Eur J Nutr (2013) 52:145–151
DOI 10.1007/s00394-011-0296-y

ORIGINAL CONTRIBUTION

Relationship between the body adiposity index and cardiometabolic risk factors in obese postmenopausal women

Belinda Elisha · Rémi Rabasa-Lhoret · Virginie Messier · Joseph Abdulnour · Antony D. Karelis

Received: 6 September 2011 / Accepted: 19 December 2011 / Published online: 1 January 2012

Abstract
Objective The purpose of the present secondary analysis study was to investigate the ability of the body adiposity index (BAI) to detect changes in % body fat levels before and after a weight loss intervention when compared to % body fat levels measured using dual-energy X-ray absorptiometry (DXA) and to examine the relationship between the BAI with cardiometabolic risk factors.

Methods The study population for this secondary analysis included 132 non-diabetic obese sedentary postmenopausal women (age: 57.2 ± 4.7 years, BMI: 35.0 ± 3.7 kg/m^2) participating in a weight loss intervention that consisted of a calorie-restricted diet with or without resistance training. We measured: (1) visceral fat using CT-scan, (2) body composition using DXA, (3) hip circumference and height from which the BAI was calculated, and (4) cardiometabolic risk factors such as insulin sensitivity (using the hyperinsulinemic-euglycemic clamp), blood pressure as well as fasting plasma lipids, hsC-reactive protein (CRP), leptin, and glucose.
Results Percent body fat levels for both methods significantly decreased after the weight loss intervention. In addition, the percent change in % body fat levels after the weight loss intervention was significantly different between % body fat measured using the DXA and the BAI (-4.5 ± 6.6 vs. $-5.8 \pm 5.9\%$; $p = 0.03$, respectively). However, we observed a good overall agreement between the two methods, as shown by the Bland–Altman analysis, for percent change in % body fat. Furthermore, similar correlations were observed between both measures of % body fat with cardiometabolic risk factors. However, results from the multiple linear regression analysis showed that % body fat using the BAI appeared to predict cardiometabolic risk factors differently than % body fat using the DXA in our cohort.
Conclusions Estimating % body fat using the BAI seems to accurately trace variations of % body fat after weight loss. However, this index showed differences in predicting cardiometabolic risk factors when compared to % body fat measured using DXA.

Keywords Obesity · % body fat · Hip circumference and DXA

B. Elisha · R. Rabasa-Lhoret · A. D. Karelis
Department of Nutrition, Université de Montréal, Montreal, QC, Canada

B. Elisha · R. Rabasa-Lhoret · V. Messier
Institut de Recherches Cliniques de Montréal (IRCM), Montreal, QC, Canada

B. Elisha · R. Rabasa-Lhoret
Montreal Diabetes Research Center (MDRC), Montreal, QC, Canada

R. Rabasa-Lhoret
Endocrinology Division, Centre Hospitalier de l'Université de Montréal (CHUM), Montreal, QC, Canada

J. Abdulnour
School of Human Kinetic, University of Ottawa, Ottawa, ON, Canada

A. D. Karelis (✉)
Department of Kinanthropology, Université du Québec à Montréal, Case postale 8888, Succursale Centre-ville, Montreal, QC H3C 3P8, Canada
e-mail: Karelis.antony@uqam.ca

A. D. Karelis
Institut Universitaire de Gériatrie de Montréal, Montreal, QC, Canada

Introduction

Obesity is widely recognized as an important risk factor for the development of metabolic complications such as insulin resistance, hypertension, and dyslipidemia, which may increase the risk of cardiovascular diseases and type 2 diabetes [8, 9]. The risk of developing obesity-related complications could be proportional to the degree of obesity and more specifically to android fat accumulation [3]. Several methods have been developed to measure % body fat such as the dual-energy X-ray absorptiometry (DXA), which could be considered as the gold-standard method in clinical research [16]. However, this method is expensive and not practical in a clinical routine setting or large epidemiological studies. Bioelectrical impedance analysis is a noninvasive and simple method that has also been used for the measurement of % body fat. However, several studies have reported contradictory results with the accuracy of bioelectrical impedance analysis for the measurement of % body fat with the DXA in adults and children [4–7, 14, 15], and thus health professionals may want to proceed with caution. Finally, the body mass index is routinely used as a clinical marker for the identification of obese subjects; however, this method lacks accuracy for the assessment of % body fat [13, 17, 18]. Therefore, other simple, accurate, and inexpensive methods are needed to estimate body fat percentage for clinical and epidemiological research.

