Validity of self-reported anthropometry in adult Mexican women

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Abstract

Objective. To compare direct and self-reported anthropometry in Mexican women. **Materials and methods.** Women aged 30-72 years, participating in the Mexican Teachers' Cohort, completed a questionnaire with their anthropometric data in 2006-2008. After eleven months (median time), technicians performed anthropometry in 3 756 participants. We calculated correlations and multivariable-adjusted mean differences between direct and self-reported anthropometric measures. **Results.** Correlations between direct and self-reported anthropometric measures ranged from 0.78 (waist circumference) to 0.93 (weight). On average, women over-reported their height by 2.2 cm and underreported their weight, body mass index (BMI) and waist and hip circumferences by 1.3 kg, 1.3 kg/m^2, 1.8 cm and 1.9 cm, respectively. Errors in self-reported anthropometry increased with rising measured BMI and were also independently associated with age, education and socioeconomic status. **Conclusion.** Self-reported anthropometry is sufficiently valid for epidemiological purposes in adult Mexican women. Errors in self-reported anthropometry might result in underestimation of the prevalence of overweight and obesity.

Keywords: validity of tests; anthropometry; self report; women; Mexico

Ortiz-Panozo E, Yunes-Díaz E, Lajous M, Romieu I, Monge A, López-Ridaura R. Validez de la antropometría autorreportada en mujeres mexicanas adultas. Salud Publica Mex 2017;59:266-275.
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Resumen

Objetivo. Comparar antropometría directa y autorreportada en mujeres mexicanas. **Material y métodos.** Participantes de la cohorte ESMaestras completaron un cuestionario con sus datos antropométricos en 2006-2008. Once meses después (tiempo mediano), técnicos realizaron antropometría (n=3 756). Se calcularon correlaciones y diferencias de medias ajustadas entre medidas antropométricas directas y autorreportadas. **Resultados.** Las correlaciones entre medidas antropométricas directas y autorreportadas variaron entre 0.78 (circunferencia de cintura) y 0.93 (peso). En promedio, las mujeres sobrerreportaron su estatura en 2.2 cm y subreportaron su peso, índice de masa corporal (IMC) y circunferencias de cintura y cadera en 1.3 kg, 1.3 kg/m^2, 1.8 cm y 1.9 cm, respectivamente. Los errores en la antropometría autorreportada se incrementaron a mayor IMC medido y se asociaron de manera independiente con edad, escolaridad y nivel socioeconómico. **Conclusión.** La antropometría autorreportada es suficientemente válida para fines epidemiológicos en mujeres mexicanas. Los errores en la antropometría autorreportada podrían originar subestimación de la prevalencia de sobrepeso y obesidad.

Palabras clave: validez de las pruebas; antropometría; autoinforme; mujeres; México

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Anthropometric measurements are crucial for nutritional and chronic disease epidemiology. However, in large-scale population-based studies direct anthropometry is not logistically feasible, and researchers must rely on self-reported anthropometry. Correlations between direct and self-reported height and weight are usually high (over 0.9),[1-3] however systematic errors of self-reported anthropometry may result in an underestimation of the prevalence of obesity,[1-5] residual confounding after adjusting for an imperfect measure,[6] and depending on their predictors, bias on the causal associations between anthropometric indicators and disease incidence.[7] The magnitude of such errors and their associated factors differ across populations and settings.[4] In addition, the validity of waist and hip circumferences have seldom been evaluated, resulting in lower correlations between self-reported and direct measurements (ranging from 0.62 to 0.89).[2,5,8,9]

The Mexican Teachers' Cohort (MTC), also known as ESMaestras (Spanish acronym), is an ongoing prospective study aimed at evaluating the relationship of dietary and lifestyle factors and chronic diseases. As the largest cohort study in Latin-America and among Hispanics, the MTC offers a unique sample from which to assess the validity of self-reported anthropometry among Mexican women due to its large sample size, wide age range (25 to 84 years at enrollment) and the economically and culturally diverse origin of participants.

Given the multiple and central causal role of adiposity on the development of many chronic diseases, understanding the validity of self-reported anthropometry and the main factors associated with its measurement error is critical for a comprehensive evaluation of the relationship of risk factors and chronic disease, not only within the MTC but also in other observational studies in similar populations that rely on self-reported anthropometry. Therefore, our primary objective was to compare self-reported anthropometric data with direct measures performed by standardized personnel in a subsample of 3 756 female participants of the MTC.

Materials and methods

Study population and analytical sample

We included participants from the MTC in our cross-sectional study. The MTC is a cohort study of 115 315 female Mexican teachers 25 years and older from twelve economically and culturally diverse states in Mexico. Participant selection, distribution of instruments and data collection procedures for the MTC has been previously described.[10] Briefly, between 2006 and 2008, eligible female teachers were identified through an administrative database. A baseline self-administered questionnaire was distributed to assess socio-demographic and reproductive characteristics, diet, lifestyle, risk factors for chronic diseases and medical conditions. Between 2007 and 2010, 3 913 study participants from four study sites (Hidalgo, Jalisco, Mexico City and Veracruz) underwent a clinical evaluation. These women were a random sample of cohort participants living in a 30 km radius from clinical sites stratified by menopausal status.

