.131 (0.0004)
Mean SAD/WC ratio*	0.240 (0.0007)[a,b]	0.239 (0.0007)[a]	0.241 (0.0008)[b,c]	0.242 (0.0009)[c,d]	0.243 (0.0007)[d]	0.241 (0.0004)

Within each row of means, any two values that share the same superscripted letter were statistically indistinguishable ($P > 0.05$) by pairwise comparison. The mean SAD/height ratio was consistently greater ($P \leq 0.01$) for women compared with men by pairwise comparisons *except* for the column at ages 30–39 years.

*The mean values of SAD/WC are adjusted for four body mass index categories (<25, 25 to <30, 30 to <35, 35+ kg m^{-2}). SAD, sagittal abdominal diameter; SE, standard error; WC, waist circumference.

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Table 2

Population percentile values of SAD and SAD/height ratio for men and women in five age groups

	Men					Women				
Percentiles: Ages (years)	**5 SAD (cm)**	**25**	**50**	**75**	**95**	**5**	**25**	**50**	**75**	**95**
30–39	17.1	18.8	20.4	22.2	26.2	15.7	17.4	18.9	20.7	24.9
40–49	17.8	19.7	21.3	23.2	27.5	16.1	18.2	19.8	22.1	26.4
50–59	18.1	20.3	22.3	24.4	29.1	16.9	19.1	21.1	23.4	26.8
60–69	18.0	20.7	22.7	24.6	28.4	17.6	19.9	21.8	24.0	28.2
70+	18.2	20.4	22.2	24.7	29.2	17.3	20.1	22.3	24.3	27.8
Ages (years)	SAD/height ratio									
30–39	0.098	0.107	0.115	0.126	0.147	0.097	0.106	0.115	0.127	0.150
40–49	0.102	0.113	0.121	0.132	0.154	0.100	0.112	0.123	0.136	0.163
50–59	0.105	0.117	0.128	0.141	0.163	0.104	0.118	0.130	0.147	0.168
60–69	0.106	0.121	0.132	0.144	0.168	0.110	0.125	0.137	0.152	0.180
70+	0.110	0.120	0.132	0.147	0.170	0.111	0.130	0.144	0.157	0.181

SAD, sagittal abdominal diameter.

Table 3

Population means (95% confidence interval) of adult SAD associated with three levels of education by sex, including age stratifications

Sex and age	Educational attainment	Sample *N*	Mean SAD, cm	(95% CI)
Men				
All ages 30+	Basic	1058	22.6	(22.3–22.8)
	Middle	1055	22.2[a]	(22.0–22.4)
	High	678	22.0[a]	(21.7–22.2)
30–49	Basic	284	22.0	(21.6–22.3)
	Middle	666	21.5[b]	(21.3–21.7)
	High	419	21.3[b]	(21.0–21.6)
50–69	Basic	519	23.2	(22.9–23.5)
	Middle	334	22.9[c]	(22.6–23.3)
	High	224	22.7[c]	(22.3–23.1)
70+	Basic	255	23.0[d]	(22.6–23.4)
	Middle	55	23.0[d]	(22.2–23.8)
	High	35	22.4[d]	(21.6–23.3)
Women				
All ages 30+	Basic	1347	21.8	(21.5–22.0)
	Middle	895	21.3	(21.0–21.5)
	High	1070	20.6	(20.4–20.8)
30–49	Basic	265	20.8[e]	(20.3–21.2)
	Middle	520	20.3[e]	(20.0–20.6)
	High	715	19.9	(19.6–20.1)
50–69	Basic	622	22.4	(22.2–22.7)
	Middle	285	21.9	(21.5–22.2)
	High	294	21.1	(20.8–21.4)
70+	Basic	460	22.8[f]	(22.5–23.1)
	Middle	90	22.6[f]	(21.8–23.3)
	High	61	21.4	(20.7–22.1)

Within the column of mean SAD, any two values that share the same superscripted letter were statistically indistinguishable ($P > 0.05$) by pairwise comparison. Estimated from linear regression models, controlling for sex, age and age × sex interaction. CI, confidence interval; SAD, sagittal abdominal diameter.