Published in final edited form as:

J Nutr Health Aging. 2009 November ; 13(9): 821–825.

LEFT VENTRICULAR MASS, ABDOMINAL CIRCUMFERENCE AND AGE: THE FELS LONGITUDINAL STUDY

W.C. CHUMLEA¹, C.M. SCHUBERT², B. TOWNE¹, R.M. SIERVOGEL¹, and S.S. SUN²

¹. Departments of Community Health, Lifespan Health Research Center, Wright State University Boonshoft School of Medicine, Dayton, OH

². Department of Biostatistics, Virginia Commonwealth University, Richmond, VA.

Abstract

Purpose—To determine the relationship of abdominal circumference with increased left ventricular mass (LVM) from young adulthood into old age.

Methods—Cross-sectional echocardiographic images were taken from 182 men and 220 women in the Fels Longitudinal Study 20 to 75 years of age to determine left ventricular mass. Left ventricular mass was divided by stature raised to the power of 2.7 ($LVM/ht^{2.7}$) in order to minimize the impact of heart size variation from body size without overcompensating for the adverse effect of obesity. Abdominal circumference was measured and BMI calculated from stature and weight and categories of overweight, obesity and abdominal obesity were determined using published cut points. Regression models were used to describe the relationships of age, abdominal circumference, BMI and self-reported physical activity to $LVM/ht^{2.7}$.

Results—Age, abdominal circumference and BMI were each positively and significantly related to an increased $LVM/ht^{2.7}$ in men and women ($p < 0.05$). In the men, multivariate models indicated that abdominal circumference and BMI were both significantly related to an increased $LVM/ht^{2.7}$, but the inclusion of BMI in these models for the women reduced the association of abdominal circumference and physical activity below significant levels. In the men, there was also a quadratic association of abdominal circumference with $LVM/ht^{2.7}$ that was significant along with BMI and physical activity. Sex-specific logistic regressions with BMI and abdominal circumference obesity categories did not change or improve the initial findings in men or women.

Conclusions—In women, increases in abdominal fatness as reflected in abdominal circumference at any age are linearly related to an increase in $LVM/ht^{2.7}$, but the relationship of overall fatness as reflected in BMI with $LVM/ht^{2.7}$ is stronger. In men, both abdominal fatness and overall fatness at any age are linearly related to an increase $LVM/ht^{2.7}$. However, the significant curvilinear association of abdominal circumference and a linear association of BMI and physical activity with $LVM/ht^{2.7}$ indicate the possible positive covariate relationship of overall muscle mass with $LVM/ht^{2.7}$. This reflects the physiological changes with age and demonstrate, in part, the complexity of the interpretations of the inter associations of body composition, the cardiovascular system and the aging process, but the impact among the elderly and the known inadequacy of BMI at these ages remains an area for continued clinical study.

The Journal of Nutrition, Health & Aging©

Address Correspondence to: Wm. Cameron Chumlea, Ph.D.Fels Professor, Departments of Community Health and Pediatrics, Lifespan Health Research Center, Wright State University Boonshoft School of Medicine, 3171 Research Blvd. Dayton, OH 45420, 937-775-1428, 937-775-1422 (fax), cameron.chumlea@wright.edu.

Financial disclosure: None of the authors had any financial interest or support for this paper.

Introduction

Left ventricular mass (LVM) and left ventricular hypertrophy are independent and strong predictors for cardiovascular morbidity and mortality (1-3). These and other left ventricular parameters are positively associated with the body mass index (BMI) which reflects overall adiposity (4-10). BMI and its criteria for overweight and obesity have well established predictive associations with cardiovascular disease outcomes and with all cause mortality (8, 11-13). Recently, the importance of central adiposity which increases with age has been examined as the possible underpinning between obesity and adverse health, over and above the effects of overall obesity as reflected by BMI (14-18). Abdominal circumference, an index of intra-abdominal adiposity, is also an independent risk factor for cardiovascular disease, (19-21) the metabolic syndrome and type 2 diabetes, 22-24 but these associations vary by sex, age and health risk (25). The health relationship of LVM and abdominal circumference has been examined, but the latter was either combined with hip circumference (which is no longer recommended) or used categorically (10, 26, 27). In only a few studies has abdominal circumference been used as a continuous variable, and it was positively related to LVM even in the presence of obesity (9, 28). LVM and abdominal circumference change with age and levels of body fatness, and both are responsive to levels of physical activity (PA) and overall body fatness. LVM is positively related to muscle mass also (29).

