Supplemental File 1 Data sources and statistical methods

Data sources

Data at two time points from nationally representative health and nutritional household surveys conducted between 2005 and 2013 in Mexico, Colombia, and Peru were used. All the surveys were household surveys implemented with stratified multistage cluster sampling. Used surveys were:

Mexico:	National Health and Nutritional Survey (Encuesta Nacional de Salud y Nutrición, ENSANUT) 2006[1–3] and 2012[4,5]
Colombia:	Demographic and Health Survey / Nutritional Situation National Household Surveys (Encuesta Nacional de Demografía y Salud / Encuesta Nacional de la Situación Nutricional en Colombia, ENDS/ENSIN) 2005[6,7] and 2010[8,9]
Peru:	National Household Survey, Module for Monitoring of Nutritional Indicators (Encuesta Nacional de Hogares, Modulo de Monitoreo de Indicadores Nutricionales, ENAHO-MONIN) 2007-8[10–13]; and Nutritional Indicator Surveillance (Vigilancia de Indicadores Nutricionales, VIN)[14–16] 2012-3

In Peru, surveys were conducted in 2009-2010 and 2011 as well; however, the data of 2012-13 were used to have a similar inter-survey period as the other two countries. Among the surveys we used, overall household response rates ranged from 85 to 92%. Overall individual response rate for obtaining anthropometric measurements ranged from 75 to 84%, where the rates were lower among men (61-81%) than women (80-89%).

Inclusion criteria

All adults aged 20 to 69 years were included in the study. Adults aged 70 years or over were not included due to their small number of observations. For Colombia, only adults aged 20 to 64 years were included since they did not measure adults aged 65 years or over for anthropometry. Women who were pregnant or whose records did not have information on pregnancy status were excluded from analyses. Records with height < 110 cm or > 210 cm, weight < 20 kg, body mass index (BMI) < 12 kg/m^2 or > 120 kg/m^2 were excluded as having implausible values possibly due to measurement, recording, or data entry error. Those implausible or incomplete (i.e. either height or weight is missing) data were between 0.1% and 0.8% per survey. Final sample sizes were 64,413 for Mexico, 144,628 for Colombia, and 36,082 for Peru.

Response variable

BMI was used as an indicator to measure overweight and obesity, and its distributions were modelled and assessed. BMI was assumed to follow a Box-Cox power exponential (BCPE) distribution, which allows a

response variable that exhibits skewness and kurtosis[17]. The BCPE distribution consists of 4 parameters, μ, σ, ν, and τ, which can be interpreted as relating to location (median), scale (approximate coefficient of variation), skewness (transformation to symmetry), and kurtosis (power exponential parameter), respectively[17].

Covariates

Age (in 5-year age group as a categorical variable, i.e., 20-24, 25-30, …, 65-69), time in calendar year (as a continuous variable), and their interaction terms were included in the model. The interaction terms enabled us to estimate age-specific annual change in BMI distribution. Time of each survey was calculated as the mean of anthropometry measurement dates; if the measurement dates were not available, the midpoint of data collection period was used.

Statistical analysis methods

As an exploratory analysis, histograms of BMI were constructed for each combination of county, survey, sex, and age group. Then, in order to verify the goodness-of-fit of the BCPE distributions to the data, the BCPE distribution, as well as the log-normal and normal distributions as a comparison, were fitted, and the estimated distribution curves were superimposed on the histograms of the observed BMI.

In order to estimate the year- and age-specific BMI distributions by country and sex, each of 4 parameters of the BCPE distribution was modelled as a function of age, calendar time, and their interaction terms.

$$BMI \sim BCPE(\mu, \sigma, \nu, \tau)$$

$$\mu = \sum\nolimits_k \left[{}^{\mu}\beta_{1k} age_k + {}^{\mu}\beta_{2k} (age_k \times time) \right]$$

$$\log \sigma = \sum\nolimits_k \left[{}^{\sigma}\beta_{1k} age_k + {}^{\sigma}\beta_{2k} (age_k \times time) \right]$$

$$\nu = \sum\nolimits_k \left[{}^{\nu}\beta_{1k} age_k + {}^{\nu}\beta_{2k} (age_k \times time) \right]$$

$$\log \tau = \sum\nolimits_k \left[{}^{\tau}\beta_{1k} age_k + {}^{\tau}\beta_{2k} (age_k \times time) \right]$$

where

age_k: the indicator variable for the age group k (20-24, 25-29, …, or 65-69)

$time$: the continuous variable for calendar time centred at July 1, 2010

${}^{\theta}\beta_{1k}$: the coefficient for the age group k for the parameter $\theta = \mu, \sigma, \nu,$ or τ

${}^{\theta}\beta_{2k}$: the coefficient for the interaction between the age group k and calendar time for the parameter θ.

