

Title: Air displacement plethysmography for estimating body composition changes with weight loss in middle-aged Japanese men

Short running head: Body composition change by air displacement method

Section: Original Article

Summary:

Aim: To examine the degree to which air displacement plethysmography (ADP) can track body composition changes in response to weight loss in obese Japanese men. **Method:** Fifty men, aged 30–65 yr, with a mean body mass index of 30 kg/m², received a 3-month weight-loss program. Percentage of fat mass (%FM) was determined by dual energy X-ray absorptiometry (DXA) and ADP at baseline and month 3. **Results:** With 6.2 ± 4.3 kg of weight loss, %FM, as determined by DXA and ADP, significantly decreased by 3.9 ± 2.9% and 3.9 ± 3.3%, respectively. There was no mean difference for change (Δ) in %FM between the two methods. DXA-derived Δ %FM significantly correlated with Δ %FM determined by ADP ($R^2 = 0.48$, $P < 0.01$). Furthermore, the Bland-Altman plots demonstrated no systematic bias for Δ %FM ($r = -0.20$, $P = 0.17$). However, %FM by ADP at baseline and Δ %FM by ADP were significantly correlated to the differences between Δ %FM by DXA and ADP ($r = 0.42$, -0.54 , respectively). **Conclusion:** These results suggest that ADP is comparably accurate for evaluating Δ %FM determined by DXA, although there were proportional biases.

Keywords: air displacement plethysmography; dual energy X-ray absorptiometry; percentage of fat mass; weight loss; obesity

1. Introduction

The obesity epidemic has become one of the biggest public health concerns worldwide including within Asian countries [1,2], because of its close relationship to chronic diseases such as hypertension, dyslipidemia, diabetes and cardiovascular disease [3,4]. Since obesity is characterized and defined as the excess accumulation of body fat, accurate measurements of body composition are of utmost importance for public health and clinical perspectives. The ability of health professionals to accurately estimate body composition changes in obese individuals is also critical for determining the effectiveness of weight loss or management strategies.

Several body composition methods are available, which differ in terms of their theoretical bases and scientific assumptions, as well as their cost, complexity, and subject acceptability. For example, hydrostatic weighting (HW) has long been considered the gold standard for measuring body composition [5]. However, it requires many methodological assumptions and inconveniences that limit its usefulness and widespread application. Consequently, dual energy X-ray absorptiometry (DXA) has emerged as one of the most accurate techniques to assess body composition. DXA uses a 3-compartment model to provide an estimate of bone mineral content, fat and lean soft tissue. DXA is easier to administer than HW and correlates well with other measures of body composition such as HW, total body water, and multi-compartment approaches [6,7]. DXA can also detect body composition changes due to weight loss [8].

Air displacement plethysmography (ADP) has emerged as a fairly novel technique that provides a body composition estimate from body density using a 2-compartment model, as does HW [9]. The biggest difference between ADP and HW is that ADP does not require participants to exhale maximally while submerged under water. Therefore, ADP seems much more feasible and comfortable than HW. Cross-sectional studies showed that percentage of fat mass (%FM) estimated from ADP highly correlate with those from DXA [10,11].

A few studies have demonstrated that ADP was sensitive enough to detect moderate body composition changes compared to DXA over various time periods (from 2 to 16 months) and percent weight loss (from 4.7% to 7.0%), primarily among Caucasian adults [11-13]. Asians, including Japanese, have greater %FM than Caucasians for the same BMI and age [14]. Therefore, it is important to determine whether ADP is a valid method of tracking body

composition changes in Japanese men.

The purpose of this study, then, was to examine whether ADP could accurately track body composition changes in response to weight loss in obese Japanese men, using DXA as a reference method. Better understanding of this issue will be useful for designing longitudinal studies regarding body composition, as well as in providing clinically-relevant information for health professionals.