Despite its lack of specificity (30), BMI is a common index of obesity at all ages, but its association with body fatness, disease risk and mortality declines with old age and varies by sex and ethnicity (18, 31-34). BMI and abdominal circumference are not diagnostic measures (35, 36), but abdominal circumference is potentially of greater clinical utility than BMI in describing fat distribution and obesity related health risks (37), and some consider it an important health risk indicator independent of BMI (15, 17, 23, 38-40).

The goal of this cross-sectional study was to evaluate the relationship of LVM and abdominal circumference in healthy men and women from young adulthood into old age while controlling for the influence of BMI and levels of physical activity (PA). Measuring LVM is time consuming and expensive, but abdominal circumference as a surrogate for central adiposity is quick and easy. If abdominal circumference is positively associated with an increased LVM, then it could have cardiovascular disease screening and prognostic value beyond its use as a measure of central adiposity and serve as a possible link between a marker for the metabolic syndrome and heart disease as part of the aging process. Improving our understanding of the distribution of LVM in association with abdominal circumference (i.e., central adiposity), BMI and PA categories in healthy adults free of known chronic disease could help to identify those individuals miss-classified by BMI alone who have increased chronic disease risks or potential associations with diabetes and the metabolic syndrome and thus should be considered for a thorough health assessment. The increase in obesity among the elderly concurrent with their increase in cardiac associated morbidity places them as a group where such miss-classification could occur at several of these levels.

Sample and Methods

The study sample included 182 white men and 220 white women, 20 to 75 years of age who are participants in the Fels Longitudinal Study and were observed between January 2003 and December 2005. These healthy adults were not selected for this study based on any specific disease or criteria, and they are long term participants in the Fels Longitudinal Study since childhood (41). All participants signed an informed consent statement, and the Institutional Review Board at Wright State University approved all procedures.

Echocardiography was performed by a single certified sonographer in the echocardiography laboratory of the Lifespan Health Research Center, Dayton, OH. All echocardiographs were

obtained with an ATL Philips Medical System HDI 5000 ultrasound imaging system according to a standardized protocol. Following a minimum five-minute rest in a quiet examination room, all images were taken with participants in the supine position. Two-dimensional, directed M-mode echocardiographs were recorded from at least ten cardiac cycles using multiple 10-15 second recordings in slightly different projections to identify LV chamber and wall interfaces and to determine LVM according to American Society of Echocardiography recommendations. LVM was divided by stature raised to the power of 2.7 to create a left ventricular mass index ($LVM/ht^{2.7}$) in order to minimize the impact of heart size variation from body size without overcompensating for the adverse effect of obesity.

Abdominal circumference was measured at the level of the highest point on the right iliac crest in a plane parallel with the floor, which is identical to the protocol used in NHANES III. (42). BMI was calculated from standardized measures of stature and weight. Physical activity data were obtained through the Baecke Physical Activity questionnaire and a score for total activity was calculated and used in the present study. Details of these protocols have been reported previously (43).