The above model was fitted using a regression called the generalized additive model for location, scale and shape (GAMLSS), with which not only the location (mean or median) but also other parameters of the distribution of the response variable can be modelled as parametric functions of covariates[18]. The model was

applied to the data separately for each country and sex, instead of fitting a single model on the pooled data, since the primary objective is to have country- and sex-specific estimates and we were not interested in statistical comparisons across countries and sexes.

After fitting the model, values of 4 BCPE parameters were estimated for each combination of year (2005 or 2010) and age group, and then, estimated BMI distribution curves (i.e., density functions of BCPE distribution) were constructed. In order to quantify the estimated BMI distributions, prevalence of 4 BMI categories was calculated from the estimated cumulative density function $\hat{F}_{BMI}$. The 4 BMI categories were: undernutrition (BMI < 18.5 kg/m^2); normal (18.5 ≤ BMI < 25.0 kg/m^2); overweight (25.0 ≤ BMI < 30.0 kg/m^2); and obese (BMI ≥ 30 kg/m^2), which can be given by $\hat{F}_{BMI}(18.5)$, $\left[\hat{F}_{BMI}(25.0) - \hat{F}_{BMI}(18.5)\right]$, $\left[\hat{F}_{BMI}(30.0) - \hat{F}_{BMI}(25.0)\right]$, and $\left[1 - \hat{F}_{BMI}(30.0)\right]$, respectively[19].

Sampling weights and clustering within primary sampling units (PSUs) were incorporated in all analyses. Sampling weights were calibrated after the elimination of incomplete and implausible records so that age- and sex-specific total sums of sampling weights are equal to those of the original data. Then, sampling weights were re-calibrated referring to the UN population estimates[20,21] before pooling datasets of two time points in order to accommodate population sizes possibly estimated using different estimation methods when sampling weights were created. To estimate variances accounting for clustering at the sampling unit level, 2,000 bootstrap samples were generated. A bootstrap sample was obtained by sampling (n_h – 1) PSUs with replacement per stratum for all strata, where n_h stands for the number of PSUs in the stratum h[22]. For each bootstrapped sample, sampling weights were calibrated again so that sex- and age-specific sums of sampling weights are equal to those of the pre-bootstrapping data. Using estimated coefficients from the 2,000 bootstrap samples, the variance-covariance matrix of coefficients was estimated[23] and used for the hypothesis testing. Confidence intervals were reported as 95% bootstrap percentile confidence intervals. The model did not converge in 100 iterations with some bootstrap samples (0-29 out of 2,000 bootstrap samples depending on country-sex-specific dataset), and for these samples, an average of estimates from the last 50 iterations was used as the final estimate after verifying that the estimates of each iteration were not diverging.

R (version 3.2.2) was used to fit the GAMLSS regression models, and Stata (version 14.1) was used for the rest of the analyses.

References

1. Olaiz-Fernández G, Rivera-Dommarco J, Shamah-Levy T, et al. (2006) *Encuesta Nacional de Salud y Nutrición 2006*. Cuernavaca, Mexico: Instituto Nacional de Salud Pública (INSP).
2. Shamah-Levy T, Villalpando-Hernández S & Rivera-Dommarco JA (2007) *Resultados de Nutrición de la ENSANUT 2006*. Cuernavaca, Mexico: Instituto Nacional de Salud Pública (INSP).

