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## Regional Body Volumes, BMI, Waist Circumference, and Percentage Fat in Severely Obese Adults

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### Abstract

**Objective**—This study presents total body volume (TBV) and regional body volume, and their relationships with widely used body composition indices [BMI, waist circumference (WC), and percentage body fat (% fat)] in severely obese adults ( $BMI \geq 35 \text{ kg/m}^2$ ).

**Research Methods and Procedures**—We measured TBV, trunk volume (TV), arm volume (AV), leg volume (LV), and WC and estimated % fat in 32 severely obese persons with BMI 36 to  $62 \text{ kg/m}^2$  (23 women; age, 19 to 65 years; weight, 91 to 182 kg) and in 58 persons with BMI  $<35 \text{ kg/m}^2$  (28 women; age, 18 to 83 years; weight, 48 to 102 kg) using a newly validated 3-day photonic image scanner (3DPS, Model C9036 - 02, Hamamatsu Co., Japan) and calculated TV/TBV, AV/TBV, and LV/TBV.

**Results**—Men had significantly larger TBV and higher TV/TBV and AV/TBV, but significantly lower LV/TBV than women, independently of BMI. TV/TBV increased while AV/TBV and LV/TBV decreased with increasing BMI, WC, and % fat, and the rate of increase in TV/TBV per % fat was significantly greater in severely obese individuals than in individuals with BMI  $<35 \text{ kg/m}^2$ . The relationships for TBV with % fat were much lower than with BMI or WC.

**Conclusion**—Body volume gains were mainly in the trunk region in adults, irrespective of sex or BMI. For a given BMI, WC, or % fat, men had a significantly larger TV than women. The implication is that men could have higher health risks due to having higher trunk body weight as a proportion of total body weight compared with severely obese or less severely obese women.

### Keywords

body composition; body image; body fat distribution

### Introduction

Numerous studies have documented that an increase in central adiposity as indicated by an enlarged waist circumference (WC)<sup>1</sup> is associated with the presence of hypertension, coronary heart disease, type 2 diabetes, and increased mortality risk (1-4). Other studies have reported that greater lower body obesity as indicated by increased thigh circumference is negatively associated with insulin and glucose levels, and the accumulation of fat in the legs may be protective against abnormal glucose metabolism, especially in women (5-7), because the adipocytes in the leg region are less sensitive than the adipocytes in the trunk region to lipolytic stimuli (8,9). Because of the lack of reliable methodology for measuring body size or volumes

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in severely obese individuals, information on total or regional body size or body volume in severely obese individuals is unavailable. Body circumferences have been used as indices of fat distribution at different body regions across various levels of BMI ( $\text{kg}/\text{m}^2$ ). Seidell et al. (5) reported that persons with a small WC and large hip circumference have a lower risk of cardiovascular disease. However, it is difficult to obtain reliable values for body circumferences using traditional tape measures in severely obese individuals (10).

We recently validated a 3-day photonic scanner (3DPS, Model C9036 - 02; Hamamatsu Co., Japan) for measuring total and regional body volumes and dimensions in humans (11). The 3DPS can accommodate the maximum adult body size and is, therefore, without body size constraints.

The main objective of this study was to investigate the efficacy of this newly developed 3DPS technique in the assessment of body composition, body volumes, and dimensions, and secondly to investigate the relationships between regional body volumes as proportions of total body volume and their associations with BMI, WC, and percentage body fat (% fat) in severely obese individuals ( $\text{BMI} \geq 35 \text{ kg}/\text{m}^2$ ) and to compare the results to persons with  $\text{BMI} < 35 \text{ kg}/\text{m}^2$ . The cut-off point at  $35 \text{ kg}/\text{m}^2$  was selected for two reasons: 1) the standard classification for severe obesity is  $\text{BMI} \geq 35 \text{ kg}/\text{m}^2$  (12), and 2) persons with  $\text{BMI} \geq 35 \text{ kg}/\text{m}^2$  are likely to weigh  $>250$  lbs and are usually excluded from measurements using scanning techniques that could generate total or regional body volumes, such as magnetic resonance imaging (MRI) or computed tomography (CT); therefore, body volume data are unavailable in severely obese individuals.

## Research Methods and Procedures

### Subjects

Thirty-two severely obese adults with BMI 36 to  $63 \text{ kg}/\text{m}^2$  were recruited for the study (23 women; age, 19 to 65 years; weight, 91 to 182 kg). Fifty-eight adults with  $\text{BMI} > 18$  to  $34 \text{ kg}/\text{m}^2$  were included in the study as controls (28 women; age, 18 to 83 years). The study was approved by the St. Luke's-Roosevelt Hospital Institutional Review Board. A written consent form was obtained from each participant.

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<sup>1</sup>Nonstandard abbreviations:

<b>WC</b>	waist circumference
<b>3DPS</b>	3-day photonic scanner
<b>MRI</b>	magnetic resonance imaging
<b>CT</b>	computed tomography
<b>TBV</b>	total body volume
<b>AV</b>	arm volume
<b>LV</b>	leg volume.

## Measurements

Body weight was measured to the nearest 0.1 kg (Ohaus Champ General Purpose Bench Scale; Ohaus Corp., Pine Brook, NJ) and height to the nearest 1 mm using a stadiometer (Holtain, Ltd., Crymych, U.K.) while the subjects wore minimal underwear and no shoes.