Statistical Analyses

BMI and abdominal circumference were analyzed as continuous variables, and participants were also classified into groups of overweight and obesity and abdominal obesity using the following cut points: obesity ($BMI > 30 \text{ kg/m}^2$), overweight ($BMI > 25 \text{ kg/m}^2$) and abdominal obesity (abdominal circumference $> 102 \text{ cm}$ in men or $> 88 \text{ cm}$ in women). Descriptive statistics for men and women were computed and sex differences were determined using t-tests. Pearson correlation coefficients were calculated between the independent variables and $LVM/ht^{2.7}$. Sex-specific multiple regression models were applied to examine the effects of overall and central obesity on $LVM/ht^{2.7}$ while including age, BMI, and PA as covariates. In addition, sex-specific logistic regressions were applied using the categories for BMI and abdominal circumference along with systolic and diastolic blood pressure as additional covariates.

Results

Descriptive statistics for the independent variables are presented in Table 1. Men have significantly larger means for abdominal circumference, $LVM/ht^{2.7}$ and PA than the women, but there are no significant sex differences in means for BMI or age. In women and in men, $LVM/ht^{2.7}$ is positively and significantly ($p < 0.05$) related with age, abdominal circumference and BMI but not with PA (Table 2). These correlations are slightly larger in the men than the women indicating that those with larger values for BMI and abdominal circumference also have larger values for $LVM/ht^{2.7}$.

Sex-specific multivariate regression models of abdominal circumference, BMI and PA on $LVM/ht^{2.7}$ are presented in Table 3. In the men, abdominal circumference, BMI and PA are significantly and linearly related to $LVM/ht^{2.7}$. BMI and PA are positively associated but abdominal circumference is negatively related with $LVM/ht^{2.7}$, in spite of their positive univariate relationship (Table 3). Polynomial regression analysis showed a significant positive quadratic association between abdominal circumference and $LVM/ht^{2.7}$.

In the women, age and BMI are positively and significantly related to $LVM/ht^{2.7}$. Abdominal circumference and PA were not associated with $LVM/ht^{2.7}$ in the multivariate analysis (Table 3) because the inclusion of BMI eliminated the linear association for abdominal circumference and PA so the model was recalculated with only age and BMI.

These relationships were further examined using logistic regression based on categories for BMI and abdominal circumference using established cut points and with systolic and diastolic blood pressure as additional covariates. For the men, this additional analysis produced no real change in the inter-relationships among the variables or their order of importance within the models as seen in Table 3. Obesity in the men, either as a high level of BMI or abdominal circumference and physical activity were positively associated with LVM and blood pressure was not a significant factor in explaining these associations. The use of categories for BMI and abdominal circumference based on established cut points also did not change the overall pattern among the variables for the women as seen in Table 3 except that systolic and diastolic blood pressures did have small positive associations with high BMI and LVM.

Discussion

In the present sample representing healthy individuals from young adulthood into old age, the older adults have larger values for abdominal circumference reflecting abdominal fatness, BMI, reflecting overall fatness and $LVM/ht^{2.7}$ with means for these variables larger in men than women. Men also have larger amounts of visceral adipose tissue than women (Demerath et al., 2007). These are conventional findings; as adults get older they tend to get fatter, and this fatness is reflected in an increase in BMI and abdominal circumference. Coincident with these increases in fatness and age is a large $LVM/ht^{2.7}$. Thus, age, BMI and abdominal circumference each are positively associated with $LVM/ht^{2.7}$ in the men as are BMI and age in the women. Other investigators have reported similar findings for BMI and $LVM/ht^{2.7}$, but associations between abdominal circumference and $LVM/ht^{2.7}$ have only been noted in a few reports on obese adults (9, 28)