2. Participants and Methods

Participants

We recruited participants from communities around the University of Tsukuba for 3-month weight-loss programs through local newspaper advertisements and study flyers. Eligibility criteria included the following: 1) men, 2) aged 30–65 yr, 3) a body mass index (BMI) of greater than 25 kg/m² according to the domestic obesity guideline [15] and 4) no history of cardiovascular disease. In Japan, despite the fact that only 2–3% has been characterized as having a BMI ≥ 30 kg/m², the prevalence of metabolic disorders are relatively high [16,17]. Thus, the cutoff value for the definition of obesity for Asian populations was used [15]. After an orientation session, 54 men participated in the weight-loss programs in 2007. The men were non-randomly assigned to receive either a dietary program ($n = 30$) or an exercise program ($n = 24$). These two weight-loss methods were employed to achieve a wide range of %FM changes. We excluded four men with incomplete assessments after the programs. Thus, data from the remaining 50 men (dietary program: $n = 26$; exercise program: $n = 24$) were analyzed. We fully explained the purpose and design of the study to each participant before they gave written informed consent. The research protocol was approved by the institutional review board at the University of Tsukuba, and thus meets the standards of the Declaration of Helsinki.

Weight-loss programs

The dietary program consisted of weekly group-based 90-min instructional sessions for 3 months, as well as individual counseling by trained staff. In each session, the participants received lectures on low-calorie diets and eating behavior. We instructed them to consume a well-balanced 1680 kcal diet per day. The exercise program consisted of 90-min sessions of

aerobic exercise three times per week for 3 months. Each exercise session began with 15–30 minutes of warm-up activities such as stretching. The session was followed by 30–60 minutes of brisk walking performed outdoors in the campus of the University of Tsukuba and finished with 15–30 minutes of cool-down activities.

Energy intake and expenditure

Energy intake in kilocalorie was assessed before and during a 2-week period (weeks 9 and 10) of both weight-loss programs by 3-day weighed dietary records, and dietary recall interviews for each participant were performed by skilled dietitians. The dietary data for each participant were analyzed by using commercially-available computer software (Excel Eiyokun, Kenpakusha, Tokyo, Japan). Total energy expenditure was also assessed by a validated uniaxial accelerometer (Lifecorder-EX; Suzuken, Nagoya, Japan). The accelerometer was firmly attached to the participant's clothing (belt or waistband) during all waking hours (except while bathing and sleeping) 2 weeks before starting the 3-month programs, for baseline examination, and throughout the programs. Forty-two men (23 for the dietary group and 19 for the exercise group) successfully completed the above measurements before and throughout the 3-month programs.

Measurement procedures

We instructed the participants not to participate in vigorous physical activity or alcohol consumption within 24 h prior to body composition measurement, as well as to refrain from eating or drinking for 2 h prior to the measurements. They removed all metal objects and jewelry during the measurements. We assessed height to the nearest 0.1 cm using a wall-mounted stadiometer. Body weight was measured to the nearest 0.01 kg using DXA equipment. We then calculated BMI as body weight in kilograms divided by squared height in meters. Waist circumference was measured to the nearest 0.1 cm at the level of the umbilicus using a flexible retractable fiberglass tape measure. We always implemented DXA measurement first, and then ADP within 30 min. All measurements were conducted in the same order at baseline and at month 3.

Dual energy X-ray absorptiometry

We measured %FM by DXA (e.g., %FM_{DXA}) using a Lunar DPX-NT densitometer (Lunar, Madison, WI). We calibrated the densitometer every day according to manufacturer's recommendations. The densitometer calculated soft tissue mass, including fat and lean tissue mass, from the ratio of mass-attenuation coefficients (R-value) at 40–50 keV and 80–100 keV. We defined fat-free mass as lean tissue mass plus bone mineral content. During each measurement, the participants remained motionless in the supine position while the scanning arm passed over his body in parallel 1-cm strips. To minimize technical error, the same examiner operated the densitometer and positioned the participant at baseline and month 3. The CVs in %FM with repeated examinations were less than 2% in our laboratory ($n = 33$).