The 3DPS used in this study is a non-invasive optical method (Model # C9036 - 02; Hamamatsu Photonics K.K., Japan). The scan system has 4 photonic image production units mounted on four poles in the scanner. Each unit has an eye-safe Class 1 laser-light source (664 nm) and a digital camera (charge-coupled device camera), which uses high-speed digital sensors. The scan field is 200 cm high × 100 cm wide × 60 cm deep. The software uses triangulation mathematics to detect the actual position of the light point that projected onto the surface of an object and reflected to the cameras. During the scanning process, the 4 scanning units move vertically and simultaneously, producing a maximum of 2560 data points at each of the 800 cross sections over the 2-m vertical scan field in 10 seconds with a 2.5-mm pitch interval to generate a total 2,048,000 data points. The software connects the points to generate a 3-day body image and calculates values for total and regional body volumes and dimensions such as body circumferences, lengths, widths, and thicknesses. The size of a cross section on the scanned surface is calculated from all detected data points at the cross section, and the distance between any 2 body surface points is determined by all data points on the line between the 2 points. The software can also calculate volume for any selected region of the body. Using traditional underwater weighing and tape measure results as the criterion methods, we have documented that this newly developed 3DPS has a high accuracy and reproducibility for the measurement of total and regional body volumes and dimensions in children and adults with a wide range of age, weight, and body fatness, and in a commercially available mannequin. The above information was described in detail in a previous report (11).

Figure 1 defines the total body volume (TBV) and regional body volumes measured by the 3DPS. Arm volume (AV) was the sum of left and right arms, and leg volume (LV) was the sum of left and right legs. Each subject wore a tight-fitting cap to minimize air-spaces between the hair and skull and well-fitting underwear that clung to the skin surface. The arms and legs were positioned using the standard 3DPS landmarks, and the subject was instructed to remain motionless during the scan. Subjects were scanned 3 times during normal breathing and 3 times at the end of a maximal expiration; % fat was estimated using the TBV measure at the end of maximal expiration as described previously. The reported total and regional body volume values and WC were measured at normal breathing. The measurement reproducibility by the 3DPS for circumferences range from 99.2% for chest to 99.6% for thigh, and for body volumes range from 99.4% for total body to 95.7% for leg (11).

## Data Analysis

Descriptive statistics, mean, standard deviation, minimum value, and maximum value were calculated for each variable. Linear regression analysis was used to model the associations of TBV and each regional body volume as a proportion of TBV with BMI, WC, and % fat for each sex within each group. All statistical analyses were calculated using SAS version 9.1 (SAS Institute, Inc., Cary, NC) and STATA version 9.2 (StataCorp LP., College Station, TX) statistical software packages for personal computers. The level of significance was set at 0.05 for all statistical tests.

## Results

Table 1 shows the physical characteristics of both study groups. Within the severely obese group, men were significantly heavier and taller and had higher BMI and larger WC than women, but there were no differences in age and % fat compared with women. Within the BMI

<35 kg/m<sup>2</sup> group, men were significantly heavier and taller and had larger WC and lower % fat, but there were no differences in age and BMI compared with women.

Table 2 shows the TBV, regional volumes, and regional volumes as proportions of TBV in both groups. In the severely obese group, men had significantly higher TBV, TV, and AV than women ( $p = 0.0055$  to  $0.0003$ ), but there was no significant difference in LV between men and women ( $p = 0.97$ ). When the regional volumes were expressed as proportions of the TBV in the severely obese group, men had higher TV/TBV ( $0.68$  vs.  $0.62$ ,  $p = 0.0014$ ), but lower LV/TBV ( $0.21$  vs.  $0.26$ ,  $p = 0.0009$ ), than women, and there was no significant difference in AV/TBV between sexes ( $p = 0.53$ ). However, the latter may, in part, be due to the smaller sample size in men. In the BMI <35 kg/m<sup>2</sup> group, men had significantly higher TV ( $p = 0.0125$ ) and AV ( $p = 0.0001$ ) than women. Men had higher TV/TBV and AV/TBV, but lower LV/TBV ( $0.0001$ ), than women.

Table 3 presents the linear regression equations for the relationships of TBV and each regional volume as proportion of TBV with BMI, WC, and % fat in the severely obese women and men. In women, all of the relationships were significant (except AV/TBV vs. BMI): TBV and TV/TBV increased with increasing BMI, WC, and % fat, while AV/TBV and LV/TBV decreased with increasing BMI, WC, and % fat. In men, TBV also increased with increasing BMI, WC, and % fat, while for regional volumes, only TV/TBV increased with increasing WC. The  $r^2$  values for TBV with BMI and WC were higher than those with % fat in both sexes.

Between-sex differences were found for TV/TBV vs. % fat ( $p = 0.001$ ), LV/TBV vs. % fat ( $p = 0.001$ ), AV/TBV vs. WC, AV/TBV vs. BMI ( $p = 0.009$ ), and LV/TBV ( $p = 0.010$ ) vs. BMI ( $p = 0.019$ ).

Table 4 presents similar equations in the BMI <35 kg/m<sup>2</sup> group. In women, TBV increased with increasing BMI, WC, and % fat, but there were no other significant relationships. In men, TBV increased with increasing BMI and WC, but not with increasing % fat, while for regional volumes, TV/TBV and LV/TBV, but not AV/TBV, increased with increasing BMI and WC. Similar to the results in the severely obese group, the  $r^2$  values for TBV with BMI and WC were higher than those with % fat in both sexes.