All women with a baseline questionnaire who participated in a clinical evaluation were eligible for this analysis. We excluded participants for whom all measured (n=80), or self-reported (n=70) anthropometry or both (n=7) were unavailable. The final analytical sample included 3 756 female teachers, who had direct and self-reported anthropometric data on either weight and height (n=3 413) or waist and hip circumferences (n=3 258). The median time from self-reported to direct anthropometric measures was 11 months (inter-quartile range 7-15).

This study was approved by the Research, Biosafety and Ethics Committees at the National Institute of Public Health, Mexico. All participants gave written informed consent.

Anthropometric measures

Self-report

Participants reported their weight (kg), height (cm), waist circumference (cm), and hip circumference (cm) on the baseline questionnaire. They received a plastic measuring tape (commercially available) and instructions to measure their own waist and hip circumferences.

Direct measures

Anthropometry was performed by experienced personnel, previously standardized following Lohman's guidelines.[11] Participants were barefoot and wearing light clothing. Weight was measured to the nearest 0.1 kg with a digital scale (Tanita Corp., Japan), and height to the nearest 0.1 cm with a stadiometer (Seca Corp., Hanover, MD). Waist and hip circumferences were measured standing, to the nearest 0.1 cm, using a plastic measuring tape (commercially available): waist at the midway between the lowest rib and the iliac crest, and hip at the maximum circumference of the buttocks.

Table I
Sociodemographic characteristics of the 3 756 women included[a] in the analysis. The Mexican Teachers' Cohort, 2007-2010

Characteristic	*N*	*%*
Age at self-report, years		
30-39	685	18.2
40-44	1 109	29.6
45-49	954	25.4
50-72	1 008	26.8
Marital status		
Single	612	16.3
Married or with a partner	2 474	65.9
Divorced or separated	512	13.6
Widowed	112	3.0
Unknown	46	1.2
Indigenous language spoken (parent or self)		
No	3 367	89.6
Yes	351	9.4
Unknown	38	1.0
Rurality		
Teaches at an urban school	3 202	85.3
Teaches at a rural school	554	14.7
Education		
Less than university degree	354	9.4
Bachelor's degree	2 101	55.9
Graduate	353	9.4
Unknown	948	25.3
Number of durable assets		
0-4	1 200	31.9
5	708	18.9
6-7	1 433	38.2
Unknown	415	11.0
Study area		
Mexico City	879	23.4
Hidalgo	1 021	27.2
Jalisco	903	24.0
Veracruz	953	25.4
Time between self-reported and direct measures, months		
2-6	763	20.3
7-12	1 450	38.6
13-19	1 543	41.1

a Complete information (self-reported and direct measures) in weight and height or waist and hip circumferences

Statistical analysis

Body mass index (BMI) was calculated for direct and self-reported measures, and participants were categorized as normal weight (<24.9 kg/m^2), overweight (25.0 to 29.9 kg/m^2) and obesity (≥30.0 kg/m^2).[12,13] The linear relationship between direct and self-reported anthropometric measures was assessed by Pearson correlation coefficients and their 95%CI and graphically explored in scatterplots where regression lines and 95% prediction limits were added. To explore non-linear relations between direct and self-reported anthropometry, regression specification error (RESET) tests were performed, the gain in R^2 from including higher-order terms to the linear models was calculated and locally weighted regression (lowess) curves were fitted.

Errors in self-reported anthropometry were estimated by calculating mean differences of direct minus self-reported measures and their 95%CI. Positive values in that difference indicate underreporting, and negative values, over-reporting. Errors in self-reported anthropometry were further explored using Bland-Altman plots.[14] Predicted mean differences and 95% limits of agreement as well as lowess curves were added to the plots. To explore whether the magnitude of the errors in self-reported anthropometry depend on the actual measurement, the null hypothesis that the slope of regression line in the Bland-Altman plot is zero was tested. To identify factors associated with errors in self-reported anthropometry, mean differences of direct minus self-reported measures were adjusted by: age (30 to 39, 40 to 44, 45 to 49 and 50 to 72 years); marital status (single, married or with a partner, divorced or separated, widowed and unknown); indigenous language spoken (yes, no, unknown); rurality (teaching at a rural/urban school); education (less than university degree, bachelor's degree, graduate and unknown); number of durable assets at home: phone, car, computer, vacuum cleaner, microwave oven, mobile and internet access, categorized as 0 to 4, 5 (median), 6 to 7 assets and unknown; study site; time between direct and self-reported measures; and measured BMI categories. Multiple linear regression models with dummy variables for the unknown categories were used to estimate the multivariate-adjusted mean differences. To calculate P_{trend} in ordinal variables with the unknown category, values of that category were imputed to their respective marginal median.

Misclassification that resulted from using self-reported data was explored by comparing the prevalence of overweight or obesity, obesity and abdominal obesity (waist circumference≥88 cm) as derived from direct and self-reported measures.[12,13,15] Also, using direct measures as the gold standard, sensitivity and specificity of self-reported anthropometry and their 95%CI were calculated.

In a sensitivity analysis, in order to attenuate the effect of extreme values, all analyses were repeated in a subsample defined as the 90% central of the distribution of the errors of self-reported anthropometry for each anthropometric measure. To explore the potential misspecification of regression models including variables with the unknown category, complete-case analysis was conducted.