Interestingly, a potential method in estimating body fat percentage using height and hip circumference has been proposed by the study of Bergman et al. [1]. The authors developed the body adiposity index (BAI) using the following equation to determine estimated % body fat: BAI = Hip/Height 1.5–18. In that study, the BAI was shown to be strongly associated with % body fat using DXA ($r = 0.85$; $p < 0.001$) in a population of Mexican-Americans and African-Americans. Moreover, the relationship between % body fat using DXA and the BAI was comparable for men and women. In addition, the BAI offers an additional advantage since the use of body weight is not required, which strengthens the practical use of this index.

However, to our knowledge, the possible association between % body fat, estimated using the BAI, with cardiometabolic risk factors and the ability to detect changes in % body fat by way of weight loss has not been investigated. Such research may give us a better understanding on the potential use of this index to examine health outcomes such as cardiovascular diseases and type 2 diabetes. Therefore, in order to provide additional essential elements supporting the use of this surrogate measure of % body fat, the purpose of the present study was (1) to examine the ability of the BAI to detect changes in % body fat levels before and after a weight loss intervention when compared to % body fat levels measured using a DXA and (2) to determine if both measures of % body fat have comparable associations with cardiometabolic risk factors in a population of sedentary obese postmenopausal women, a group at increased risk for developing metabolic complications.

Methods

Subjects

The present study is a secondary analysis of two 6-month weight loss studies with identical interventions and inclusion criteria [2, 10–12], i.e., the weight loss study from the MONET group ($n = 84$) and the weight loss study from the CAO group ($n = 48$). The study sample consisted of 132 obese postmenopausal women aged between 46 and 69 years old. Out of the 132 subjects, 100 were randomized in the calorie-restricted diet group and 32 in the calorie-restricted diet group with resistance training. The studies were approved by the *Université de Montréal* ethics committee. After reading and signing the consent form, each participant was invited to the Metabolic Unit for a series of tests. Methods for body composition, anthropometrics (hip and waist circumference), visceral fat, blood samples, blood pressure, and insulin sensitivity were determined as previously described [2, 10–12]. Briefly, insulin sensitivity was measured using the hyperinsulinemic-euglycemic clamp technique. A GE High Speed Advantage CT scanner (General Electric Medical Systems, Milwaukee, WI) was used to measure visceral fat content. Serum concentrations of total-cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides, and glucose were analyzed using the COBAS INTEGRA 400 (Roche Diagnostic, Montreal, Canada). Serum levels of high sensitivity C-reactive protein (hsCRP) were assessed by immunonephelometry on IMMAGE analyzer (Beckman-Coulter, Villepinte, France); the inter- and intra-assay variations were below 5%. Serum leptin levels were measured by a commercial radioimmunoassay (Linco Research, St-Charles, MO, USA); the intra- and inter-assay variations were below 10 and 15%, respectively. In addition, weight loss intervention protocols that consisted of a calorie-restricted diet with and without resistance training were performed as previously described [2, 12]. Women were included in the study if they met the following criteria: (1) body mass index of 30 kg/m^2 or more, (2) cessation of menstruation for more than 1 year and a follicle-stimulating hormone level $\geq$30 U/L, and (3) free of known inflammatory disease. On physical examination or biological testing, all participants had no history or evidence of: (1) cardiovascular disease, peripheral vascular

disease, or stroke, (2) diabetes (fasting glucose <7.0 mmol/L and 2-h post 75 g OGTT < 11.1 mmol/L), and (3) medications that could affect cardiovascular function and/or metabolism.

Body fat percentage measurement and estimation

Body composition

Body weight, % body fat, and lean body mass were measured using dual-energy X-ray absorptiometry (General Electric Lunar Corporation version 6.10.019, Madison, USA).

Body adiposity index (BAI)

Percent body fat levels were also estimated using the BAI [1]. This method uses hip circumference (in cm) and height (in m) to estimate % body fat. The authors developed the following equation to determine estimated % body fat: BAI = Hip/Height 1.5–18. In that study, the BAI was shown to be strongly associated with % body fat using DXA ($r = 0.85$; $p < 0.001$). This index was validated in a population of Mexican-Americans (age: 35 years, BMI: 29.5 kg/m^2, % body fat: 33.2%) and African-Americans (age: 35 years, BMI: 30.0 kg/m^2, % body fat: 29.7%).

