

Supplemental material

Temporal trends in obesity defined by the relative fat mass (RFM) index among adults in the United States from 1999 to 2020: a population-based study

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Supplemental Table 1. Prevalence of general and abdominal obesity among study participants by sex and ethnicity.*			
	Mexican American	European American	African American
Women	n=4,204	n=9,710	n=5,417
RFM-defined obesity, % (95% CI) †	72.7 (70.3-75.1)	56.6 (55.2-58.0)	69.9 (68.3-71.4)
BMI-defined obesity, % (95% CI) ‡	45.5 (43.2-47.9)	35.4 (34.0-36.7)	54.5 (52.9-56.1)
Abdominal obesity, % (95% CI) §	71.5 (69.2-73.8)	62.8 (61.4-64.1)	75.0 (73.6-76.3)
Men	n=4,212	n=9,981	n=5,256
RFM-defined obesity, % (95% CI) †	47.0 (44.9-49.1)	41.7 (40.3-43.2)	33.7 (32.1-35.3)
BMI-defined obesity, % (95% CI) ‡	38.4 (36.3-40.4)	35.0 (33.6-36.5)	35.9 (34.2-37.6)
Abdominal obesity, % (95% CI) §	41.2 (39.1-43.2)	47.6 (46.2-49.1)	37.5 (35.9-39.0)
<p>* Sample size represents unweighted data. Estimates represent weighted data. BMI, body mass index; CI, confidence interval; IQR, interquartile range; RFM, relative fat mass; SD, standard deviation. † Defined as an RFM $\geq 40\%$ for women and $\geq 30\%$ for men. Estimates are not adjusted for age. ‡ Defined as a BMI ≥ 30 kg/m². Estimates are not adjusted for age. § Defined as a waist circumference >88 cm for women and >102 cm for men, according to the recommendations of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Estimates are not adjusted for age.</p>			

Supplemental Table 2. Characteristics of study participants with missing data.*			
Characteristic	All†	With complete data	With missing data
Sample size, n (%)	50,283 (100)	47,667 (95.6)	2,616 (4.4)
Median age (IQR), years	45 (33-58)	45 (33-58)	47 (34-63)
Male sex, n (%)	24,954 (49.2)	23,736 (49.4)	1,218 (45.4)
Ethnicity, n (%)			
Mexican American	8,827 (8.3)	8,416 (8.3)	411 (8.6)
European American	20,618 (66.9)	19,691(67.2)	927 (58.6)
African American	11,433 (11.4)	10,673(11.2)	760 (16.7)
Other/multi-racial	9,405 (13.4)	8,887 (13.2)	518 (16.1)
<p>* Sample size represents unweighted data. Estimates represent weighted data. † This group includes participants with complete data and participants with missing data on body weight (n=666), height (n=596), and waist circumference (n=2,340).</p>			

Supplemental Table 3. Age-adjusted U.S. adult prevalence temporal trends in RFM-defined obesity by ethnicity: 1999-2000 through 2017-March 2020.*