3. Instituto Nacional de Salud Pública (INSP) (2012) *Encuesta Nacional de Salud y Nutrición (ENSANUT) 2006 [datasets]*. Cuernavaca, Mexico: INSP [producer and distributor]. https://ensanut.insp.mx. Accessed March 25, 2016.
4. Gutiérrez JP, Rivera-Dommarco J, Shamah-Levy T, et al. (2013) *Encuesta Nacional de Salud y Nutrición 2012. Resultados nacionales.* 2nd ed. Cuernavaca, Mexico: Instituto Nacional de Salud Pública (INSP).
5. Instituto Nacional de Salud Pública (INSP) (2012) *Encuesta Nacional de Salud y Nutrición (ENSANUT) 2012 [datasets]*. Cuernavaca, Mexico: INSP [producer and distributor]. https://ensanut.insp.mx. Accessed March 25, 2016.
6. Ojeda G, Ordóñez M & Ochoa LH (2005) *Colombia Salud Sexual y Reproductiva: Resultados Encuesta Nacional de Demografía y Salud 2005*. Bogotá, Colombia: Profamilia.
7. Ojeda G, Ordóñez M & Ochoa LH (2005) *Colombia Salud Sexual y Reproductiva: Resultados Encuesta Nacional de Demografía y Salud 2005 [datasets]*. Bogotá, Colombia: Profamilia [producer]. Rockville, USA: ICF [distributor]. https://dhsprogram.com/data. Accessed March 25, 2016.
8. Ojeda G, Ordóñez M & Ochoa LH (2011) *Colombia Encuesta Nacional de Demografía y Salud 2010*. Bogotá, Colombia: Profamilia.
9. Ojeda G, Ordóñez M & Ochoa LH (2011) *Colombia Encuesta Nacional de Demografía y Salud 2010 [datasets]*. Bogotá, Colombia: Profamilia [producer]. Rockville, USA: ICF [distributor]. https://dhsprogram.com/data. Accessed March 26, 2016.
10. Centro Nacional de Alimentación y Nutrición (CENAN) & Instituto Nacional de Estadística e Informática (INEI) (2009) *Informe Final: perfil nutricional y pobreza en Perú. ENAHO I trimestre 2008*. Lima, Peru: CENAN and INEI.
11. Instituto Nacional de Estadística e Informática (INEI) (2012) *Encuesta nacional de hogares sobre condiciones de vida y pobreza, ENAHO 2007 [datasets]*. Lima, Peru: INEI [producer and distributor]. http://iinei.inei.gob.pe/microdatos. Accessed March 25, 2016.
12. Instituto Nacional de Estadística e Informática (INEI) (2012) *Encuesta nacional de hogares sobre condiciones de vida y pobreza, ENAHO 2008 [datasets]*. Lima, Peru: INEI [producer and distributor]. http://iinei.inei.gob.pe/microdatos. Accessed March 25, 2016.
13. Instituto Nacional de Estadística e Informática (INEI) & Centro Nacional de Alimentación y Nutrición (CENAN) (2010) *Encuesta Nacional de Hogares - Modulo Mediciones Antropométricas, 2007-2008 [datasets]*. Lima, Peru: INEI and CENAN [producer]. INEI [distributor]. http://iinei.inei.gob.pe/microdatos. Accessed March 25, 2016.
14. Dirección Ejecutiva de Vigilancia Alimentaria y Nutricional (DEVAN) (2015) *Informe técnico: estado nutricional en el Perú por etapas de vida; 2012-2013*. Lima, Peru: DEVAN.
15. Instituto Nacional de Estadística e Informática (INEI) (2013) *Encuesta nacional de hogares sobre condiciones de vida y pobreza, ENAHO 2012 [datasets]*. Lima, Peru: INEI [producer and distributor]. http://iinei.inei.gob.pe/microdatos. Accessed March 25, 2016.