Statistical analysis

Data are expressed as the mean ± standard deviation. A paired t-test was performed to compare pre and post % body fat values as well as percent change in % body fat between the DXA and the BAI. Pearson correlations were performed to examine the relationship between percent change in % body fat levels and percent change in cardiometabolic risk factors. In addition, a stepwise multilinear regression analysis was performed to identify predictors of percent change in visceral fat, LDL-cholesterol, HDL-cholesterol, triglycerides, insulin sensitivity, blood pressure, hsC-reactive protein (hsCRP), and leptin. Independent variables considered in the final model for all of the previous cardiometabolic risk factors were percent change in % body fat, visceral fat, LDL-cholesterol, HDL-cholesterol, triglycerides, insulin sensitivity, blood pressure, leptin, and hsCRP. It should be noted that we used two separate models for each cardiometabolic risk factor that either included % body fat from the DXA in one model and the BAI in another model as an independent variable. This analysis was performed in order to examine if % body fat using both methods predicted cardiometabolic risk factors similarly. Finally, Bland and Altman analysis was performed to evaluate the extent of agreement between both methods for % body fat. Statistical analysis was performed using SPSS for Windows version 19 (Chicago, IL, USA). Significance was accepted at $p < 0.05$.

Results

Physical and metabolic characteristics of the 132 obese postmenopausal women are presented in Table 1.

There were no differences in % body fat levels between the calorie-restricted group with resistance training and the calorie-restricted only group using both measures of % body fat before and after the weight loss intervention (data not shown). Therefore, we pooled all data from both groups.

Table 2 shows % body fat values of both methods before and after the weight loss intervention. Both % body fat levels measured with the DXA and the BAI significantly decreased after the weight loss intervention. In addition, the percent change in % body fat levels after the weight loss intervention was significantly different between % body fat measured using the DXA and the BAI (−4.6 ± 6.6 vs. −5.8 ± 5.9%; $p = 0.03$, respectively). Moreover, we noted significant differences in % body fat levels between the DXA and the BAI before (48.0 ± 4.0 vs. 41.2 ± 4.9%; $p < 0.001$, respectively) and after

Table 1 Baseline physical and metabolic characteristics of the 132 participants

Variables	Mean ± SD	Range
Age (years)	57.2 ± 4.7	46.0–69.3
Body mass index (kg/m^2)	35.0 ± 3.7	30.0–48.5
Lean body mass (%)	49.1 ± 4.0	39.7–59.8
% Body fat	48.0 ± 4.0	37.6–57.9
Body adiposity index (%)	41.2 ± 4.9	32.0–61.3
Waist circumference (cm)	101 ± 8.2	85.5–117
Hip circumference (cm)	121.1 ± 9.4	105.5–166.5
Visceral fat (cm^2)	206 ± 51	104–346
Insulin sensitivity (mg/min/kg LBM)	11.4 ± 3.4	3.0–22.9
Total-cholesterol (mmol/L)	5.2 ± 0.9	3.1–7.3
LDL-cholesterol (mmol/L)	3.1 ± 0.7	1.4–5.1
HDL-cholesterol (mmol/L)	1.4 ± 0.3	0.9–2.5
Triglycerides (mmol/L)	1.6 ± 0.8	0.5–5.1
Fasting glucose (mmol/L)	5.3 ± 0.5	4.1–6.6
hsC-reactive protein (mg/L)	3.7 ± 2.4	0.4–10.1
Leptin (ng/mL)	26.0 ± 10.4	8.3–71.2
Systolic blood pressure (mmHg)	123 ± 13	93–167
Diastolic blood pressure (mmHg)	77.6 ± 7.6	60–100

Values are mean ± SD

Table 2 Body fat values % before and after the weight loss intervention

	Body fat % (DXA)	% Body fat (BAI)	*p* value (between both methods)
Pre (%) ($n = 131$)	48.0 ± 4.0	41.2 ± 4.9	0.000
Post (%) ($n = 84$)	45.5 ± 5.1*	38.5 ± 5.4*	0.000
Percent change ($n = 84$)	−4.5 ± 6.6	−5.8 ± 5.9	0.03

Values are mean ± SD

* Significantly different between pre values ($p < 0.001$)