Between-sex differences were found for all dependent variables (TV/TBV, AV/TBV, and LV/TBV) vs. % fat, WC, and BMI ( $p = 0.046$  -  $p = 0.001$ ). Across both groups, there were no significant differences between the slopes for men and women; i.e., there were no significant interactions between sex and % fat, WC, and BMI. However, the intercepts for men were different than for women. That is, for a given BMI, WC, or % fat, men had higher TV/TBV and AV/TBV but lower LV/TBV than women.

Figures 2, 3, and 4 are scatter plots of the relationships between TBV and BMI, WC, and % fat in the severely obese women and men. Figures 5, 6, and 7 are similar plots for each regional volume as a proportion of TBV vs. BMI, WC, and % fat in the severely obese women and men.

## Discussion

In this study, we found that men had a greater body weight and TBV compared with women. TBV was highly and positively associated with BMI and WC (Figures 2 and 3) for both women and men in both BMI cohorts, with  $r^2$  values ranging from 0.60 to 0.77 in the study group with BMI  $\geq 35$  kg/m<sup>2</sup> (Table 3) and  $r^2$  values ranging from 0.69 to 0.79 in subjects with BMI < 35 kg/m<sup>2</sup> (Table 4). TBV was also positively associated with % fat in women (Figure 4) for both BMI cohorts, but the  $r^2$  values were much lower than the  $r^2$  values with BMI or WC. No significant relationship was found between TBV and % fat in men with BMI <35 kg/m<sup>2</sup>. Since TBV is determined by body weight, and body weight alone is not a reliable predictor for %

fat, we were not surprised by the low correlations between TBV and % fat. In this study, we found that  $r^2$  was  $>0.998$  for the relationships between TBV and body weight in the combined study cohorts.

However, it is important to point out that the relatively low association between TBV and % fat does not imply that measurement of TBV by this technique is less useful in this population. Indeed, TBV can be used to estimate % fat (13). In this study, all of the severely obese subjects were able to perform the 10-second scan measurements. Also, there were no body size constraints imposed by the 3DPS, unlike other currently available techniques such as CT, MRI, or DXA (14-16), which is the major advantage of this technique for studying body composition in severe obesity.

To our knowledge, this is the first study to indicate that men, irrespective of BMI, have a greater trunk volume as a proportion of total body volume compared with women, while women have a greater leg volume (Table 2), and TV/TBV is positively associated with BMI, WC, and % fat, while LV/TBV is negatively associated with BMI, WC, and % fat in severely obese men and women (Figures 5 to 7). These results suggest that, in both sexes, with increasing weight gain, more weight is gained in the trunk region, independently of BMI, but men have more trunk weight than women for a given BMI. Since abdominal obesity is associated with health risks while greater leg fat appears to be protective against unfavorable glucose metabolism (5-7), the implication from these findings is that the health risks due to unfavorable regional body mass distribution could be greater in men than in women. These findings apply in conditions of normal-weight, overweight, and severely overweight.

CT and MRI could be used to measure total or regional body volumes. CT has been used to measure adipose tissue volume (14). MRI has been used to measure volume of the breast during the menstrual cycle (15), skeletal muscle and adipose tissue (17-19), and select organs (20). However, no attempt has been made to use these techniques to measure whole-body volumes, even though such information is important for various health-related reasons.

We also failed to find any previous studies presenting such results in individuals with BMI  $<35$  kg/m<sup>2</sup>. Therefore, no published reference data are available for us to make any comparisons of the results obtained in this study. Our previous results obtained in studies of mannequins documented the accuracy of the 3DPS in measuring total and regional body volumes and dimensions compared with underwater weighing and tape measure techniques (11) and are supportive of the reliability of the results presented in this report.

Various body circumferences have been used to estimate body fat content. WC measurement using the simple and inexpensive tape measure technique has been considered a reliable anthropometric measurement for identifying obesity, establishing risks for obesity, and monitoring the effects of treating obesity (21). However, anthropometric results using the traditional tape measure technique may vary by the instrument used, protocol definitions, and observer's measurement skill. Also, the measurement reliability is low for studies in obese subjects (10). Our previous studies in children and adults, as well as in a mannequin, have documented that the newly developed 3-day photonic scanner measures body circumferences at chest, waist, hip, and midhigh accurately (11). In this study, we found that the association of % fat with WC ( $r = 0.62$  for women, and  $r = 0.81$  for men) was higher than with BMI ( $r = 0.57$  for women, and  $r = 0.62$ ) in individuals with BMI  $\geq 35$  kg/m<sup>2</sup>. These results further confirm that, in severely obese individuals, WC is also a better predictor than BMI for % fat.

This study used the 3DPS technique, which is easy, fast, and accurate, to determine total and regional body volumes and dimensions and to estimate volume or mass distribution in a population that has historically been neglected due to the lack of reliable measurement techniques. All subjects were able to perform the measurements, and there were no body size

constraints imposed by the 3DPS in the current study population where the maximum body weight and BMI were 182 kg and 63 kg/m<sup>2</sup>, respectively.

Measurements of changes in total and regional body volume and in body dimensions reflect changes in total and regional body fat and lean tissue storage. The outcomes from this study indicate that the 3DPS could be used to determine changes in total and regional body volumes and dimensions during obesity treatments and/or interventions in severely obese individuals and to investigate whether regional body volumes as proportions of total body volume have any influence on lipid metabolism.