16. Dirección Ejecutiva de vigilancia Alimentaria y Nutricional (DEVAN) (2015) *Encuesta nacional de hogar - modulo mediciones antropométricas, 2012-2013 [datasets]*. Lima, Peru: DEVAN [producer]. Instituto Nacional de Salud (INS) [distributor]. http://www.portal.ins.gob.pe/es/cenan/cenan-c2/vigilancia-alimentaria-y-nutricional/vigilancia-de-indicadores-nutricionales-b. Accessed March 25, 2016.
17. Rigby RA & Stasinopoulos DM (2004) Smooth centile curves for skew and kurtotic data modelled using the Box-Cox power exponential distribution. *Stat. Med.* **23**, 3053–3076.
18. Rigby RA & Stasinopoulos DM (2005) Generalized additive models for location, scale and shape. *J.R.Stat.Soc. Ser. C Appl.Statist.* **54**, 507–554.
19. Majer IM, Mackenbach JP & van Baal PH (2013) Time trends and forecasts of body mass index from repeated cross-sectional data: a different approach. *Stat. Med.* **32**, 1561–1571.
20. United Nations (UN) (2015) *World Population Prospects: The 2015 Revision. File POP/15-2: Annual male population by five-year age group, major area, region and country, 1950-2100 (thousands). Estimates, 1950 - 2015 [dataset]*. New York, USA: UN.
21. United Nations (UN) (2015) *World Population Prospects: The 2015 Revision. File POP/15-2: Annual female population by five-year age group, major area, region and country, 1950-2100 (thousands). Estimates, 1950 - 2015 [dataset]*. New York, USA: UN.
22. Kolenikov S (2010) Resampling variance estimation for complex survey data. *Stata J.* **10**, 165–199.
23. Rao JNK, Wu CFJ & Yue K (1992) Some recent work on resampling methods for complex surveys. *Surv. Methodol.* **18**, 209–217.

Supplemental Table 1 Demographic characteristics of the study populations (adult aged 20-69 years[*])[†]

	Mexico (*n* = 64,413)				Colombia (*n* = 144,628)				Peru (*n* = 36,082)			
	Men (*n* = 26,347)		Women (*n* = 38,066)		Men (*n* = 59,993)		Women (*n* = 84,635)		Men (*n* = 16,349)		Women (*n* = 19,733)	
	2006	2012	2006	2012	2005	2010	2005	2010	2007-8	2012-3	2007-8	2012-3
Number of observations												
Number of records	11,982	14,365	18,178	19,888	23,275	36,718	36,247	48,388	8,191	8,158	9,507	10,226
Weighted counts (000)	29,166	33,855	29,680	33,980	11,763	13,096	11,973	13,382	7,773	8,304	7,607	8,067
Age (%)												
20-29	29	29	27	26	33	30	30	28	29	24	27	22
30-39	25	24	27	27	25	25	26	24	25	22	27	23
40-49	21	21	22	21	22	23	23	23	24	23	24	24
50-59	15	16	14	16	15	16	16	18	13	18	14	19
60-69	10	10	10	10	5	6	6	6	9	13	9	13
Type of residence (%)												
Urban	78	79	77	79	73	74	77	78	68	75	71	78
Rural	22	22	23	21	27	26	23	22	32	25	29	22
Educational attainment (%)												
Primary	44	34	53	40	41	38	42	36	28	24	39	35
Secondary	41	48	37	45	40	42	41	42	43	41	35	35
Higher	14	18	10	16	17	20	18	22	29	34	26	30
Missing	1	0	0	0	1	1	0	0	0	0	0	0
Household wealth quartile[‡] (%)												
Lowest	22	23	24	23	25	26	21	21	21	23	20	21
Lower	25	24	25	25	26	25	26	25	24	24	23	23
Higher	26	25	26	26	25	25	27	27	26	23	27	25
Highest	27	27	25	26	25	24	27	27	25	25	27	25
Missing	0	0	0	0	0	0	0	0	4	6	4	7

* In the case of Colombia, adults aged 20-64 years.