Table 3 Bivariate correlations between percent change in % body fat and percent change in cardiometabolic risk factors

Risk factors	Δ % Body fat (DXA)	Δ % Body fat (BAI)
Δ % Body fat (BAI)	0.60**	–
Δ Body mass index	0.59**	0.68**
Δ Waist circumference	0.55**	0.70**
Δ Visceral fat	0.49**	0.47**
Δ % Lean body mass	0.34**	0.30*
Δ Total-cholesterol	0.20	0.13
Δ LDL-cholesterol	0.17	0.12
Δ HDL-cholesterol	−0.04	0.02
Δ Triglycerides	0.17	0.13
Δ Fasting glucose	0.07	0.11
Δ Insulin sensitivity	−0.08	−0.22
Δ hsC-reactive protein	0.22	0.29**
Δ Leptin	0.36**	0.36**
Δ Systolic blood pressure	−0.13	0.05
Δ Diastolic blood pressure	−0.10	0.09

* $p < 0.05$; ** $p < 0.01$

(45.5 ± 5.1 vs. 38.5 ± 5.4%; $p < 0.001$, respectively) the weight loss intervention.

A significant relationship was found between % body fat measured using DXA and % body fat estimated by the BAI at baseline ($r = 0.54$, $p < 0.01$) and after the intervention ($r = 0.59$, $p < 0.01$). Pearson correlation coefficients between the percent change in both measures of % body fat and percent change in cardiometabolic characteristics are presented in Table 3. We noted a significant relationship between percent change in % body fat measured using DXA and percent change in % body fat estimated by the BAI ($r = 0.60$, $p < 0.01$). Both measures of percent change in % body fat were similarly significantly correlated with percent change in BMI, waist circumference, visceral fat, % lean body mass, and leptin. Furthermore, no associations were observed between both measures of percent change in % body fat with percent change in total-cholesterol, LDL-cholesterol, triglycerides, fasting glucose, insulin sensitivity, and blood pressure. Finally, the only correlation that varied between both measures in % body fat was with hsCRP.

We performed a stepwise regression analysis to identify independent predictors of percent change in cardiometabolic risk factors (Table 4). Our results show that the change in % body fat using the BAI predicted cardiometabolic risk factors differently than the change in % body fat using the DXA in our cohort. That is, the percent change in BAI was an independent predictor of the percent change in insulin sensitivity and hsCRP whereas the percent change in % body fat using the DXA did not predict the change in insulin sensitivity and hsCRP. Furthermore, independent predictors for the percent change in visceral fat, LDL-cholesterol, and triglycerides were different when the BAI or % body fat using the DXA were interchanged as an independent variable in the model. In contrast, both methods in % body fat predicted leptin similarly.

Finally, Bland–Altman plots were used to show the mean overall differences and limits of agreement between the DXA and the BAI for pre and post as well as percent change in % body fat (Fig. 1a–c). The *x*-axis indicates the mean of the results of the two methods, whereas the *y*-axis represents the differences of the two methods. The overall mean difference was 6.8 ± 4.3 for pre % body fat, 6.9 ± 4.8 for post % body fat, and −1.4 ± 5.6 for percent change in % body fat. Furthermore, Bland–Altman analysis showed a bias for pre % body fat and no biases for post % body fat and percent change in % body fat.

Discussion

It is important in clinical research to develop simple and accurate methods for the measurement of % body fat. Thus, the purpose of the present study was to investigate the ability of the BAI to detect changes in % body fat levels before and after a weight loss intervention when compared to % body fat levels measured using a DXA. We also examined the relationship between measured or estimated % body fat with cardiometabolic risk factors. Such data could be essential to establish the validity of this surrogate measure for routine clinical and practical use in research protocols as well as in epidemiological studies.

The present study extends the findings of Bergman et al. [1] by examining the ability of this index to detect changes in % body fat before and after a weight loss intervention and by exploring its relationship with cardiometabolic risk factors. Our results showed that % body fat values at baseline were underestimated with the BAI compared to %

Table 4 Stepwise linear regression analysis regarding independent predictors of cardiometabolic risk factors