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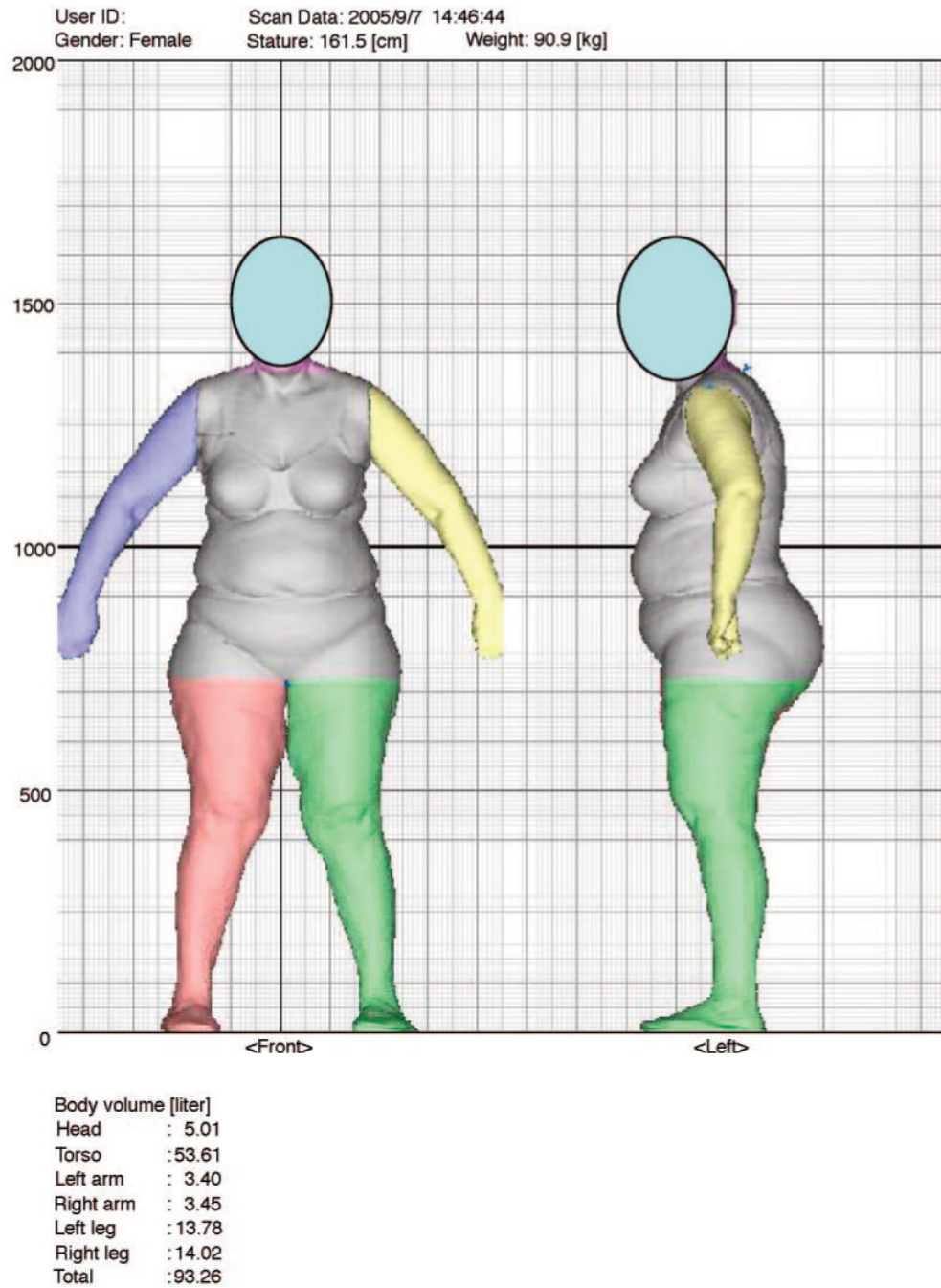
The authors thank all of the participants in the study, as well as Hideo Hiruma of the Mamamatsu Photonics K.K. of Japan, and his colleagues for their technical and instrumentation supports to make the study possible. This study was supported by DK26687-05 and D1DDK-42618.