In the men, abdominal circumference, reflecting central adiposity and BMI as an index of overall fatness each are positively related to $LVM/ht^{2.7}$ as is physical activity (Table 2). However, in plots of abdominal circumference against $LVM/ht^{2.7}$, this relationship appeared non linear, and this fact was confirmed in the polynomial regression model using abdominal circumference squared (Table 3). The significant quadratic association of abdominal circumference with $LVM/ht^{2.7}$ along with linear associations of BMI and PA suggest that there may be an unknown covariate or interaction that is confounding or modifying the observed association for the fatness variables and PA with $LVM/ht^{2.7}$. Within this sample, men with a large BMI and high physical activity level, but a low abdominal circumference have a large $LVM/ht^{2.7}$. This group represents men for whom a large $LVM/ht^{2.7}$ (and BMI) might be in response to high levels of physical activity and muscle mass (44). At the same time, low values of abdominal circumference are also associated with high physical activity levels without a weight loss (45). These present results also indicate that in older men a large abdominal circumference and BMI representing high levels of overall fatness are related to a large $LVM/ht^{2.7}$. In this instance, a large $LVM/ht^{2.7}$ might be in response to increased adiposity (with older age) as reported by others (9, 28). The inclusion of blood pressure into the models for these healthy men did not provide any additional clarity on the inter-relationships or a possible mechanism for them.

These findings for men are another example of the limited ability of BMI to discriminate between individuals of the same weights and statures but significant differences in body composition and their association with possible cardiovascular morbidity, and these associations are compounded in elderly men. The inclusion of abdominal circumference was able to clarify the relationship between BMI and $LVM/ht^{2.7}$. At the same time, dependence only on BMI would possibly have misclassified those men with a high BMI and a high physical activity level but a low abdominal circumference as possibly associated with a large

$LVM/ht^{2.7}$. Abdominal circumference alone was an insufficient discriminator of $LVM/ht^{2.7}$ as reported also by Whalley and colleagues (44).

In the women these associations were more straight forward than in the men. Large values for abdominal fatness as reflected by higher abdominal circumference at any age were linearly and positively related to $LVM/ht^{2.7}$. However, the positive relationship of BMI (reflecting overall fatness) as reflected by large BMI values with $LVM/ht^{2.7}$ was stronger than that of abdominal circumference and physical activity levels (Table 3), and there was a slight positive association with systolic and diastolic blood pressure. In women, high levels of fatness, regardless of its body location, i.e. central adiposity, are related to large values for $LVM/ht^{2.7}$. This parallels the association between measures of body fatness and blood pressure in these women previously (46).

These findings are, in part, a function of recognized sex differences in body composition and heart size among adults, with men having larger amounts of overall and central adiposity, larger hearts and higher physical activity levels than women. It is well established that men and women with increased abdominal circumferences are at increased health risks especially at older ages. It would also appear that abdominal circumference improves in the ability of BMI to discriminate differences among men in regard to the possibility of an enlarged heart and also clarifies the possible misclassification of those with an enlarged heart due to exercise and an increased muscle mass as being due to adiposity. These present results confirm in part the recommendations by some that abdominal circumference is a good indicator of cardiovascular health conditions but not better than BMI nor is BMI better than abdominal circumference, and that this improvement is in men more so than in women. However, it has been reported that in the absence of risk factors or disease, associations between levels of obesity and LVM are questionable or reflect expected physiologically related changes rather than possible pathology (47, 48). The present findings in these healthy adults reflect the physiological changes with age and demonstrate, in part, the complexity of the interpretations of the inter associations of body composition, the cardiovascular system and the aging process. However, the impact of these associations combined with increased obesity among the elderly and the known inadequacy of BMI at these ages remains an area for continued clinical study.

Acknowledgments

This work was supported by NIH grants HL72838, HD12252, and HL69995.