Dependent variable	Step	Independent variable	Partial r^2	Total r^2 cumulative	Beta-coefficients	p value
Δ Insulin sensitivity	1	Δ Visceral fat	0.07	0.07	−0.27	0.03
Δ Insulin sensitivity*	1	Δ BAI	0.08	0.08	−0.29	0.02
Δ Visceral fat	1	Δ % Body fat	0.307	0.307	0.56	<0.01
	2	Δ Blood pressure	0.084	0.391	0.27	0.04
	3	Δ Triglycerides	0.035	0.426	0.19	0.05
Δ Visceral fat*	1	Δ BAI	0.256	0.256	0.51	<0.01
Δ LDL-cholesterol	1	Δ Triglycerides	0.08	0.08	0.28	0.02
Δ LDL-cholesterol*	1	Δ Leptin	0.078	0.078	0.28	0.02
Δ Triglycerides	1	Δ Visceral fat	0.086	0.086	0.26	0.03
	2	Δ LDL-cholesterol	0.059	0.145	0.25	0.03
Δ Triglycerides*	1	Δ Leptin	0.098	0.098	0.31	0.03
Δ hsCRP	1	Δ Leptin	0.074	0.074	0.27	0.02
Δ hsCRP*	1	Δ BAI	0.09	0.09	0.31	0.02
Δ Leptin	1	Δ % Body fat	0.161	0.161	0.37	<0.01
	2	Δ Triglycerides	0.049	0.210	0.22	0.04
Δ Leptin*	1	Δ BAI	0.140	0.140	0.33	<0.01
	2	Δ Triglycerides	0.065	0.205	0.26	0.03

* The BAI was used as an independent variable instead of % body fat from the DXA

body fat values using DXA as shown by the Bland–Altman analysis. However, we observed a good overall agreement between the two methods for post % body fat and percent change in % body fat. This suggests that the bias seems to decrease after a weight loss intervention. Moreover, similar relationships (significant or non-significant) were observed between both measures of % body fat with cardiometabolic risk factors. For example, we found comparable correlations between percent change for both measures of % body fat with percent change in BMI, waist circumference, visceral fat, % lean body mass, and leptin. Finally, results from the multiple linear regression analysis showed that % body fat using the BAI predicted cardiometabolic risk factors differently than % body fat using the DXA in our cohort.

Collectively, these results suggest that the BAI may lack accuracy in measuring % body fat before a weight loss intervention. This may be due to a lower correlation observed between the BAI and DXA in the present study ($r = 0.54$) compared to the study of Bergman et al. [1] ($r = 0.85$). Furthermore, the population of the present study was composed of only Caucasian obese postmenopausal women whereas the study of Bergman et al. [1] was composed of Mexican-Americans and African-Americans. Therefore, the present results may be explained, at least in part, by the differences in ethnicities used in both studies. Additional research on the precision of this index may be needed in other populations. However, this index appears to have a good ability to detect changes in % body fat after weight loss. Finally, this index showed inconsistencies to predict cardiometabolic risk factors compared to % body fat measured with DXA in our cohort of obese postmenopausal women.

This study has several limitations. Our findings are limited to a cohort composed of Caucasian non-diabetic sedentary obese postmenopausal women who participated in a university-based research weight loss program. Further research of this index should be performed in other populations. However, our results are strengthened by the use of pre and post weight loss data as well as the use of gold-standard techniques to measure body composition, visceral fat, insulin sensitivity, and blood profile in a relatively large sample size of well-characterized obese postmenopausal women.

In conclusion, the BAI seems to underestimate % body fat levels at baseline in Caucasian obese postmenopausal women. Furthermore, changes in % body fat after a weight loss intervention appeared to be well detected with this index. Finally, this index showed differences in predicting cardiometabolic risk factors when compared to % body fat measured using DXA. Further research in obese postmenopausal women may be needed to support the usefulness of this index for the surrogate measure of % body fat in clinical research.