All analyses were performed with the statistical software Stata/SE 13.1.* The level of significance was 5%, two-tailed.

Results

Socio-demographic characteristics of participants are shown in table I. The median (interquartile range) age at baseline questionnaire was 45 (41, 50) years. Most participants were married (65.9%). On average, 9.4% spoke an indigenous language and had a university education. With the exception of median age (45 *vs.* 44) and the percentage of teachers who taught in a rural school (14.7 *vs.* 25%), socio-demographic characteristics of participants included in this analysis had a similar distribution to that observed for all MTC participants.

Table II includes the correlations and mean differences between direct and self-reported measures. Pearson correlation coefficients between direct and self-reported measures were above 0.80 for all anthropometric measures, excepting waist circumference (r=0.78). The linear fit of the relationship between direct and self-reported measures showed slopes ranging from 0.79 to 1.00 and R^2 from 61 to 87% for waist circumference and weight, respectively (figure 1). RESET tests indicated that for all anthropometric measures the linear approximation was not the correctly specified. However, only a marginal gain (ranging from 0.0 to 2.2 percent points) in R^2 from including quadratic or cubic terms in the linear model was found for all anthropometric measures. Accordingly, in lowess curves, mild deviations from linearity (larger errors of self-report) were observed in the lowest values of waist and hip circumferences and in both extremes of the distribution of height (figure 1).

Mean differences (95%CI) of direct minus self-reported measures were 1.3 (1.2, 1.5) kg for weight; -2.2 (-2.3, -2.1) cm for height; 1.3 (1.3, 1.4) kg/m^2 for BMI; 1.8 (1.5, 2.0) cm for waist circumference; and 1.9 (1.7, 2.1) cm for hip circumference. Bland-Altman analysis further supported those results and showed that slopes of regression lines were close to zero for all anthropometric measures, except BMI (β_1=0.12), suggesting that proportional bias would be an important issue only for BMI. Lowess curves in general confirmed the results from linear fit (figure 1).

In table III multivariable-adjusted mean differences of direct minus self-reported measures according to participant's characteristics are shown. Age was directly associated with over-reporting of height and inversely associated with underreporting of weight, BMI and hip circumference (all $P_{trend}\leq 0.01$). Mean differences of direct minus self-reported anthropometric measures were smaller in indigenous language speakers than in non-speakers; however differences were statistically significant only for waist circumference. Over-reporting of height was larger in women teaching at a rural school than in those teaching at an urban school. Education and number of durable assets were directly associated

* StataCorp., TX, USA

Table II

Mean differences and Pearson correlation coefficients between direct and self-reported anthropometric measures. The Mexican Teachers' Cohort, 2007-2010

Anthropometric measure	*n*	*Direct*		*Self-report*		*Difference**‡		*Correlation*	
		Mean	*SD*	*Mean*	*SD*	*Mean*	*95%CI*	*r*	*95%CI*
Weight, kg	3 413	68.8	12.7	67.5	11.9	1.3	1.2 - 1.5	0.93	0.93-0.94
Height, cm	3 413	154.9	6.0	157.0	6.3	-2.2	-2.3 - -2.1	0.84	0.83-0.85
BMI, kg/m^2	3 413	28.7	5.0	27.4	4.5	1.3	1.3 - 1.4	0.89	0.88-0.90
Waist circumference, cm	3 258	90.6	10.9	88.9	10.8	1.8	1.5 - 2.0	0.78	0.77-0.79
Hip circumference, cm	3 258	105.5	10.2	103.6	10.4	1.9	1.7 - 2.1	0.83	0.82-0.84

* Difference was calculated as direct minus self-reported measures. Positive values indicate underreporting and negative values indicate over-reporting
‡ Due to rounding error, some mean differences do not match with the difference of the means shown in the table