Air displacement plethysmography

We measured %FM by ADP (e.g., %FM_{ADP}) using a Bod Pod (Life Measurement Inc., Concord, CA) according to manufacturer's instructions. The physical concepts and operational principles of ADP were described elsewhere [10]. Before each measurement, an examiner calibrated the Bod Pod six consecutive times to estimate the mean volume of the chamber with the 49.490 L cylinder. The participant wore trunks and a swim cap to minimize clothing and compress air, thereby estimating volume variations. Then, the participant was weighed on an electronic scale which was calibrated in advance with two standard 10-kg weights. The participant sat quietly in the chamber while their raw body volume (V_b) was measured consecutively until two values within 150 mL were obtained. We estimated thoracic gas volume (V_{tg}) by having participants perform the panting maneuver according to manufacturer's instruction until a successful measurement (the *merit* and *airway* value was less than 1 or 35 cm H₂O) was obtained. Briefly, the participant wore a nose clip and breathed normally for three breathing cycles through a tube connected to the internal system. At the midpoint of an exhalation, the airway tube was momentarily occluded. And, the examiner signaled him to perform three small puffs of air into the tube while maintaining a tight seal around the end of the tube. We used the measured V_{tg} to calculate a corrected V_b (raw V_b minus V_{tg}) and computed body density as body weight divided by the corrected V_b . We calculated %FM_{ADP} using the Siri's equation [18]. The CVs in %FM with repeated examinations were less than 5% in our

laboratory ($n = 8$).

Statistical Analysis

We chose DXA, which is not a recognized gold standard, as the reference method, as it has been considered a reasonable alternative to a multi-compartment approach [8]. After stratifying by program, we applied a paired Student's *t*-test to compare the mean %FM from DXA and ADP at each time point, and to assess the difference between measurements at baseline and month 3. A simple linear regression analysis examined the proportion of %FM_{DXA} at each time point could be accounted for by %FM_{ADP}. Bland-Altman plots [19] assessed the potential bias between DXA and ADP at each time point in wide ranges of body composition and the changes (Δ). We tested the null hypothesis that the slope was equal to zero in the models to consider the presence of bias. In addition, Pearson's correlation coefficients were calculated to explain the variance of the difference between $\Delta\%$ FM by DXA and ADP. A *P* value less than 0.05 was regarded as statistically significant. We performed all statistical analyses using SAS, version 9.1 (SAS Institute, Inc., Cary, NC).

3. Results

Table 1 describes baseline characteristics, and compares body composition results obtained using DXA and ADP at baseline and month 3. Attendance rates were 77.5% for dietary sessions and 86.8% for exercise sessions. The weight-loss programs significantly reduced body weight, waist circumference, body volume and %FM, and significantly increased body density in both programs and in the combined data. Fat-free mass measured by DXA was significantly decreased in dietary program and combined data. In contrast, bone mass remained unchanged for the all groups. There were no significant differences in %FM at both time points or in $\Delta\%$ FM in response to weight loss between the two methods.

Energy intake was significantly decreased from 2062 ± 236 to 1567 ± 285 kcal/day in the dietary program. Total energy expenditure significantly increased from 2422 ± 242 to 2662 ± 284 kcal/day during the exercise program. In the combined data, there were significant reductions in energy intake (from 2172 ± 351 to 1841 ± 496 kcal/day) and significant increase in total energy expenditure (from 2462 ± 230 to 2585 ± 263 kcal/day) through the weight-loss

programs.

Table 2 summarizes the simple regression analyses and the Bland-Altman plots for %FM at baseline and month 3 using DXA as the reference method. Coefficients of determination (R^2) were moderate to high (≥ 0.7) for %FM at baseline. After weight loss, the R^2 for %FM slightly increased (≥ 0.8). The Bland-Altman plots demonstrated no significant bias in %FM at both time points.

Fig. 1 displays the results of simple regression analyses for $\Delta\%$ FM by DXA and ADP. The R^2 coefficients for $\Delta\%$ FM were moderate (≥ 0.4). Almost all plots for $\Delta\%$ FM were within the 95% prediction intervals.

Fig. 2 depicts the results of the Bland-Altman plots for assessing bias in the estimation of $\Delta\%$ FM between the two methods. The plots demonstrated no significant bias in $\Delta\%$ FM. In addition, almost all individual plots for $\Delta\%$ FM in both programs were within the 95% limits of agreement.