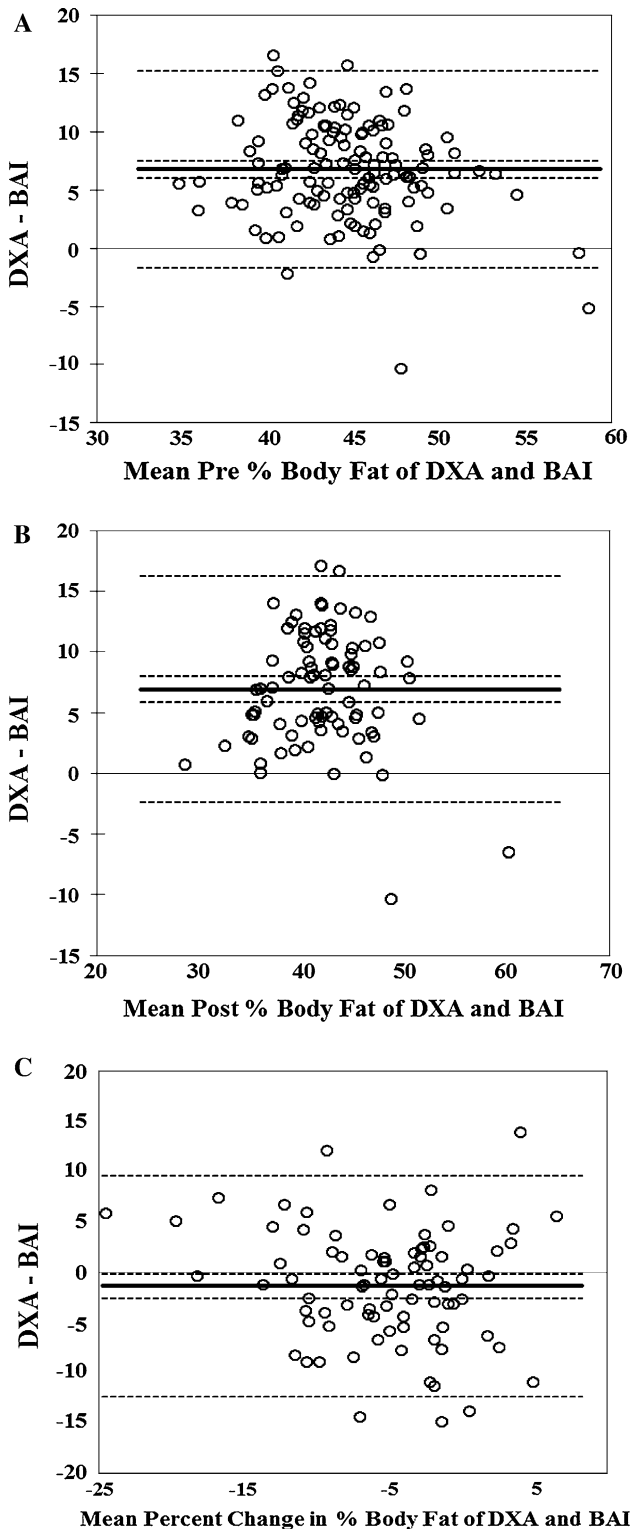

Fig. 1 **a** Limits of agreement between the DXA and the BAI for pre % body fat ($r = -0.21$, $p = 0.01$); **b** post % body fat ($r = -0.06$, $p = 0.58$); and **c** percent change in % body fat ($r = -0.15$, $p = 0.19$). *Solid line* represents the mean difference

Acknowledgments This manuscript was supported by CIHR (Canadian Institute for Health Research) grants: 63279 MONET study (Montreal Ottawa New Emerging Team) and 88590 SOMET study (Sherbrooke Montreal Ottawa Emerging Team) as well as the J-A DeSève chair for clinical research to RRL. RRL and AK hold scholarships from the *Fonds de Recherche en Santé du Québec*. BE holds a Vanier scholarship from the CIHR.

Conflict of interest The authors declare no conflict of interest.