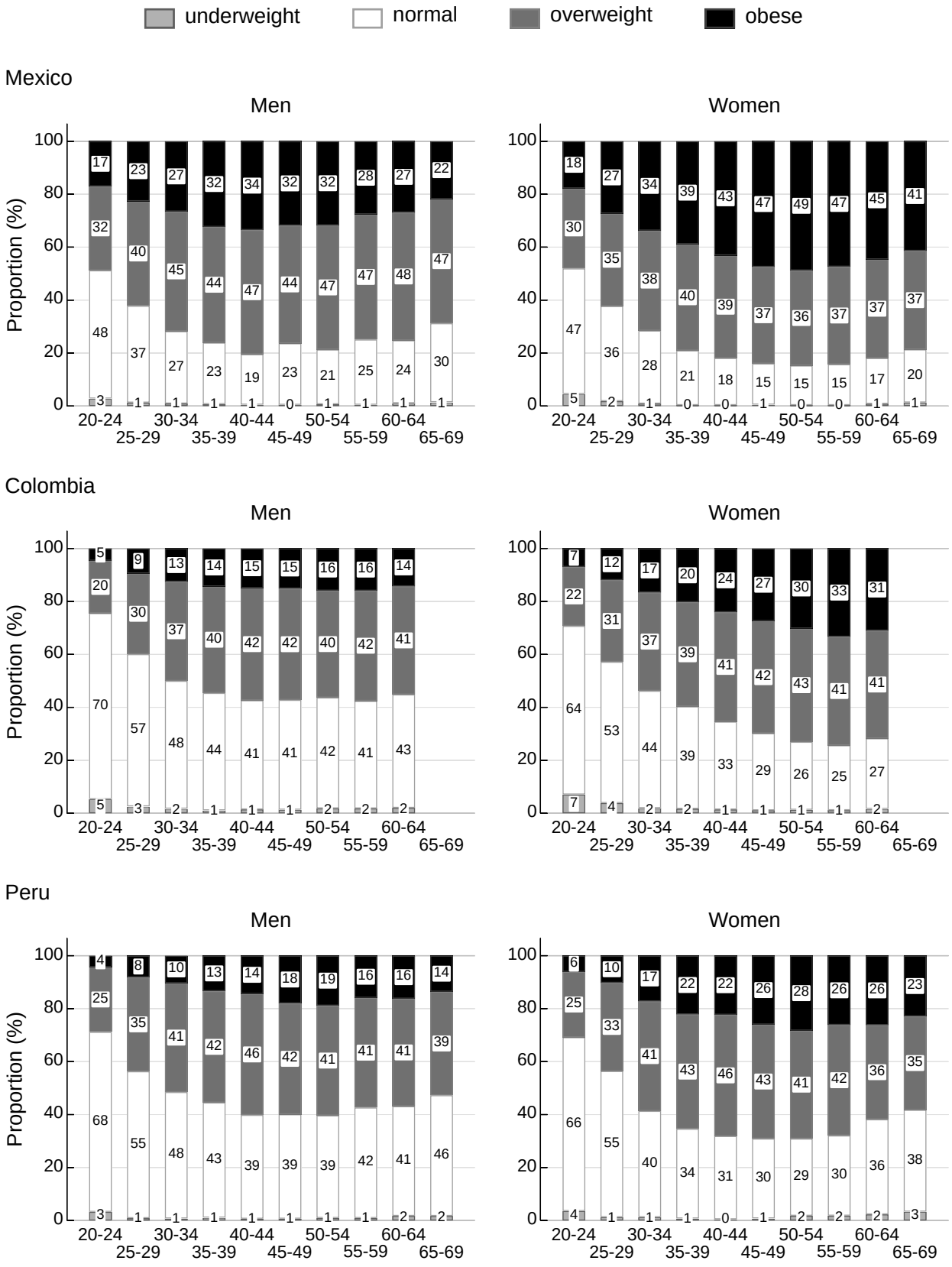
† All numbers were presented as weighted numbers except the number of records.

‡ A household wealth index score was constructed for each survey from variables on dwelling characteristics, available household services and assets following a method established by the Demographic Health Surveys (DHS) Program[1-4]. And then, quartiles of the wealth score were calculated.