Fig. 3 shows relation of $\Delta\%$ FM determined with DXA minus $\Delta\%$ FM estimated from ADP to baseline %FM determined by ADP and the $\Delta\%$ FM determined by ADP. ADP-derived %FM at baseline proved to be positively related to the differences between $\Delta\%$ FM by DXA and ADP ($r = 0.42$, $P < 0.01$). Similarly, ADP-derived $\Delta\%$ FM was inversely associated with the difference ($r = -0.54$, $P < 0.01$).

4. Discussion

The present study examined whether ADP could track body composition changes with weight loss using DXA as the reference method in middle-aged Japanese men. We found that ADP with the use of Siri's equations tracked $\Delta\%$ FM in a manner similar to that derived by DXA. We also demonstrated a uniform distribution of measurement errors (DXA minus ADP) in $\Delta\%$ FM across the range of $\Delta\%$ FM in the Bland-Altman analysis. However, we also showed that %FM from individuals with larger %FM by ADP and/or with greater $\Delta\%$ FM is overestimated as compared to DXA method.

To date, few studies have examined the ability of ADP to accurately estimate body composition change over a period of weight loss [11-13]. In 22 obese men and women with a mean BMI of 30 kg/m^2 , Weyers et al. reported no significant mean differences in $\Delta\%$ FM

between DXA and ADP using Siri's equation after an 8 week moderately energy restricted diet [11]. The R^2 between DXA and ADP in their study was 0.44 for $\Delta\%FM$ ($P < 0.05$). Frisard et al. also reported that R^2 between DXA and ADP exhibited 0.24–0.28 for $\Delta\%FM$ (Brozek's and Siri's equations) in 56 obese men and women [12]. Elberg et al. revealed good agreement of $\Delta\%FM$ between DXA and ADP with the use of Siri's equation in natural changes over 1 year in 86 boys and girls ($R^2 = 0.59$) [20]. Moreover, a recent study of Minderico et al. demonstrated no significant differences in $\Delta\%FM$ between DXA and ADP in 93 obese women [13]. They described an R^2 of 0.76 for $\Delta\%FM$ between DXA and ADP. The current study also demonstrated no significant differences in $\Delta\%FM$. R^2 between DXA and ADP were 0.48 for $\Delta\%FM$ ($P < 0.01$). Our results are consistent with these prior studies.

Of the four previous studies, two examined the presence of systematic bias in the estimation of $\Delta\%FM$ by using a Bland-Altman approach. Minderico et al. indicated no significant bias, suggesting the ability of ADP to assess $\Delta\%FM$ against the wide spread variations ($P = 0.67$; r value not shown) [13]. In contrast, Elberg et al. reported that ADP underestimated $\Delta\%FM$ as the $\%FM$ gain was increased in children ($r = 0.35$, $P < 0.01$) [20]. In the current study, we found, in the Bland-Altman approach, no significant bias in $\Delta\%FM$, suggesting that the ability of ADP to track $\%FM$ ($r = 0.20$, $P = 0.17$). These mixed results might be accounted for by the amount of $\Delta\%FM$ during follow-up periods. Along with Minderico et al., we conducted weight-loss intervention studies that produced large $\Delta\%FM$ (mean changes of greater than 3%) [13], while Elberg et al. detected less than 1% of $\Delta\%FM$ [20]. Similar results were also found when comparing DXA to bioelectrical impedance, potassium counting and deuterium dilution [12,21]. However, our data also suggest that $\%FM$ from individuals with larger $\%FM$ by ADP and/or with greater $\Delta\%FM$ by ADP are overestimated as compared to DXA method. Thus, results of similar interventions might be interpreted with cautions. To our knowledge, this is the first study assessing the ability of ADP to detect $\Delta\%FM$ in Asians populations using DXA as the reference method. Asians have a generally greater $\%FM$ than Caucasians for the same BMI and age [14]. Therefore, it is important to examine the validity of ADP for body composition change in Asian populations.

It is worth addressing the advantages of ADP uses in research, clinical, and public health settings. ADP can measure a large number of participants and a wide range of participant types.