References

1. Bergman RN, Stefanovski D, Buchanan TA, Sumner AE, Reynolds JC, Sebring NG, Xiang AH, Watanabe RM (2011) A better index of body adiposity. Obesity (Silver Spring) 19:1083–1089. doi:10.1038/oby.2011.38
2. Brochu M, Malita MF, Messier V, Doucet E, Strychar I, Lavoie JM, Prud'homme D, Rabasa-Lhoret R (2009) Resistance training does not contribute to improving the metabolic profile after a 6-month weight loss program in overweight and obese postmenopausal women. J Clin Endocrinol Metab 94:3226–3233. doi:10.1210/jc.2008-2706
3. Despres JP, Lemieux I, Bergeron J, Pibarot P, Mathieu P, Larose E, Rodes-Cabau J, Bertrand OF, Poirier P (2008) Abdominal obesity and the metabolic syndrome: contribution to global cardiometabolic risk. Arterioscler Thromb Vasc Biol 28:1039–1049. doi:10.1161/ATVBAHA.107.159228
4. Gibson AL, Holmes JC, Desautels RL, Edmonds LB, Nuudi L (2008) Ability of new octapolar bioimpedance spectroscopy analyzers to predict 4-component-model percentage body fat in Hispanic, black, and white adults. Am J Clin Nutr 87:332–338
5. Haroun D, Taylor SJ, Viner RM, Hayward RS, Darch TS, Eaton S, Cole TJ, Wells JC (2010) Validation of bioelectrical impedance analysis in adolescents across different ethnic groups. Obesity (Silver Spring) 18:1252–1259. doi:10.1038/oby.2009.344
6. Jaffrin MY (2009) Body composition determination by bioimpedance: an update. Curr Opin Clin Nutr Metab Care 12:482–486. doi:10.1097/MCO.0b013e32832da22c
7. Jensky-Squires NE, Dieli-Conwright CM, Rossuello A, Erceg DN, McCauley S, Schroeder ET (2008) Validity and reliability of body composition analysers in children and adults. Br J Nutr 100:859–865. doi:10.1017/S0007114508925460
8. Katzmarzyk PT, Gagnon J, Leon AS, Skinner JS, Wilmore JH, Rao DC, Bouchard C (2001) Fitness, fatness, and estimated coronary heart disease risk: the HERITAGE family study. Med Sci Sports Exerc 33:585–590
9. Lau DC, Douketis JD, Morrison KM, Hramiak IM, Sharma AM, Ur E (2007) 2006 Canadian clinical practice guidelines on the management and prevention of obesity in adults and children (summary). CMAJ 176:S1–13. doi:10.1503/cmaj.061409
10. Lavoie ME, Rabasa-Lhoret R, Doucet E, Mignault D, Messier L, Bastard JP, Faraj M (2010) Association between physical activity energy expenditure and inflammatory markers in sedentary overweight and obese women. Int J Obes (Lond) 34:1387–1395. doi:10.1038/ijo.2010.55
11. Messier V, Karelis AD, Prud'homme D, Primeau V, Brochu M, Rabasa-Lhoret R (2010) Identifying metabolically healthy but obese individuals in sedentary postmenopausal women. Obesity (Silver Spring) 18:911–917. doi:10.1038/oby.2009.364
12. Messier V, Rabasa-Lhoret R, Doucet E, Brochu M, Lavoie JM, Karelis A, Prud'homme D, Strychar I (2010) Effects of the addition of a resistance training programme to a caloric restriction weight loss intervention on psychosocial factors in overweight and obese post-menopausal women: a Montreal Ottawa new emerging team study. J Sports Sci 28:83–92. doi:10.1080/02640410903390105

13. Okorodudu DO, Jumean MF, Montori VM, Romero-Corral A, Somers VK, Erwin PJ, Lopez-Jimenez F (2010) Diagnostic performance of body mass index to identify obesity as defined by body adiposity: a systematic review and meta-analysis. Int J Obes (Lond) 34:791–799. doi:10.1038/ijo.2010.5
14. Pateyjohns IR, Brinkworth GD, Buckley JD, Noakes M, Clifton PM (2006) Comparison of three bioelectrical impedance methods with DXA in overweight and obese men. Obesity (Silver Spring) 14:2064–2070. doi:10.1038/oby.2006.241
15. Pietrobelli A, Rubiano F, St-Onge MP, Heymsfield SB (2004) New bioimpedance analysis system: improved phenotyping with whole-body analysis. Eur J Clin Nutr 58:1479–1484. doi:10.1038/sj.ejcn.1601993
16. Plank LD (2005) Dual-energy X-ray absorptiometry and body composition. Curr Opin Clin Nutr Metab Care 8:305–309. doi:00075197-200505000-00011
17. Romero-Corral A, Somers VK, Sierra-Johnson J, Jensen MD, Thomas RJ, Squires RW, Allison TG, Korinek J, Lopez-Jimenez F (2007) Diagnostic performance of body mass index to detect obesity in patients with coronary artery disease. Eur Heart J 28:2087–2093. doi:10.1093/eurheartj/ehm243
18. Romero-Corral A, Somers VK, Sierra-Johnson J, Thomas RJ, Collazo-Clavell ML, Korinek J, Allison TG, Batsis JA, Sert-Kuniyoshi FH, Lopez-Jimenez F (2008) Accuracy of body mass index in diagnosing obesity in the adult general population. Int J Obes (Lond) 32:959–966. doi:10.1038/ijo.2008.11