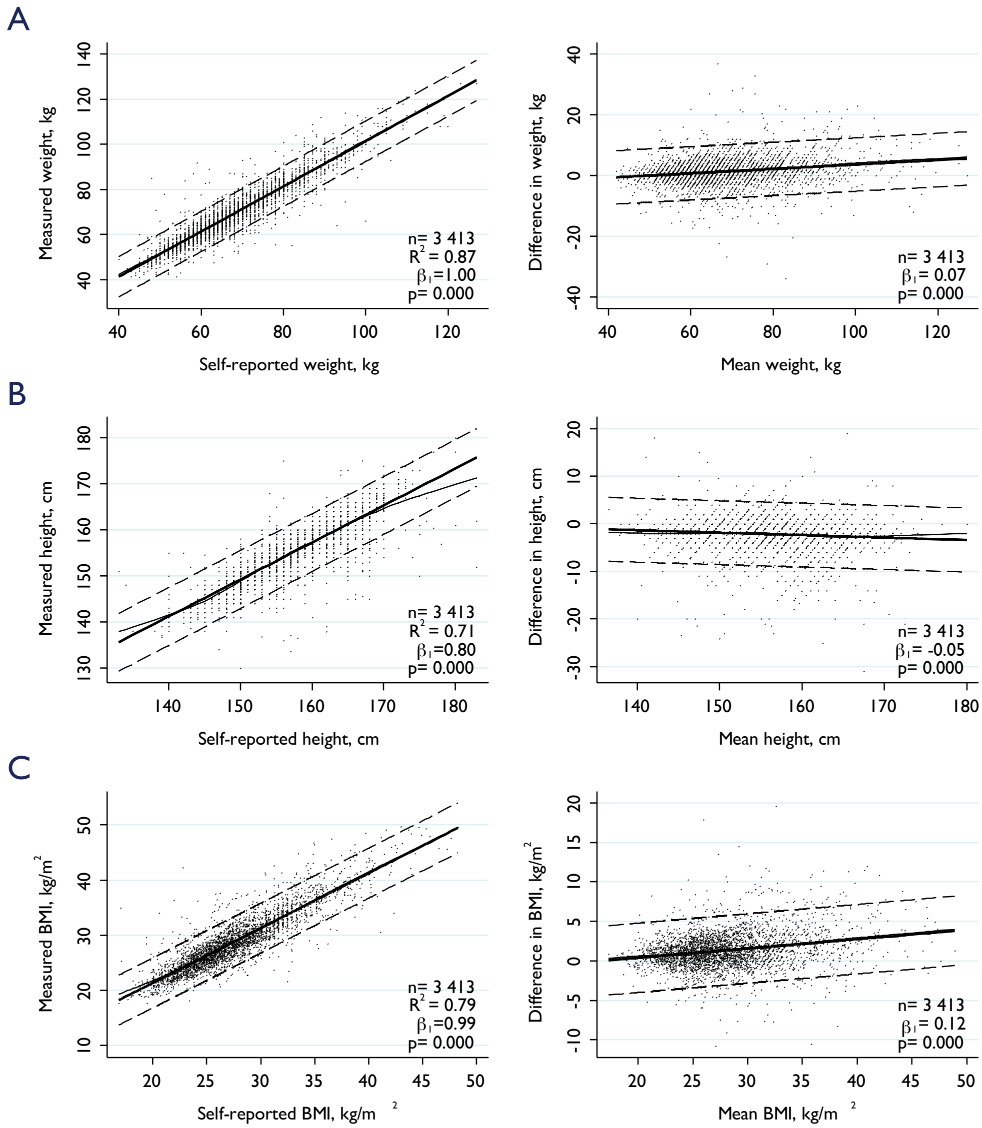

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Figure 1. Plots comparing direct and self-reported anthropometric measures. A: weight, B: height, C: BMI, D: waist circumference, E: hip circumference (see next page for D and E). Left: Linear regression analysis comparing direct vs. self-reported measures. Thick solid line, fitted linear model; dashed lines, 95% prediction limits; thin solid line, locally weighted regression (lowess) curve. Right: Bland-Altman plots comparing differences of direct minus self-reported measures vs. their average. Thick solid line, fitted linear model; dashed lines, 95% limits of agreement; thin solid line, lowess curve. Circ., circumference

with underreporting of weight (P_{trend}<0.01) and waist circumference (P_{trend}<0.05). Women with increasing number of durable assets showed larger underreporting of hip circumference (P_{trend}=0.02). Time between direct and self-reported measures was inversely associated with over-reporting of height (P_{trend}<0.001) and BMI (P_{trend}=0.02), and directly but not statistically significant with underreporting of waist circumference (P_{trend}=0.11). Women who were overweight and obese, according to measured BMI, showed larger differences between di-

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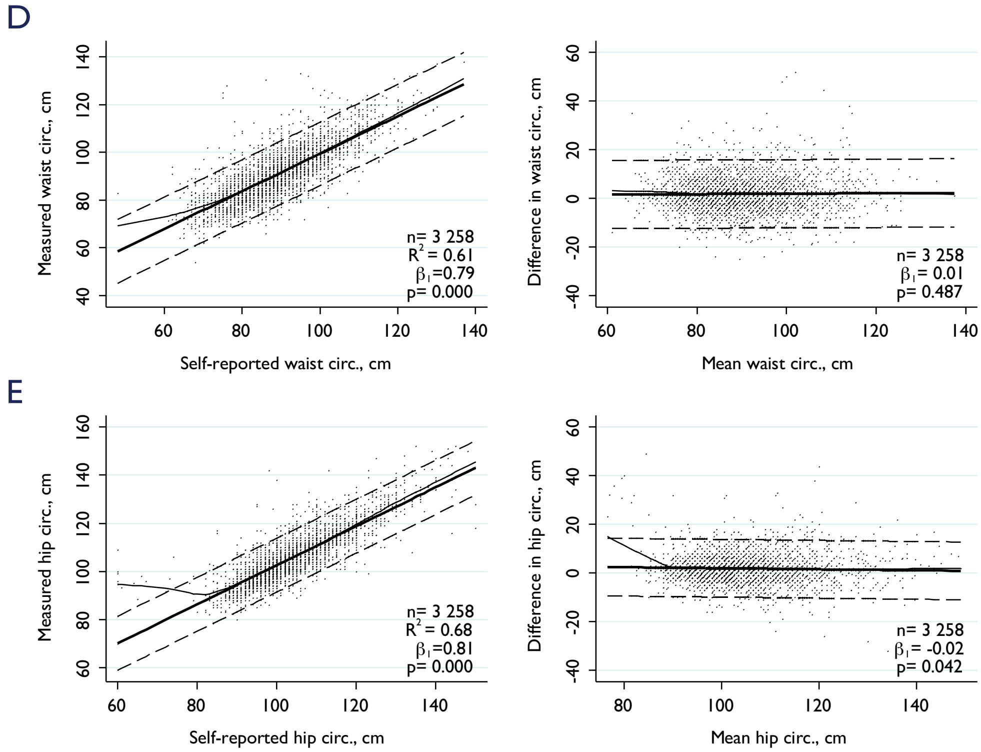

Figure 1. (See previous page for caption)

rect and self-reported measures (all P_{trend}<0.001, except hip circumference, P_{trend}=0.02).