It also has the advantages of lower initial investment and no radiation exposure, even though the radiation exposure of DXA is extremely low. Since the current study revealed that ADP can track $\Delta\%$ FM with no significant bias, ADP can be applied to longitudinal intervention studies around body composition to estimate $\Delta\%$ FM as well as weight management strategies in clinical or public health settings. Even though researchers and practitioners should consider the possibility of a $\pm 2\%$ standard error of estimate may exist in the estimation of $\Delta\%$ FM when the participants experienced approximately 7% of weight loss.

This study has several strengths to address. First, the study population was Asian men. Previous studies with similar designs all included mainly Caucasians men and women [11-13], whereas our study enrolled a Japanese population. Our results were mostly consistent with previous studies, so the ethnic difference may not contribute to, or hinder, the ability of ADP to track body composition changes. Second, this study elicited enough weight loss to investigate the study purpose. Previous studies with similar designs produced 4.7–7.0% weight loss [11-13]. Our study also obtained 7.0% weight loss (approximately 10% weight loss in the dietary program), allowing us to utilize one of the widest ranges of weight loss of all published studies.

However, there were also several limitations to the current study. First, we did not validate ADP compared to the multi-compartment models. Obviously, DXA is not a gold standard and seems to include certain limitations such as an ability to detect lean tissue mass changes in regions with large areas of bone pixels. In addition to this, weight loss resulted in slight (1-2 %) reduction in hydration fraction of fat-free mass according to the previous studies [22,23]. This would potentially increase %FM determined by DXA. However, Nord and Payne reported DXA was relatively insensitive to tissue hydration status compared to other clinical methods using classical 2-compartment model [24]. Taken together, it is difficult to dismiss a possibility that DXA itself could be the cause of the observed bias. To correct the bias, further investigations would be warranted by using multi-compartment models. Second, we were unable to consider any gender-specific or age-related differences, since our study recruited only middle-aged men. Therefore, it remains unclear whether our results can be extrapolated to women and older adults. In addition, we acknowledge our relatively small sample size as a limitation.

In summary, the current study indicated that the mean changes in %FM were similar

between the two methods investigated. DXA- and ADP-derived $\Delta\%$ FMs were highly correlated, after an approximately 7% weight loss in obese Japanese men. In the Bland-Altman approach, measurement errors (DXA minus ADP) in $\Delta\%$ FM were uniformly distributed across the ranges of body composition changes. However, %FM from individuals with larger %FM by ADP and/or with greater $\Delta\%$ FM might be overestimated as compared to DXA method.

Literature cited

- [1] Caterson ID, Hubbard V, Bray GA, Grunstein R, Hansen BC, Hong Y, Labarthe D, Seidell JC, Smith SC: Prevention Conference VII: Obesity, a worldwide epidemic related to heart disease and stroke: Group III: worldwide comorbidities of obesity. *Circulation* 2004;110:e476-e483.
- [2] Yoshiike N, Seino F, Tajima S, Arai Y, Kawano M, Furuhata T, Inoue S: Twenty-year changes in the prevalence of overweight in Japanese adults: the National Nutrition Survey 1976-95. *Obes Rev* 2002;3:183-190.
- [3] Ishikawa-Takata K, Ohta T, Moritaki K, Gotou T, Inoue S: Obesity, weight change and risks for hypertension, diabetes and hypercholesterolemia in Japanese men. *Eur J Clin Nutr* 2002;56:601-607.
- [4] Cui R, Iso H, Toyoshima H, Date C, Yamamoto A, Kikuchi S, Kondo T, Watanabe Y, Koizumi A, Wada Y, Inaba Y, Tamakoshi A: Body mass index and mortality from cardiovascular disease among Japanese men and women: the JACC study. *Stroke* 2005;36:1377-1382.
- [5] Roubenoff R, Kehayias JJ, Dawson-Hughes B, Heymsfield SB: Use of dual-energy x-ray absorptiometry in body-composition studies: not yet a "gold standard". *Am J Clin Nutr* 1993;58:589-591.
- [6] Wellens R, Chumlea WC, Guo S, Roche AF, Reo NV, Siervogel RM: Body composition in white adults by dual-energy x-ray absorptiometry, densitometry, and total body water. *Am J Clin Nutr* 1994;59:547-555.
- [7] Kohrt WM: Preliminary evidence that DEXA provides an accurate assessment of body composition. *J Appl Physiol* 1998;84:372-377.
- [8] Evans EM, Saunders MJ, Spano MA, Arngrimsson SA, Lewis RD, Cureton KJ:

- Body-composition changes with diet and exercise in obese women: a comparison of estimates from clinical methods and a 4-component model. *Am J Clin Nutr* 1999;70:5-12.
- [9] McCrory MA, Gomez TD, Bernauer EM, Molé PA: Evaluation of a new air displacement plethysmograph for measuring human body composition. *Med Sci Sports Exerc* 1995;27:1686-1691.
- [10] Fields DA, Goran MI, McCrory MA: Body-composition assessment via air-displacement plethysmography in adults and children: a review. *Am J Clin Nutr* 2002;75:453-467.
- [11] Weyers AM, Mazzetti SA, Love DM, Gómez AL, Kraemer WJ, Volek JS: Comparison of methods for assessing body composition changes during weight loss. *Med Sci Sports Exerc* 2002;34:497-502.
- [12] Frisard MI, Greenway FL, Delany JP: Comparison of methods to assess body composition changes during a period of weight loss. *Obes Res* 2005;13:845-854.
- [13] Minderico CS, Silva AM, Teixeira PJ, Sardinha LB, Hull HR, Fields DA: Validity of air-displacement plethysmography in the assessment of body composition changes in a 16-month weight loss program. *Nutrition & Metabolism* 2006;3:32.
- [14] Levitt DG, Heymsfield SB, Pierson RN, Shapses SA, Kral JG: Physiological models of body composition and human obesity. *Nutrition & Metabolism* 2009;6:7.
- [15] The Examination Committee of Criteria for 'Obesity Disease' in Japan; Japan Society for the Study of Obesity: New criteria for 'obesity disease' in Japan. *Circ J* 2002;66:987-992.
- [16] Kuzuya T: Prevalence of diabetes mellitus in Japan compiled from literature. *Diabetes Res Clin Pract* 1994;24 Suppl:S15-S21.
- [17] Sakata K, Labarthe DR: Changes in cardiovascular disease risk factors in three Japanese national surveys 1971-1990. *J Epidemiol* 1996;6:93-107.
- [18] Siri WE: Body composition from fluid spaces and density: analysis of methods. 1961. *Nutrition* 1993;9:480-491.
- [19] Bland JM, Altman DG: Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307-310.
- [20] Elberg J, McDuffie JR, Sebring NG, Salaita C, Keil M, Robotham D, Reynolds JC, Yanovski JA: Comparison of methods to assess change in children's body composition. *Am J Clin Nutr* 2004;80:64-69.

- [21] Pødenphant J, Gotfredsen A, Engelhart M, Andersen V, Heitmann BL, Kondrup J: Comparison of body composition by dual energy X-ray absorptiometry to other estimates of body composition during weight loss in obese patients with rheumatoid arthritis. *Scand J Clin Lab Invest* 1996;56:615-625.
- [22] Jebb SA, Siervo M, Murgatroyd PR, Evans S, Frühbeck G, Prentice AM: Validity of the leg-to-leg bioimpedance to estimate changes in body fat during weight loss and regain in overweight women: a comparison with multi-compartment models. *International Journal of Obesity* 2007;31:756-762.
- [23] Ritz P, Sallé A, Audran M, Rohmer V: Comparison of different methods to assess body composition of weight loss in obese and diabetic patients. *Diabetes Res Clin Pract* 2007;77:405-411.
- [24] Nord RH, Payne RK: Dual-energy X-ray absorptiometry vs underwater weighing comparison of strengths and weaknesses. *Asia Pac J Clin Nutr* 1995;4:173-176.

Tables

Table 1 Comparison of body composition results obtained using dual-energy X-ray absorptiometry (DXA) and air displacement plethysmography (ADP) at baseline and month 3 among middle-aged obese Japanese men.