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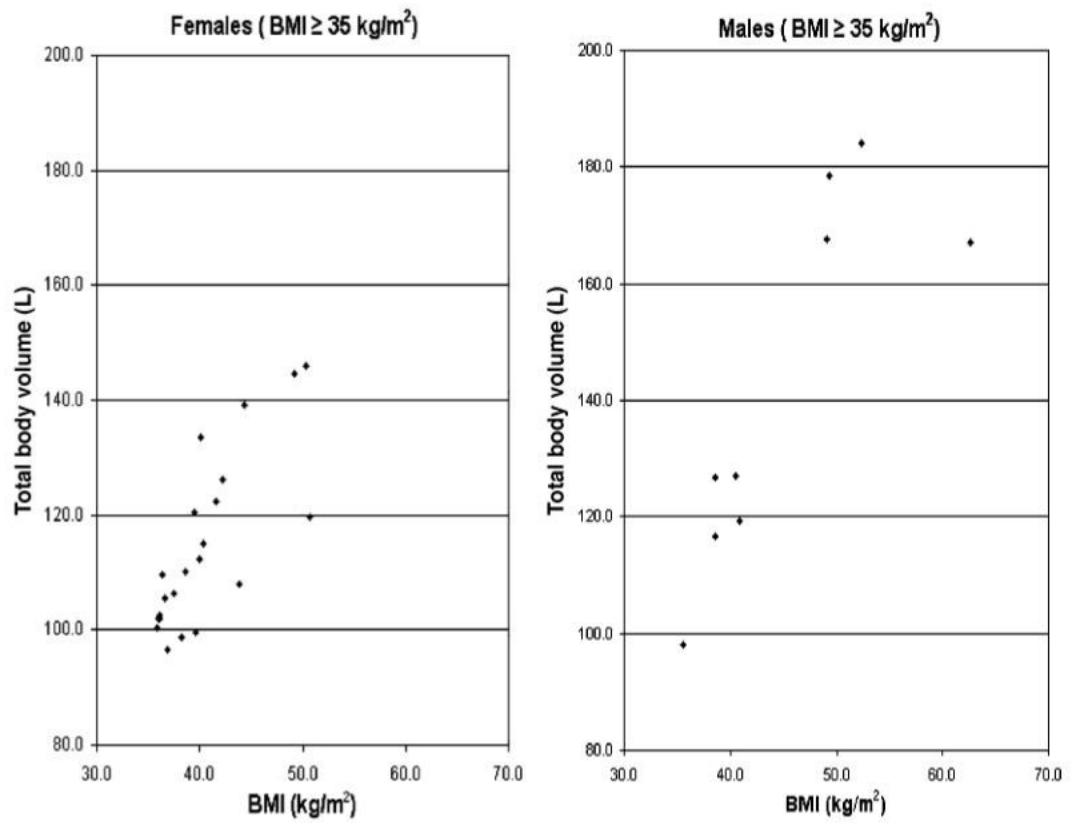


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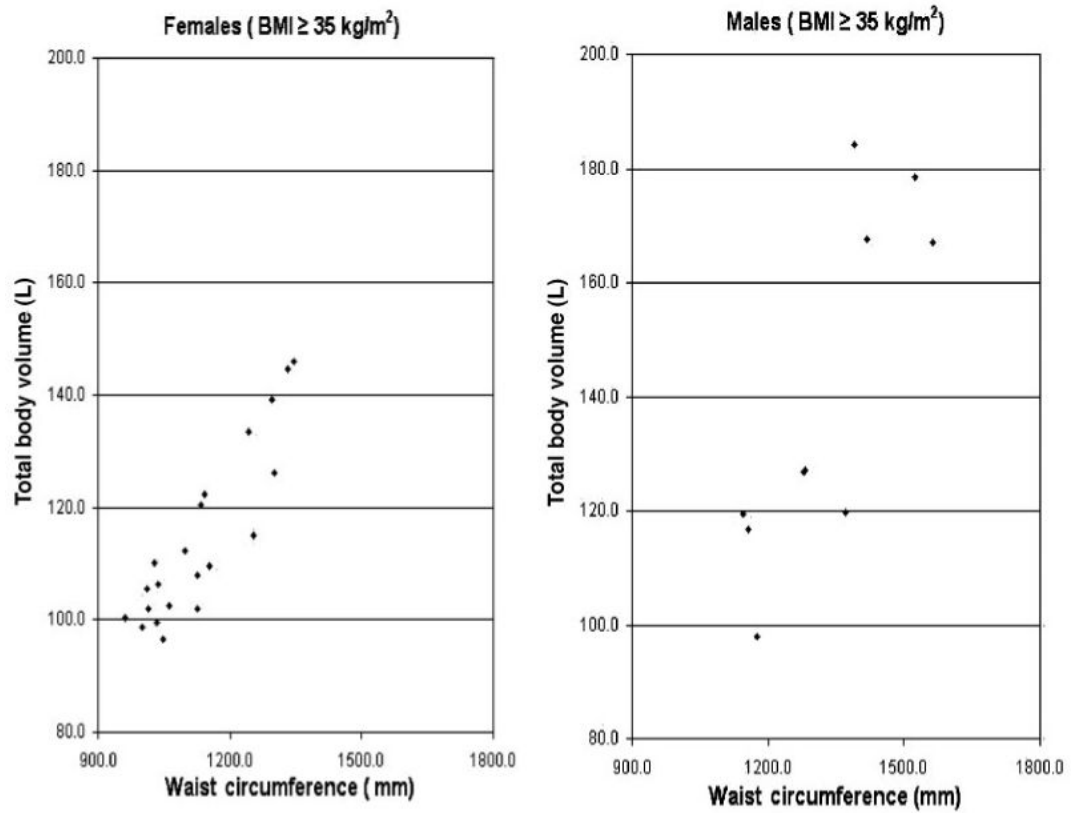


**Figure 1.** The image of a total body scan and the definition of regional body volumes of a participant measured by the 3DPS scanner. AV is the sum of left arm and right arm volumes, and LV is the sum of left leg and right leg volumes.