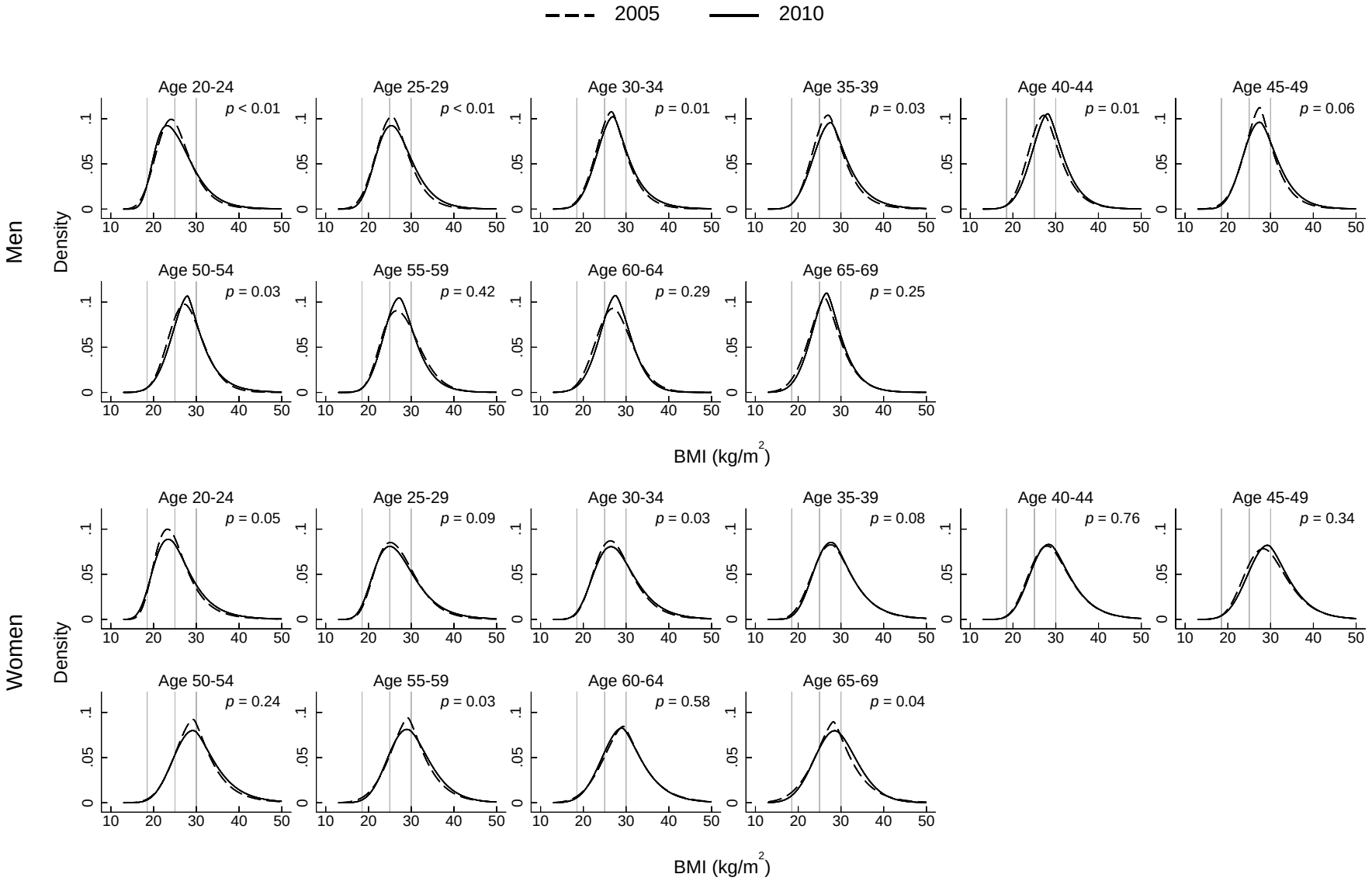
References

1. Rutstein SO & Kiersten J (2004) *The DHS Wealth Index. DHS Comparative Reports No. 6*. Calverton, Maryland, USA: ORC Macro.
2. Rutstein SO (2008) *The DHS Wealth Index: Approaches for Rural and Urban Areas. DHS Working Papers. No. 60*. Calverton, Maryland, USA: Macro International.
3. The DHS Program & ICF International Wealth Index Construction. http://www.dhsprogram.com/topics/wealth-index/Wealth-Index-Construction.cfm (accessed November 2015).
4. Fry K, Firestone R & Chakraborty NM (2014) *Measuring equity with nationally representative wealth quintiles*. Washington, DC, USA: PSI.

Supplemental Figure 1 Estimated prevalence of 4 BMI categories by age for year 2010