Variables	Dietary program (<i>n</i> = 26)			Exercise program (<i>n</i> = 24)			Combined (<i>n</i> = 50)		
	Baseline	Month 3	Change	Baseline	Month 3	Change	Baseline	Month 3	Change
Age, yr	47.1 (7.9)			48.5 (9.4)			47.8 (8.6)		
Height, cm	170.1 (5.1)			170.0 (6.3)			170.1 (5.6)		
Body weight, kg	87.6 (11.2)	78.7 (11.2)	-8.8 (3.6) ^e	87.8 (10.1)	84.4 (9.2)	-3.4 (2.9) ^e	87.7 (10.6)	81.5 (10.6)	-6.2 (4.3) ^e
BMI, kg/m ²	30.2 (3.2)	27.1 (3.1)	-3.1 (1.3) ^e	30.4 (3.4)	29.2 (3.0)	-1.2 (1.0) ^e	30.3 (3.2)	28.1 (3.2)	-2.2 (1.5) ^e
Overweight ^a , %	46.2	53.8		58.3	62.5		52.0	58.0	
Obese ^b , %	53.8	15.4		41.7	33.3		48.0	24.0	
Waist circumference, cm	102.1 (7.8)	92.9 (8.8)	-9.2 (4.5) ^e	102.4 (7.8)	97.9 (6.9)	-4.5 (2.8) ^e	102.3 (7.7)	95.3 (8.3)	-7.0 (4.4) ^e
Fat-free mass ^c , kg	57.1 (6.4)	55.4 (5.7)	-1.7 (1.6) ^e	58.8 (5.5)	58.5 (5.1)	-0.3 (1.5)	57.9 (5.9)	56.9 (5.6)	-1.0 (1.7) ^e
Bone mass ^c , g	3046 (475)	3065 (466)	19 (126)	3074 (363)	3113 (394)	39 (113)	3060 (421)	3088 (429)	29 (119)
Body volume ^d , L	85.5 (11.6)	75.8 (11.7)	-9.7 (4.1) ^e	85.1 (10.7)	81.1 (9.6)	-4.1 (3.2) ^e	85.3 (11.0)	78.3 (10.9)	-7.0 (4.6) ^e
Body density ^d , kg/L	1.02 (0.01)	1.03 (0.01)	0.01 (0.01) ^e	1.03 (0.01)	1.03 (0.01)	0.01 (0.01) ^e	1.02 (0.01)	1.03 (0.01)	0.01 (0.01) ^e
Percentage of fat mass, %									
DXA	34.5 (4.4)	29.1 (6.0)	-5.4 (3.0) ^e	32.8 (4.1)	30.4 (4.9)	-2.4 (1.8) ^e	33.7 (4.3)	29.7 (5.4)	-3.9 (2.9) ^e
ADP	34.9 (4.6)	29.7 (5.4)	-5.2 (3.3) ^e	31.8 (4.6)	29.2 (4.8)	-2.6 (2.8) ^e	33.4 (4.8)	29.5 (5.1)	-3.9 (3.3) ^e
Δ between DXA and ADP	-0.4 (2.8)	-0.6 (2.6)	-0.2 (2.2)	1.0 (3.0)	1.2 (3.0)	0.2 (2.8)	0.3 (2.9)	0.2 (2.9)	0.0 (2.5)

Abbreviations: Δ, differences; BMI, body mass index. Values are means (SD), ^aBMI of 25-30 kg/m², ^bBMI of greater than 30 kg/m²,

^cMeasured by DXA, ^dMeasured by ADP, ^eSignificantly different from baseline.

Table 2 Summary of simple regression analysis and Bland and Altman approach for percentage of fat by air displacement plethysmography (ADP)ct baseline and month 3 compared to dual-energy X-ray absorptiometry (DXA).

	Baseline	Month 3
Simple regression analysis		
Slope	0.71	0.91
Intercept	9.97	2.94
R	0.79	0.85
R ²	0.63	0.72
SEE	2.62	2.92
<i>P</i>	< 0.01	< 0.01
Bland and Altman approach		
Bias ^a	0.25	0.25
95% LoA ^b	-5.52, 6.02	-5.48, 5.98
R	-0.18	0.13
<i>P</i>	0.20	0.37

Abbreviations: SEE, standard error of estimate, LoA, limits of agreement. ^aMean difference between DXA and ADP (i.e., DXA minus ADP), ^bUpper and lower 95% LoA.