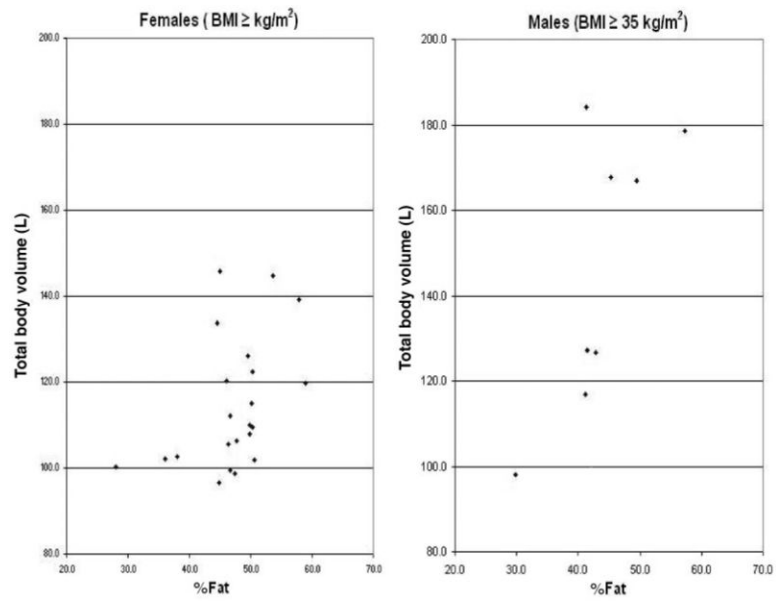




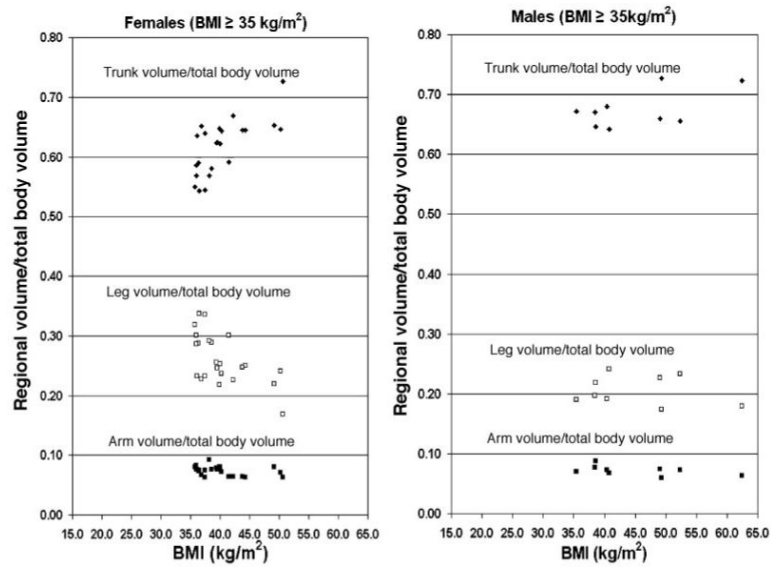
**Figure 2.** The scatter plot of TBV measured by 3DPS vs. BMI for severely obese women and men (BMI  $\geq 35$  kg/m<sup>2</sup>).



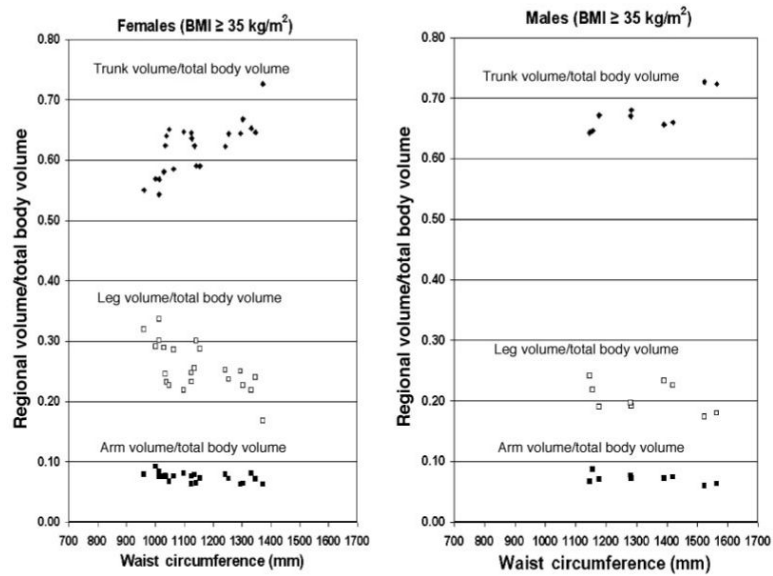
**Figure 3.** The scatter plot of TBV measured by 3DPS vs. WC for severely obese women and men (BMI  $\geq 35$  kg/m<sup>2</sup>).



**Figure 4.** The scatter plot of TBV measured by 3DPS vs. % fat for severely obese women and men (BMI  $\geq 35$  kg/m<sup>2</sup>).