References

1. Casale PN, Devereux RB, Milner M, et al. Value of echocardiographic measurement of left ventricular mass in predicting cardiovascular morbid events in hypertensive men. *Ann Intern Med.* 1986; 105:173–8. [PubMed: 2942070]
2. Hense HW, Gneiting B, Muscholl M, et al. The associations of body size and body composition with left ventricular mass: impacts for indexation in adults. *J Am Coll Cardiol.* 1998; 32:451–7. [PubMed: 9708475]
3. Koren MJ, Devereux RB, Casale PN, Savage DD, Laragh JH. Relation of left ventricular mass and geometry to morbidity and mortality in uncomplicated essential hypertension. *Ann Intern Med.* 1991; 114:345–52. [PubMed: 1825164]
4. Domanski MJ, Jablonski KA, Rice MM, Fowler SE, Braunwald E. Obesity and cardiovascular events in patients with established coronary disease. *Eur Heart J.* 2006; 27:1416–22. [PubMed: 16707546]
5. Dorbala S, Crugnale S, Yang D, Di Carli MF. Effect of body mass index on left ventricular cavity size and ejection fraction. *Am J Cardiol.* 2006; 97:725–9. [PubMed: 16490446]

6. Ferrara AL, Vaccaro O, Cardoni O, Panarelli W, Laurenzi M, Zanchetti A. Is there a relationship between left ventricular mass and plasma glucose and lipids independent of body mass index? Results of the Gubbio Study. *Nutr Metab Cardiovasc Dis.* 2003; 13:126–32. [PubMed: 12955793]
7. Krishnan R, Becker RJ, Beighley LM, Lopez-Candales A. Impact of body mass index on markers of left ventricular thickness and mass calculation: results of a pilot analysis. *Echocardiography.* 2005; 22:203–10. [PubMed: 15725154]
8. National Institute of Health NH; Lung and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res.* 1998; 6:S51–210.
9. de Simone G, Devereux RB, Maggioni AP, Gorini M, de Divitiis O, Verdecchia P. Different normalizations for body size and population attributable risk of left ventricular hypertrophy: the MAVI study. *Am J Hypertens.* 2005; 18:1288–93. [PubMed: 16202850]
10. de Simone G, Palmieri V, Bella JN, et al. Association of left ventricular hypertrophy with metabolic risk factors: the HyperGEN study. *J Hypertens.* 2002; 20:323–31. [PubMed: 11821719]
11. Flegal KM, Graubard BI, Williamson DF, Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA.* 2005; 293:1861–7. [PubMed: 15840860]
12. Yan LL, Daviglus ML, Liu K, et al. Midlife body mass index and hospitalization and mortality in older age. *JAMA.* 2006; 295:190–8. [PubMed: 16403931]
13. WHO. Obesity: Preventing and managing the global epidemic. Geneva, Switzerland: 1998. p. 1–276.
14. Bigaard J, Frederiksen K, Tjonneland A, et al. Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. *Int J Obes (Lond).* 2005; 29:778–84. [PubMed: 15917857]
15. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. *Am J Clin Nutr.* 2004; 79:379–84. [PubMed: 14985210]
16. Visscher TL, Seidell JC, Molarius A, van der Kuip D, Hofman A, Witteman JC. A comparison of body mass index, waist-hip ratio and waist circumference as predictors of all-cause mortality among the elderly: the Rotterdam study. *Int J Obes Relat Metab Disord.* 2001; 25:1730–5. [PubMed: 11753597]
17. Zhu S, Heshka S, Wang Z, et al. Combination of BMI and Waist Circumference for Identifying Cardiovascular Risk Factors in Whites. *Obes Res.* 2004; 12:633–45. [PubMed: 15090631]
18. Van Pelt RE, Evans EM, Schechtman KB, Ehsani AA, Kohrt WM. Waist circumference vs body mass index for prediction of disease risk in postmenopausal women. *Int J Obes Relat Metab Disord.* 2001; 25:1183–8. [PubMed: 11477503]
19. Nicklas BJ, Penninx BW, Cesari M, et al. Association of visceral adipose tissue with incident myocardial infarction in older men and women: the Health, Aging and Body Composition Study. *Am J Epidemiol.* 2004; 160:741–9. [PubMed: 15466496]
20. Despres JP, Moorjani S, Lupien PJ, Tremblay A, Nadeau A, Bouchard C. Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. *Arteriosclerosis.* 1990; 10:497–511. [PubMed: 2196040]
21. Han TS, van Leer EM, Seidell JC, Lean ME. Waist circumference action levels in the identification of cardiovascular risk factors: prevalence study in a random sample. *Bmj.* 1995; 311:1401–5. [PubMed: 8520275]
22. Katzmarzyk PT, Janssen I, Ross R, Church TS, Blair SN. The importance of waist circumference in the definition of metabolic syndrome: prospective analyses of mortality in men. *Diabetes Care.* 2006; 29:404–9. [PubMed: 16443895]
23. Shen W, Punyanitya M, Chen J, et al. Waist circumference correlates with metabolic syndrome indicators better than percentage fat. *Obesity (Silver Spring).* 2006; 14:727–36. [PubMed: 16741276]
24. 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. [PubMed: 15569138]