Legends for figure

Figure 1

Simple regression analysis for changes (Δ) in percentage of fat mass (%FM) determined by dual-energy X-ray absorptiometry (DXA) and air displacement plethysmography (ADP). The bold solid line indicates the regression line between $\Delta\%$ FM from DXA and ADP. The dashed lines represent 95% prediction intervals. ●: participants engaged in dietary program, ○: participants engaged in exercise program, SEE: standard error of estimate.

Figure 2

Bland-Altman plots for the systematic bias in the estimation of changes (Δ) in percentage of fat mass (%FM) between dual-energy X-ray absorptiometry (DXA) and air displacement plethysmography (ADP). The middle solid line indicates the mean difference between $\Delta\%$ FM from DXA and ADP. The upper and lower dashed lines represent limits of agreement (± 2 SD from the mean). ●: participants engaged in dietary program, ○: participants engaged in exercise program.

Figure 3

Relation of changes (Δ) in percentage of fat mass (%FM) determined with dual-energy X-ray absorptiometry (DXA) minus the $\Delta\%$ FM estimated from air displacement plethysmography (ADP) to baseline %FM determined by ADP (left) and the $\Delta\%$ FM determined by ADP (right). The middle solid line indicates the mean difference between $\Delta\%$ FM estimated from DXA and ADP. The upper and lower dashed lines represent limits of agreement (± 2 SD from the mean). ●: participants engaged in dietary program, ○: participants engaged in exercise program.

Figure 1

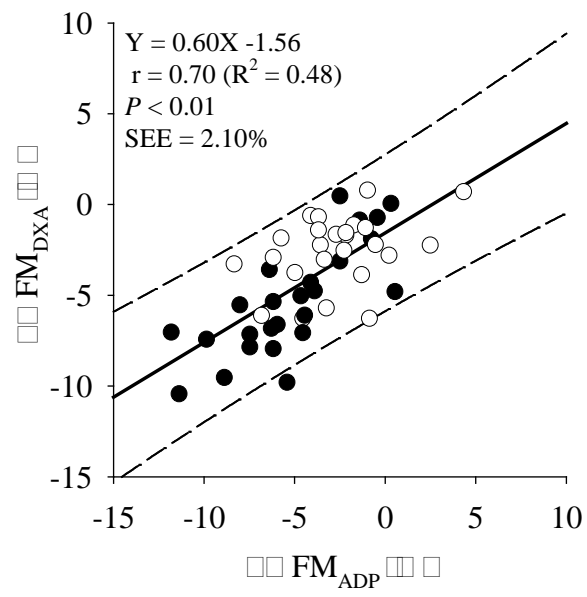


Figure 2

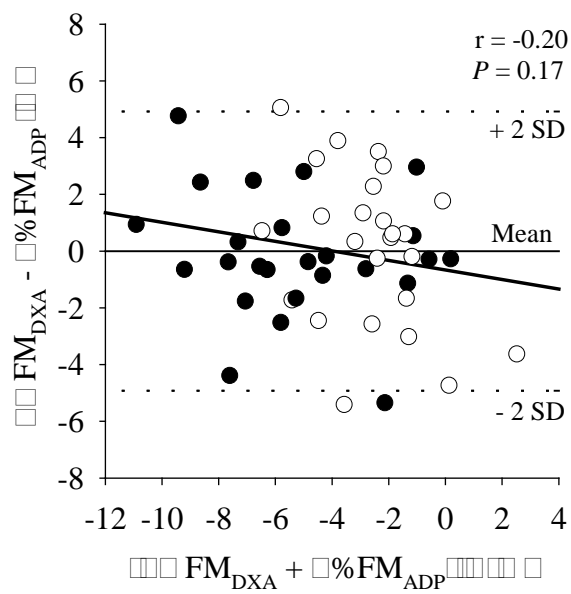


Figure 3