Prevalence of overweight and obesity estimated with direct and self-reported measures, as well as sensitivity and specificity of self-reported anthropometry, are shown in table IV. Compared to the prevalence of obesity calculated by direct measures, the prevalence of obesity with self-reported data was nine percentage points lower (33.2 vs. 24.1%). Sensitivity and specificity of self-reported obesity and abdominal obesity were 66.5 and 97.0%, and 77.4 and 81.2%, respectively.

In sensitivity analyses, although magnitude of differences and statistical significance were attenuated, findings were similar to the main analysis. Noteworthy, in complete-case analysis, the inverse relationship between age and underreporting of BMI turned non-significant.

Discussion

This study showed a strong linear relationship between measured and self-reported anthropometry in female participants of the MTC, which implies that women are ranked similarly with either measure. However, systematic errors in self-reported anthropometry were identified, namely over-reporting of height and underreporting of weight, BMI, and waist and hip circumferences. Several characteristics of the participants such as age, education and socioeconomic status were associated with those errors –the main predictor being the measured BMI, as over-reporting of height and underreporting of the remaining anthropometric measures increased with rising BMI. Systematic errors in self-reported anthropometry resulted also in lower estimates of the prevalence of overweight and obesity, compared to estimates derived from direct measures.

Correlations between direct and self-reported measures were higher for weight, height and BMI (0.93, 0.84 and 0.89, respectively) than for waist and hip circumferences (0.78 and 0.83, respectively). This was similar to other studies which showed correlations ranging from 0.95 to 0.97 for weight, 0.91 to 0.98 for height, 0.92 to 0.97 for BMI, 0.74 to 0.89 for waist circumference and 0.62 to

Table III
Multivariate-adjusted mean differences* between direct and self-reported anthropometric measures by participant characteristics. The Mexican Teachers' Cohort, 2007-2010

Characteristic	Weight, kg n=3 413		Height, cm n=3 413		BMI, kg/m² n=3 413		Waist circ., cm n=3 157		Hip circ., cm n=3 157	
	AM	SE	AM	SE	AM	SE	AM	SE	AM	SE
Age at self-report, years										
30-39	1.8	0.2	-2.0	0.1	1.4	0.1	1.8	0.3	2.1	0.2
40-44	1.6	0.1	-2.1	0.1	1.4	0.1	1.8	0.2	2.2	0.2
45-49	1.3‡	0.1	-2.2	0.1	1.3	0.1	1.9	0.3	1.7	0.2
50-72	0.7#	0.1	-2.4‡	0.1	1.2‡	0.1	1.5	0.3	1.4‡	0.2
P_{trend}	<0.001		0.01		0.01		0.42		<0.01	
Marital status										
Single	1.5	0.2	-2.0	0.1	1.4	0.1	1.6	0.3	2.3	0.3
Married or with a partner	1.3	0.1	-2.2	0.1	1.3	0.0	1.8	0.2	1.8	0.1
Divorced or separated	1.2	0.2	-2.5‡	0.2	1.4	0.1	1.7	0.3	1.6	0.3
Widowed	1.6	0.4	-2.2	0.3	1.5	0.2	2.1	0.8	2.5	0.6
Indigenous language spoken parent or self										
No	1.4	0.1	-2.2	0.1	1.4	0.0	1.9	0.1	1.9	0.1
Yes	1.0	0.3	-2.0	0.2	1.1	0.1	0.8‡	0.4	1.5	0.4
Rurality										
Teaches at an urban school	1.4	0.1	-2.1	0.1	1.3	0.0	1.8	0.1	1.9	0.1
Teaches at a rural school	1.2	0.2	-2.5‡	0.2	1.4	0.1	1.5	0.4	1.7	0.3
Education										
Less than university degree	0.9	0.2	-2.3	0.2	1.2	0.1	1.2	0.4	1.3	0.3
Bachelor's degree	1.2	0.1	-2.1	0.1	1.3	0.0	1.6	0.2	1.9	0.1
Graduate	1.9§	0.2	-2.1	0.2	1.5‡	0.1	2.6‡	0.4	1.9	0.3
P_{trend}	<0.01		0.5		0.05		0.04		0.14	
Number of durable assets										
0-4	1.2	0.1	-2.4	0.1	1.3	0.1	1.4	0.2	1.7	0.2
5	0.9	0.2	-2.1	0.1	1.1	0.1	1.5	0.3	1.5	0.2
6-7	1.7§	0.1	-2.1	0.1	1.5	0.1	2.3§	0.2	2.3‡	0.2
P_{trend}	<0.01		0.11		0.14		<0.01		0.02	
Study area										
Mexico City	1.3	0.2	-2.4	0.2	1.4	0.1	0.7	0.3	1.3	0.3
Hidalgo	1.1	0.2	-2.2	0.1	1.2	0.1	0.9	0.3	1.6	0.2
Jalisco	1.2	0.2	-2.8	0.1	1.5	0.1	3.0#	0.3	1.7	0.2
Veracruz	1.8	0.3	-1.4§	0.2	1.2	0.1	2.7§	0.4	3.1§	0.4
Time between self-reported and direct measures, months										
2-6	1.1	0.3	-3.5	0.2	1.7	0.1	1.2	0.5	2.6	0.4
7-12	1.4	0.1	-2.1#	0.1	1.3‡	0.1	1.6	0.2	1.6‡	0.2
13-19	1.4	0.2	-1.6#	0.1	1.2§	0.1	2.1	0.2	1.9	0.2
P_{trend}	0.59		<0.001		0.02		0.11		0.94	
BMI categories										
Normal weight	-0.7	0.2	-1.7	0.1	0.2	0.1	0.8	0.3	1.6	0.2
Overweight	1.0#	0.1	-2.0‡	0.1	1.1#	0.1	1.5‡	0.2	1.8	0.2
Obesity	3.2#	0.1	-2.8#	0.1	2.5#	0.1	2.8#	0.2	2.2‡	0.2
P_{trend}	<0.001		<0.001		<0.001		<0.001		0.02	