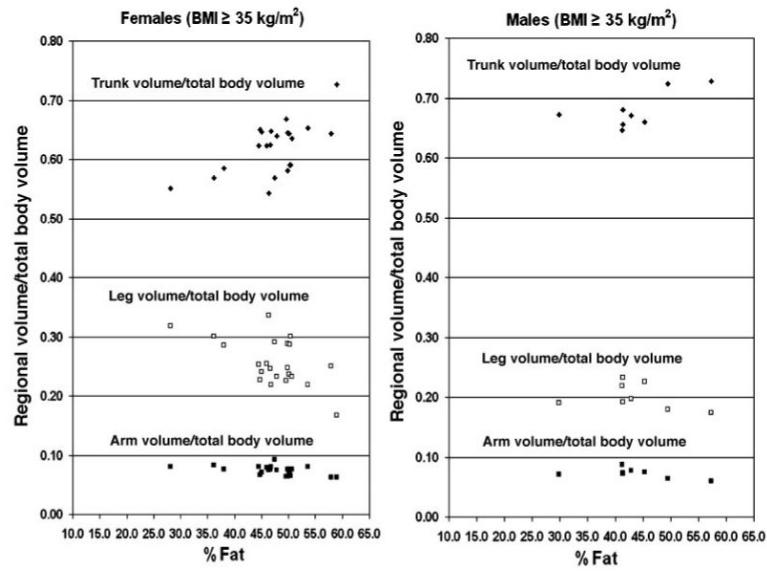


**Figure 5.** The scatter plot of TV, AV, and LV as proportion of TBV measured by 3DPS vs. BMI for severely obese women and men ( $BMI \geq 35 \text{ kg/m}^2$ ).



**Figure 6.** The scatter plot of TV, AV, and LV as proportion of TBV measured by 3DPS vs. WC for severely obese women and men ( $BMI \geq 35 \text{ kg/m}^2$ ).





**Figure 7.** The scatter plot of TV, AV, and LV as proportion of TBV measured by 3DPS vs. % fat for severely obese women and men (BMI ≥35 kg/m<sup>2</sup>).

**Table 1**  
Physical characteristics of severely obese participants (BMI  $\geq 35$  kg/m<sup>2</sup>) and participants with BMI  $<35$  kg/m<sup>2</sup>

	Females (n = 23)				Males (n = 9)				p
	Mean	SD	Range	Mean	SD	Range			
<b>BMI <math>\geq 35</math> kg/m<sup>2</sup></b>									
Age (yrs)	41	13	24 to 65	40	13	19 to 55	0.7114		
Weight (kg)	111	15	91 to 143	140	30	98 to 182	0.0007*		
Height (cm)	166	7	150 to 181	176	9	162 to 186	0.0016*		
BMI (kg/m <sup>2</sup> )	40	5	36 to 51	45	9	35 to 62	0.0431*		
WC (mm)	1142	128	960 to 1372	1326	157	1146 to 1564	0.0018*		
% fat	47	7	28 to 59	44	8	30 to 57	0.2200		
	Females (n = 28)				Males (n = 30)				p
	Mean	SD	Range	Mean	SD	Range			
<b>BMI <math>&lt;35</math> kg/m<sup>2</sup></b>									
Age (yrs)	39	17	18 to 83	44	14	18 to 74	0.1917		
Weight (kg)	72	16	48 to 102	79	11	51 to 100	0.0447*		
Height (cm)	165	8	147 to 195	174	6	160 to 192	0.0001*		
BMI (kg/m <sup>2</sup> )	26	5	18 to 34	26	4	18 to 34	0.8884		
WC (mm)	853	115	650 to 1060	928	101	741 to 1125	0.0129*		
% fat	36	7	24 to 47	25	9	11 to 47	0.0002*		

SD, standard deviation; WC, waist circumference.

\* Significant.

**Table 2**  
Total and regional body volumes (L), and regional body volumes as proportions of total body volume measured by 3DPS in severely obese participants (BMI  $\geq 35$  kg/m<sup>2</sup>) and in participants with BMI  $<35$  kg/m<sup>2</sup>

	Females (n = 23)				Males (n = 9)				p
	Mean	SD	Range	Mean	SD	Range			
BMI $\geq 35$ kg/m <sup>2</sup>									
TBV (L)	113	16	93 to 146	143	31	98 to 184	0.0013*		
TV (L)	70	13	50 to 94	97	24	66 to 129	0.0003*		
AV (L)	8	1	6 to 12	10	2	7 to 13	0.0055*		
LV (L)	29	5	20 to 37	29	7	19 to 43	0.9997		
TV/TBV	0.62	0.05	0.54 to 0.73	0.68	0.03	0.64 to 0.73	0.0014*		
AV/TBV	0.07	0.01	0.06 to 0.09	0.07	0.01	0.06 to 0.09	0.5342		
LV/TBV	0.26	0.04	0.17 to 0.34	0.21	0.02	0.17 to 0.24	0.0009*		
BMI $<35$ kg/m <sup>2</sup>									
TBV (L)	73	16	50 to 104	79	11	57 to 100	0.0928		
TV (L)	41	10	26 to 59	47	8	32 to 64	0.0103*		
AV (L)	6	1	4 to 8	8	1	6 to 12	0.0009*		
LV (L)	21	6	13 to 35	29	5	20 to 37	0.1950		
TV/TBV	0.57	0.04	0.50 to 0.65	0.60	0.03	0.54 to 0.66	0.0009*		
AV/TBV	0.08	0.01	0.06 to 0.10	0.07	0.01	0.06 to 0.09	0.0001*		
LV/TBV	0.28	0.03	0.22 to 0.35	0.26	0.04	0.17 to 0.34	0.0001*		

3DPS, 3-day photonic scanner; SD, standard deviation; TBV, total body volume; TV, trunk volume; AV, arm volume; LV, leg volume.

\* Significant.