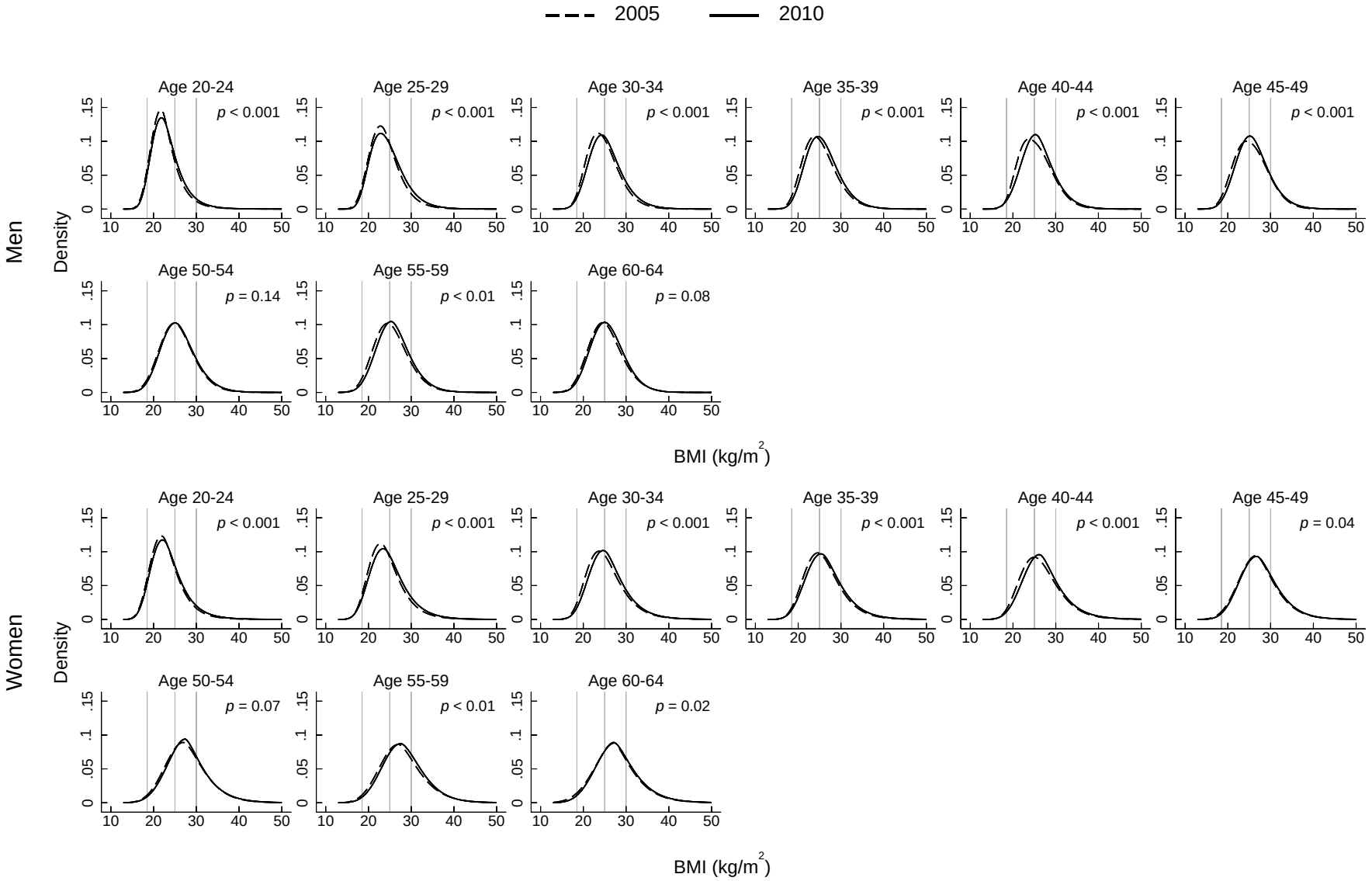


Supplemental Figure 2 Estimated BMI distributions by age for years 2005 and 2010, Mexico