* Adjusted means are from linear regression models of the differences between direct and self-reported measures on all the characteristics shown. Difference was calculated as direct minus self-reported measures. Positive values indicate underreporting and negative values indicate over-reporting

‡ *P*<0.05 for the difference vs. the first category

§ *P*<0.01 for the difference vs. the first category

\# *P*<0.001 for the difference vs. the first category

AM, adjusted mean. Circ., circumference. SE, standard error of the adjusted mean

Table IV

Prevalence of overweight and obesity as calculated from direct and self-reported anthropometry and sensitivity and specificity of self-report using direct measures as standard. The Mexican Teachers' Cohort, 2007-2010

Variable	*n*	*Prevalence, %*		*Sensitivity**		*Specificity**	
		Direct	*Self-report*	*%*	*95%CI*	*%*	*95%CI*
Overweight or obesity	3 413	76.2	67.5	84.4	83.0-85.8	86.6	84.0-88.8
Obesity	3 413	33.2	24.1	66.5	63.7-69.3	97.0	96.2-97.6
Abdominal obesity‡	3 258	57.5	52.5	77.5	75.6-79.4	81.2	79.1-83.3

* Categories were defined with the same cut-off points for direct and self-reported measures
‡ Waist circumference>88cm

0.86 for hip circumference.[1-3,5,8,9] Although we provided participants with a measuring tape and precise instructions for measuring their waist and hip circumferences, difficulties for the participants or lack of compliance by measuring those circumferences might be an explanation for these results.

As found by others, women in this study showed a trend to over-report their height, but to underreport the rest of the anthropometric measures.[1-5,8,9,16-18] The mean differences of direct minus self-reported measures we found (1.3 kg for weight, -2.2 cm for height and 1.3 kg/m^2 for BMI) were within the range for women in most studies included in a systematic review published in 2007: 0.1 to 6.5 kg for weight, -0.1 to -5.0 cm for height, and 0.0 to 2.2 kg/m^2 for BMI.[4] Our results were also similar to those published more recently, between 2009 and 2014, in Hispanic women. In Hispanic menopausal women, mean differences of direct minus self-reported measures were 1.5 kg for weight, -2.5 cm for height and 1.4 kg/m2 for BMI.[19] While the errors in self-reported weight we found were similar than those for Hispanic women living in the United States[20] and for Colombian women,[21] errors in self-reported height we found were higher than those reported in the aforementioned studies (0.6 to 1.2 cm). In our study, the possibility that the errors in self-reported anthropometry correspond partially to real changes in weight over time cannot be disregarded. In a population-based cohort study, weight gains ranging from 0.96 kg/year in African-American women to 0.55 kg/year in White women were reported.[22] However, based on our results of the non-significant trend of over-reporting across the categories of time between self-reported and direct measures, it is unlikely that weight gain between measures explain the systematic differences we found.

Underreporting of weight, BMI, and hip circumference decreased with increasing age, while over-reporting of height increased. These findings are consistent with other studies where, compared to younger women, women aged 60 to 65 reported weights closer to real values.[17,23] The association between increasing age and over-reporting of height was also observed in other studies.[16-18,23-26] As age increases, time since last height measurement might be longer. Authors argued that the value of self-reported height might reflect height at younger age, before a shrinkage due to osteoporosis.[26] However because of the relatively young age of the participants in our study, the contribution of osteoporosis to over-reporting of height would be small, if any. In general, more education and number of assets were directly associated with underreporting of weight and waist and hip circumferences. This could be due to women with higher socioeconomic status having poorer body appearance satisfaction. McLaren and colleagues suggest that women with higher education might have a higher risk of poor body appearance because they have a higher exposure to media, which might emphasize the importance of an ideal physical appearance; have higher exposure to health messages, which might inadvertently cause body dissatisfaction through a focus on diet and ideal weight; and have higher expectations on personal development, including body image.[27] Along these lines, we found that self-reported waist circumference was closer to real values in indigenous language speakers against non-speakers.