25. Chumlea WC, Baumgartner RN, Garry PJ, Rhyne RL, Nicholson C, Wayne S. Fat distribution and blood lipids in a sample of healthy elderly people. *Int J Obes Relat Metab Disord.* 1992; 16:125–33. [PubMed: 1316327]
26. Bella JN, Devereux RB, Roman MJ, et al. Relations of left ventricular mass to fat-free and adipose body mass: the strong heart study. The Strong Heart Study Investigators. *Circulation.* 1998; 98:2538–44. [PubMed: 9843460]
27. Collis T, Devereux RB, Roman MJ, et al. Relations of stroke volume and cardiac output to body composition: the strong heart study. *Circulation.* 2001; 103:820–5. [PubMed: 11171789]
28. Sukmoko S, Waspadji S, Alwi I, Nainggolan G. Correlation between left ventricular mass and visceral fat thickness in obese women. *Acta Med Indones.* 2006; 38:135–41. [PubMed: 16953030]
29. Whalley GA, Doughty RN, Gamble GD, et al. Association of fat-free mass and training status with left ventricular size and mass in endurance-trained athletes. *J Am Coll Cardiol.* 2004; 44:892–6. [PubMed: 15312877]
30. Garn SM, Leonard WR, Hawthorne VM. Three limitations of the body mass index. *Am J Clin Nutr.* 1986; 44:996–7. [PubMed: 3788846]
31. Fernandez JR, Heo M, Heymsfield SB, et al. Is percentage body fat differentially related to body mass index in Hispanic Americans, African Americans, and European Americans? *Am J Clin Nutr.* 2003; 77:71–5. [PubMed: 12499325]
32. Rimm EB, Stampfer MJ, Giovannucci E, et al. Body size and fat distribution as predictors of coronary heart disease among middle-aged and older US men. *Am J Epidemiol.* 1995; 141:1117–27. [PubMed: 7771450]
33. Stevens J, Plankey MW, Williamson DF, et al. The body mass index-mortality relationship in white and African American women. *Obes Res.* 1998; 6:268–77. [PubMed: 9688103]
34. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *Am J Clin Nutr.* 2000; 72:694–701. [PubMed: 10966886]
35. Hubbard VS. Defining overweight and obesity: what are the issues? *Am J Clin Nutr.* 2000; 72:1067–8. [PubMed: 11063427]
36. Kuczmarski RJ, Flegal KM. Criteria for definition of overweight in transition: background and recommendations for the United States. *Am J Clin Nutr.* 2000; 72:1074–81. [PubMed: 11063431]
37. Willett WC, Hu FB, Colditz GA, Manson JE. Underweight, overweight, obesity, and excess deaths. *Jama.* 2005; 294:551. author reply 552-3. [PubMed: 16077044]
38. Janssen I, Heymsfield SB, Allison DB, Kotler DP, Ross R. Body mass index and waist circumference independently contribute to the prediction of nonabdominal, abdominal subcutaneous, and visceral fat. *Am J Clin Nutr.* 2002; 75:683–8. [PubMed: 11916754]
39. Zhu S, Wang Z, Heshka S, Heo M, Faith MS, Heymsfield SB. Waist circumference and obesity-associated risk factors among whites in the third National Health and Nutrition Examination Survey: clinical action thresholds. *Am J Clin Nutr.* 2002; 76:743–9. [PubMed: 12324286]
40. Chan JM, Rimm EB, Colditz GA, Stampfer MJ, Willett WC. Obesity, fat distribution, and weight gain as risk factors for clinical diabetes in men. *Diabetes Care.* 1994; 17:961–9. [PubMed: 7988316]
41. Roche AF. Growth, Maturation and Body Composition: The Fels Longitudinal Study 1929-1991. Cambridge University Press; Cambridge: 1992.
42. Chumlea WC, Kuczmarski RJ. Using a bony landmark to measure waist circumference. *J Am Diet Assoc.* 1995; 95:12. [PubMed: 7798573]
43. Remsberg KE, Rogers NL, Demerath EW, et al. Sex differences in young adulthood metabolic syndrome and physical activity: the Fels longitudinal study. *Am J Hum Biol.* 2007; 19:544–50. [PubMed: 17546618]
44. Whalley GA, Gamble GD, Doughty RN, et al. Left ventricular mass correlates with fat-free mass but not fat mass in adults. *J Hypertens.* 1999; 17:569–74. [PubMed: 10404960]
45. Ross R, Dagnone D, Jones PJ, et al. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. A randomized, controlled trial. *Ann Intern Med.* 2000; 133:92–103. [PubMed: 10896648]