**Table 3**  
 Linear relationships of TBV and regional body volumes as proportions of TBV with BMI, WC, and % fat in severely obese participants (BMI  $\geq 35$  kg/m<sup>2</sup>)

Sex	Dependent variable	Independent variable	Linear equation	r <sup>2</sup>	SEE	P
Females	TBV	BMI	TBV = 2.63BMI +7.42	0.60	10.0	0.001*
		WC	TBV = 0.10WC - 0.96	0.72	8.3	0.001*
		% fat	TBV = 0.98% fat +67.97	0.19	14.0	0.043*
	TV/TBV	BMI	TV/TBV = 0.0068BMI +0.3434	0.47	0.0340	0.001*
		WC	TV/TBV = 0.0003WC +0.3322	0.54	0.0302	0.001*
		% fat	TV/TBV = 0.0041% fat +0.4277	0.39	0.0348	0.002*
	AV/TBV	BMI	AV/TBV = -0.00060BMI +0.0980	0.13	0.0075	0.097
		WC	AV/TBV = -0.00003WC +0.1078	0.24	0.0068	0.020*
		% fat	AV/TBV = -0.00055% fat +0.1000	0.23	0.0068	0.023*
Males	LV/TBV	BMI	LV/TBV = -0.0056BMI +0.4845	0.37	0.0342	0.002*
		WC	LV/TBV = -0.00020WC +0.4864	0.42	0.0309	0.001*
		% fat	LV/TBV = -0.0033% fat +0.4147	0.32	0.0334	0.006*
	TBV	BMI	TBV = 3.04BMI +5.04	0.71	18.0	0.004*
		WC	TBV = 0.18WC - 90.30	0.77	16.2	0.002*
		% fat	TBV = 3.03% fat +13.63	0.54	23.6	0.038*
TV/TBV	BMI	TV/TBV = 0.0020BMI +0.5834	0.33	0.0270	0.106	
	WC	TV/TBV = 0.00016WC +0.4692	0.62	0.0203	0.012*	
	% fat	TV/TBV = 0.0026% fat +0.5658	0.46	0.0241	0.066	
AV/TBV	BMI	AV/TBV = -0.00048BMI +0.0935	0.28	0.0073	0.147	
	WC	AV/TBV = -0.00003WC +0.1127	0.37	0.0068	0.085	
	% fat	AV/TBV = -0.00055% fat +0.0964	0.27	0.0077	0.188	
LV/TBV	BMI	LV/TBV = -0.00045BMI +0.2262	0.03	0.0259	0.681	
	WC	LV/TBV = -0.000072WC +0.3015	0.21	0.0233	0.214	
	% fat	LV/TBV = -0.00092% fat +0.2414	0.11	0.0224	0.428	

TBV, total body volume; WC, waist circumference; SEE, standard error of the estimate; TV, trunk volume; AV, arm volume; LV, leg volume.

\* Significant.

**Table 4**  
Linear relationships of TBV, and regional body volumes as proportions of TBV with BMI, WC, and % fat in participants with BMI <35 kg/m<sup>2</sup>

Sex	Dependent variable	Independent variable	Linear equation	r <sup>2</sup>	SEE	p
Females	TBV	BMI	TBV = 2.77BMI + 0.07	0.79	7.6	0.001*
		WC	TBV = 0.12WC - 26.53	0.70	9.0	0.001*
		% fat	TBV = 1.23% fat + 31.90	0.31	13.5	0.013*
	TV/TBV	BMI	TV/TBV = 0.00146BMI + 0.5279	0.04	0.0391	0.324
		WC	TV/TBV = 0.00011WC + 0.4782	0.10	0.0377	0.114
		% fat	TV/TBV = 0.0011% fat + 0.5378	0.04	0.0390	0.414
	AV/TBV	BMI	AV/TBV = 0.00011BMI + 0.0767	0.00	0.0080	0.726
		WC	AV/TBV = -0.00000WC + 0.0811	0.00	0.0082	0.896
		% fat	AV/TBV = -0.00029% fat + 0.0886	0.08	0.0075	0.253
LV/TBV	BMI	LV/TBV = 0.00008BMI + 0.2826	0.00	0.0340	0.948	
	WC	LV/TBV = -0.00003WC + 0.3088	0.01	0.0342	0.623	
	% fat	LV/TBV = -0.0003% fat + 0.2893	0.00	0.0358	0.805	
Males	TBV	BMI	TBV = 2.18BMI + 21.45	0.75	5.5	0.001*
		WC	TBV = 0.08WC + 4.12	0.69	5.6	0.001*
		% fat	TBV = 0.41% fat + 69.90	0.11	10.2	0.107
	TV/TBV	BMI	TV/TBV = 0.00285BMI + 0.5227	0.16	0.0277	0.027*
		WC	TV/TBV = 0.00020WC + 0.4104	0.49	0.0213	0.001*
		% fat	TV/TBV = 0.0016% fat + 0.5606	0.22	0.0275	0.024*
	AV/TBV	BMI	AV/TBV = -0.0002BMI + 0.0941	0.01	0.0080	0.553
		WC	AV/TBV = -0.00003WC + 0.1127	0.11	0.0074	0.073
		% fat	AV/TBV = -0.00015% fat + 0.0932	0.03	0.0085	0.470
LV/TBV	BMI	LV/TBV = -0.0013BMI + 0.2790	0.05	0.0246	0.255	
	WC	LV/TBV = -0.00013WC + 0.3628	0.27	0.0214	0.004*	
	% fat	LV/TBV = -0.0012% fat + 0.2753	0.19	0.0237	0.036*	

TBV, total body volume; WC, waist circumference; SEE, standard error of the estimate; TV, trunk volume; AV, arm volume; LV, leg volume.

\* Significant.