The most important predictor of the systematic errors in self-reported anthropometry was BMI derived from direct measures. Comparing obese to normal weight women, mean differences of direct minus self-reported measures were 3.9 kg for weight, -1.1 cm for height, 2.3 kg/m^2 for BMI, 2.0 cm for waist circumference and 0.6 cm for waist circumference. This is consistent with other findings.[1,3-5,16,18,23-25,28-30] However, since the correlation between direct and self-reported measures was high (roughly 0.8 to 0.9), this error might have little impact in analyses that use self-reported data as continuous variables, or as multiple ordinal categories. Standard deviations were similar between direct and self-reported measures, which support the hypothesis that errors in self-reported anthropometry would only cause a shift in the distribution of anthropometric variables. Thus, using self-reported measures in regression models might have little impact in measures of association provided that they are included as continuous or multiple ordinal categories independent variables. Other authors suggest that the role of the real BMI on bias in self-reported anthropometry could be attenuated by the individuals' perception of their own weight. Individuals who described themselves as "too heavy", regardless of their measured BMI category, were less likely to underreport weight, over-report height, and be classified in a lower BMI category than their real category.[29] However, there could be misclassification if self-reported measures were used as categorical variables with few categories (e.g., normal, overweight and obese), since values would be systematically farther away from the real values for any given cutoff point. In our study, sensitivity of self-reported obesity was 66.5% and the prevalence of obesity estimated by self-reported was nine percentage points lower than that estimated by direct measures (33.2 *vs*. 24.1%). Small differences between measured and self-reported BMI might translate into larger differences in the prevalence of obesity. The latter is especially true when the cutoff for obesity is under a high-density area of the BMI distribution. Therefore, caution is warranted when interpreting the prevalence of overweight and obesity derived from self-reported data.

The main strengths of this study are a large sample size from both rural and urban populations; the availability of several participants' characteristics, which allowed for the assessment of the factors related to the errors of self-reported anthropometry; and the standardization of measurement processes across settings. Additionally the simultaneous evaluation of several anthropometric indicators allows comparing directly the validity between indicators.

An important limitation of this study is that direct measures were made eleven months (median time) after self-report. Thus, discrepancies between direct and self-reported measures could be explained by real changes in weight, waist or hip circumferences. Time between direct and self-reported measures was independently associated with errors of self-reported height and BMI. However, contrary to what was expected, errors decreased with increasing time between measures. This might indicate improvements in the processes of collecting information over time. This is supported by the fact that time between direct and self-reported measures was longer in the study areas where clinical evaluations were most recent, which also are the sites where participants received a most recent release of the baseline questionnaire. Women included in this analysis were on average more educated and wealthier than the Mexican average. Although that is likely to impact on the generalizability of our results, we obtained estimates of errors of self-reported anthropometry adjusted for several contextual characteristics, including education, rurality and socioeconomic status. Moreover, the cultural and economic diversity of the sites included in this study may help reflecting population differences across Mexico.

These results suggest that self-reported anthropometry is sufficiently valid for epidemiological purposes, especially for the evaluation of association estimates where anthropometric measures are evaluated as exposure, outcome or adjusting variable in adult Mexican women, and can be extended to populations of similar characteristics. Moreover the measurement error model estimates presented here can be incorporated in future analyses to correct for this type of error. Differences between direct and self-reported measures might cause underestimation of the prevalence of overweight and obesity, and should be considered in analyses that rely on self-reported anthropometry.