46. Chumlea WC, Guo SS, Roche AF, Siervogel RM. Concurrent tracking of blood pressure and abdominal circumference in adults followed over a 30 year period: The Fels Longitudinal Study. *American Journal of Epidemiology*. 1995; 141:S17.
47. Iacobellis G, Ribaudo MC, Leto G, et al. Influence of excess fat on cardiac morphology and function: study in uncomplicated obesity. *Obes Res*. 2002; 10:767–73. [PubMed: 12181385]
48. Iacobellis G, Ribaudo MC, Zappaterreno A, Iannucci CV, Di Mario U, Leonetti F. Adapted changes in left ventricular structure and function in severe uncomplicated obesity. *Obes Res*. 2004; 12:1616–21. [PubMed: 15536225]

Table 1

Descriptive statistics for men and women

	Men		Women	
	Mean	Std Dev	Mean	Std Dev
Age (years)	45.6	15.1	45.9	15.1
BMI (kg/m ²)	26.9	4.5	26.3	5.3
Abdominal Circumference (cm) ^a	99.4	13.1	91.3	13.2
LVM/ht ^{2.7} (g/m ^{2.7}) ^a	31.7	8.7	29.1	8.0
Physical Activity ^a	7.7	1.2	7.4	1.2

^a p-value<0.05 between men and women

Table 2Correlations with LVM/ht^{2.7} in men and women

	Men	Women
Age (years)	0.48 ^a	0.47 ^a
Abdominal Circumference (cm)	0.52 ^a	0.48 ^a
BMI (kg/m ²)	0.55 ^a	0.47 ^a
Physical Activity	0.10	-0.09

^a
p-value<0.05

Table 3

Significant parameter estimates ($p < 0.05$) and standard errors for anthropometry models with $LVM/ht^{2.7}$ for men and women

	Parameters	Standard Error	R ²	RMSE
<i>Men</i>				
Age	0.29	0.04	0.50	6.29
Abdominal Circumference	-1.30	0.47		
Abdominal Circumference ²	0.006	0.002		
BMI	1.33	0.29		
Physical Activity	1.22	0.42		
<i>Women</i>				
Model 1 *				
Age	0.23	0.03	0.40	6.19
BMI	0.66	0.21		
Model 2				
Age	0.22	0.03	0.40	6.20
BMI	0.65	0.08		

* Model 1 in women included abdominal circumference and physical activity as covariates, but these were not statistically significant parameter estimates ($p < 0.05$).