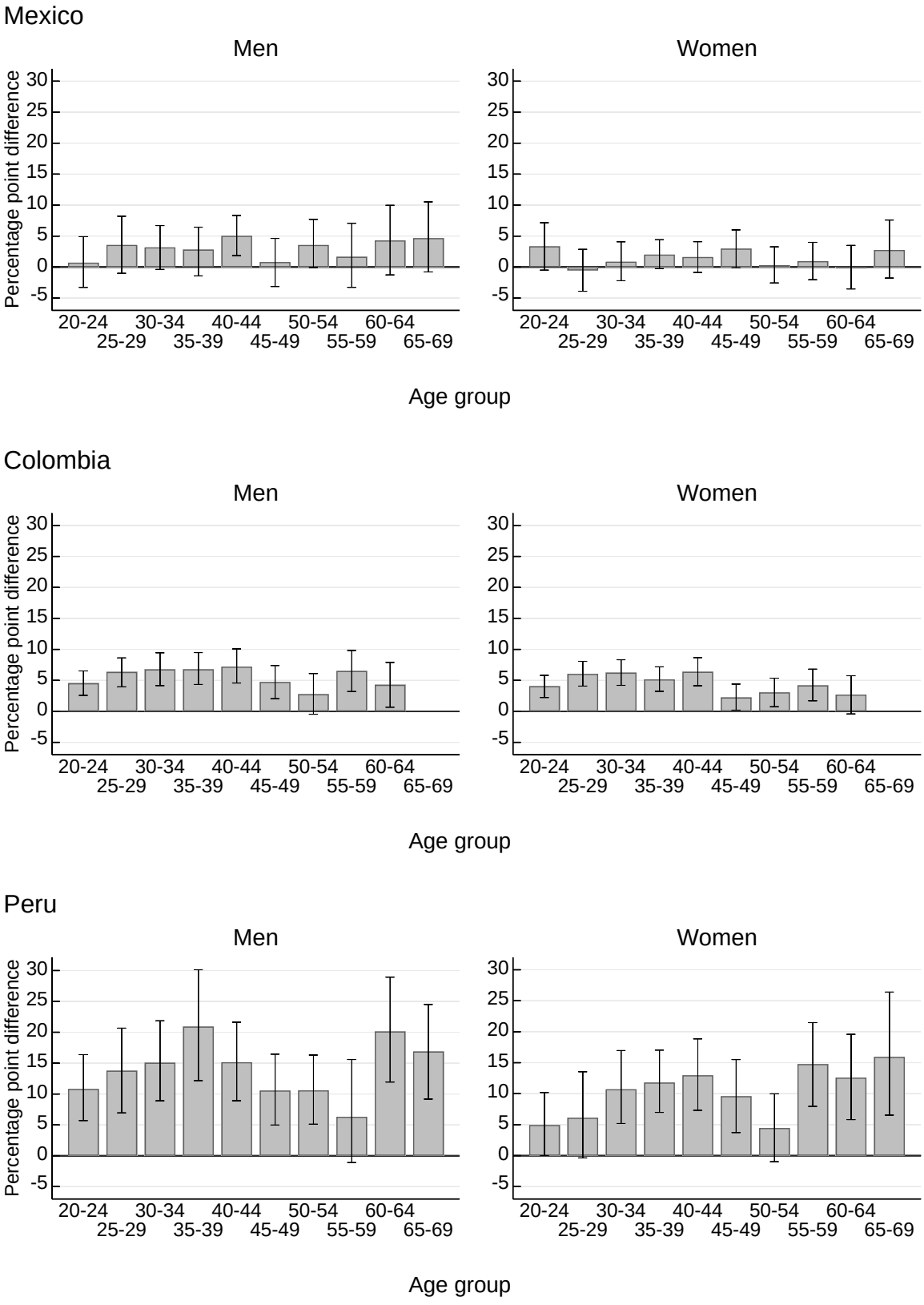
P-values (from 4-*df* Wald tests) indicate difference in distributions between years 2005 and 2010. The null hypothesis is: ${}^{\mu}\beta_{2k} = 0$, ${}^{\sigma}\beta_{2k} = 0$, ${}^{\nu}\beta_{2k} = 0$, ${}^{\tau}\beta_{2k} = 0$, where ${}^{\theta}\beta_{2k}$ is the coefficient for the interaction term between age group k and time for the parameter $\theta = \mu, \sigma, \nu,$ or τ.

Supplemental Figure 3 Estimated BMI distributions by age for years 2005 and 2010, Colombia



P-values (from 4-*df* Wald tests) indicate difference in distributions between years 2005 and 2010. The null hypothesis is: ${}^{\mu}\beta_{2k} = 0$, ${}^{\sigma}\beta_{2k} = 0$, ${}^{\nu}\beta_{2k} = 0$, ${}^{\tau}\beta_{2k} = 0$, where ${}^{\theta}\beta_{2k}$ is the coefficient for the interaction term between age group k and time for the parameter $\theta = \mu, \sigma, \nu,$ or τ.

Supplemental Figure 4 Change in prevalence of overweight and obesity prevalence by age between 2005 and 2010



Vertical lines from the bars represent 95% percentile confidence intervals.