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References

1. Cairns BJ, Liu B, Clennell S, Cooper R, Reeves GK, Beral V, *et al.* Lifetime body size and reproductive factors: comparisons of data recorded prospectively with self reports in middle age. BMC Med Res Methodol 2011;11:7. https://doi.org/10.1186/1471-2288-11-7
2. Rimm EB, Stampfer MJ, Colditz GA, Chute CG, Litin LB, Willett WC. Validity of self-reported waist and hip circumferences in men and women. Epidemiology 1990;1(6):466-473. https://doi.org/10.1097/00001648-199011000-00009
3. Bes-Rastrollo M, Sabaté J, Jaceldo-Siegl K, Fraser GE. Validation of self-reported anthropometrics in the Adventist Health Study 2. BMC Public Health 2011;11:213. https://doi.org/10.1186/1471-2458-11-213
4. Connor-Gorber S, Tremblay M, Moher D, Gorber B. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. Obes Rev 2007;8(4):307-326. https://doi.org/10.1111/j.1467-789X.2007.00347.x
5. Spencer EA, Roddam AW, Key TJ. Accuracy of self-reported waist and hip measurements in 4492 EPIC-Oxford participants. Public Health Nutr 2004;7(6):723-727. https://doi.org/10.1079/PHN2004600
6. Fewell Z, Davey-Smith G, Sterne JA. The impact of residual and unmeasured confounding in epidemiologic studies: a simulation study. Am J Epidemiol 2007;166(6):646-655. https://doi.org/10.1093/aje/kwm165
7. Grimes DA, Schulz KF. Bias and causal associations in observational research. Lancet 2002;359(9302):248-252. https://doi.org/10.1016/S0140-6736(02)07451-2
8. Park JY, Mitrou PN, Keogh RH, Luben RN, Wareham NJ, Khaw KT. Effects of body size and sociodemographic characteristics on differences between self-reported and measured anthropometric data in middle-aged men and women: the EPIC-Norfolk study. Eur J Clin Nutr 2011;65(3):357-367. https://doi.org/10.1038/ejcn.2010.259
9. Lim LL, Seubsman SA, Sleigh A, Bain C. Validity of self-reported abdominal obesity in Thai adults: a comparison of waist circumference, waist-to-hip ratio and waist-to-stature ratio. Nutr Metab Cardiovasc Dis 2012;22(1):42-49. https://doi.org/10.1016/j.numecd.2010.04.003
10. Lajous M, Ortiz-Panozo E, Monge A, Santoyo-Vistrain R, García-Anaya A, Yunes-Díaz E, *et al.* Cohort Profile: The Mexican Teachers' Cohort (MTC). Int J Epidemiol 2015 dyv123. https://doi.org/10.1093/ije/dyv123
11. Lohman T, Roche A, Martorell R. Anthropometric standardization reference manual. Champaign, IL: Human Kinetics Books, 1988.
12. WHO. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser 1995;854:1-452.
13. WHO. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organ Tech Rep Ser 2000;894(i-xii):1-253.
14. Bland JM, Altman DG. Comparing methods of measurement: why plotting difference against standard method is misleading. Lancet 1995;346(8982):1085-1087. https://doi.org/10.1016/S0140-6736(95)91748-9
15. National Cholesterol Education Program (NCEP) Expert Panel on Detection Ea, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation 2002;106(25):3143-3421.
16. Faeh D, Marques-Vidal P, Chiolero A, Bopp M. Obesity in Switzerland: do estimates depend on how body mass index has been assessed? Swiss Med Wkly 2008;138(13-14):204-210.
17. Ezzati M, Martin H, Skjold S, Vander Hoorn S, Murray CJ. Trends in national and state-level obesity in the USA after correction for self-report bias: analysis of health surveys. J R Soc Med 2006;99(5):250-257. https://doi.org/10.1258/jrsm.99.5.250
18. Großschädl F, Haditsch B, Stronegger WJ. Validity of self-reported weight and height in Austrian adults: sociodemographic determinants and consequences for the classification of BMI categories. Public Health Nutr 2012;15(1):20-27. https://doi.org/10.1017/S1368980011001911
19. Griebeler ML, Levis S, Beringer LM, Chacra W, Gómez-Marín O. Self-reported versus measured height and weight in Hispanic and non-Hispanic menopausal women. J Womens Health (Larchmt) 2011;20(4):599-604. https://doi.org/10.1089/jwh.2009.1850
20. Merrill RM, Richardson JS. Validity of self-reported height, weight, and body mass index: findings from the National Health and Nutrition Examination Survey, 2001-2006. Prev Chronic Dis 2009;6(4):A121.
21. Tsai EW, Perng W, Mora-Plazas M, Marín C, Baylin A, Villamor E. Accuracy of self-reported weight and height in women from Bogotá, Colombia. Ann Hum Biol 2014;41(5):473-476. https://doi.org/10.3109/03014460.2013.856939
22. Lewis CE, Jacobs DR, McCreath H, Kiefe CI, Schreiner PJ, Smith DE, *et al.* Weight gain continues in the 1990s: 10-year trends in weight and overweight from the CARDIA study. Coronary Artery Risk Development in Young Adults. Am J Epidemiol 2000;151(12):1172-1181. https://doi.org/10.1093/oxfordjournals.aje.a010167
23. Kuczmarski MF, Kuczmarski RJ, Najjar M. Effects of age on validity of self-reported height, weight, and body mass index: findings from the Third National Health and Nutrition Examination Survey, 1988-1994. J Am Diet Assoc 2001;101(1):28-34. https://doi.org/10.1016/S0002-8223(01)00008-6
24. Rowland ML. Self-reported weight and height. Am J Clin Nutr 1990;52(6):1125-1133.
25. Stewart AL. The reliability and validity of self-reported weight and height. J Chronic Dis 1982;35(4):295-309. https://doi.org/10.1016/0021-9681(82)90085-6
26. Vailas LI, Nitzke SA. Self-reported versus measured weight and height in an older adult meal program population. J Gerontol A Biol Sci Med Sci 1998;53(6):M481-M483. https://doi.org/10.1093/gerona/53A.6.M481
27. McLaren L, Kuh D. Women's body dissatisfaction, social class, and social mobility. Soc Sci Med 2004;58(9):1575-1584. https://doi.org/10.1016/S0277-9536(03)00209-0
28. Kuskowska-Wolk A, Karlsson P, Stolt M, Rössner S. The predictive validity of body mass index based on self-reported weight and height. Int J Obes 1989;13(4):441-453.
29. Brestoff JR, Perry IJ, Van den Broeck J. Challenging the role of social norms regarding body weight as an explanation for weight, height, and BMI misreporting biases: development and application of a new approach to examining misreporting and misclassification bias in surveys. BMC Public Health 2011;11:331. https://doi.org/10.1186/1471-2458-11-331
30. Kushi LH, Kaye SA, Folsom AR, Soler JT, Prineas RJ. Accuracy and reliability of self-measurement of body girths. Am J Epidemiol 1988;128(4):740-748. https://doi.org/10.1093/oxfordjournals.aje.a115027