	RFM-defined obesity			BMI-defined obesity		
	Mexican American	European American	African American	Mexican American	European American	African American
All participants	n=8,416	n=19,691	n=10,673	n=8,416	n=19,691	n=10,673
Prevalence, % (95% CI)						
1999-2000	53.1 (48.5-57.7)	39.4 (34.2-44.6)	48.3 (45.0-51.7)	34.7 (28.9-40.6)	28.3 (23.9-32.7)	39.8 (35.7-43.8)
2001-2002	52.1 (47.1-57.1)	41.0 (38.9-43.1)	46.0 (42.9-49.0)	30.7 (26.7-34.7)	29.8 (27.0-32.6)	38.3 (34.4-42.3)
2003-2004	60.1 (55.2-65.0)	44.8 (41.0-48.6)	52.7 (49.4-56.0)	36.9 (32.2-41.6)	30.6 (27.7-33.4)	45.1 (39.7-50.5)
2005-2006	55.4 (51.8-58.9)	44.9 (40.7-49.2)	51.5 (47.9-55.1)	33.8 (31.2-36.4)	33.1 (29.2-36.9)	45.9 (42.3-49.5)
2007-2008	62.2 (56.2-68.2)	45.7 (41.5-49.9)	52.5 (49.1-56.0)	39.9 (33.8-46.1)	32.4 (28.7-36.0)	43.7 (39.2-48.1)
2009-2010	61.5 (59.4-63.6)	46.4 (43.0-49.8)	56.8 (51.8-61.8)	40.5 (36.7-44.4)	34.2 (31.1-37.2)	49.4 (44.2-54.5)
2011-2012	63.6 (58.6-68.6)	46.8 (42.8-50.9)	57.4 (54.8-60.0)	46.1 (41.3-50.8)	33.0 (29.4-36.5)	48.4 (44.6-52.3)
2013-2014	65.0 (61.2-68.9)	49.4 (46.6-52.3)	55.0 (50.0-59.9)	46.1 (41.0-51.2)	36.6 (33.6-39.5)	47.9 (43.7-52.0)
2015-2016	70.3 (67.0-73.5)	51.2 (46.9-55.4)	56.6 (52.0-61.2)	48.7 (44.3-53.1)	38.5 (34.5-42.5)	48.7 (43.8-53.5)
2017-2020	68.8 (64.5-73.1)	54.1 (50.8-57.4)	57.1 (54.4-59.8)	50.2 (46.8-53.5)	41.7 (37.7-45.6)	49.9 (47.2-52.6)
Prevalence change†	15.7 (9.6-21.7)	14.7 (8.8-20.5)	8.7 (4.6-12.9)	15.4 (9.0-21.9)	13.4 (7.7-19)	10.2 (5.5-14.8)
P for non-linearity‡	0.58	0.97	0.25	0.52	0.10	0.35
P value for trend‡	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Women	n=4,204	n=9,710	n=5,417	n=4,204	n=9,710	n=5,417
Prevalence, % (95% CI)						
1999-2000	62.8 (55.1-70.5)	46.2 (40.2-52.1)	64.2 (59.6-68.8)	39.8 (31.1-48.5)	30.3 (25.2-35.3)	49.2 (42.5-56.0)
2001-2002	66.4 (58.6-74.3)	47.8 (44.2-51.4)	64.2 (59.0-69.4)	37.0 (30.2-43.8)	31.1 (27.6-34.7)	48.7 (42.8-54.7)
2003-2004	75.0 (68.3-81.6)	50.6 (43.9-57.2)	70.7 (65.5-75.8)	42.7 (36.0-49.3)	30.3 (25.7-34.8)	53.9 (46.3-61.5)
2005-2006	72.0 (66.4-77.5)	49.9 (45.6-54.2)	66.2 (60.9-71.5)	41.3 (34.8-47.7)	32.8 (28.3-37.3)	52.7 (48.5-56.9)
2007-2008	74.8 (71.2-78.4)	52.3 (47.5-57.2)	67.9 (63.2-72.6)	44.7 (38.8-50.6)	32.8 (28.7-36.9)	49.2 (45.2-53.3)
2009-2010	77.8 (74.8-80.9)	53.4 (49.5-57.2)	74.6 (68.6-80.7)	45.7 (42.0-49.3)	32.1 (29.0-35.3)	58.5 (52.0-64.9)
2011-2012	74.6 (66.2-83.0)	56.3 (51.4-61.3)	74.9 (72.1-77.8)	49.0 (40.4-57.5)	33.3 (28.0-38.7)	57.9 (53.5-62.3)
2013-2014	81.2 (74.7-87.6)	57.3 (53.4-61.2)	72.5 (68.8-76.2)	51.7 (45.2-58.3)	37.6 (33.7-41.6)	56.7 (53.1-60.3)
2015-2016	84.6 (79.7-89.5)	60.0 (56.2-63.8)	72.3 (68.3-76.4)	52.2 (48.4-56.1)	38.5 (34.0-43.0)	57.1 (52.6-61.5)
2017-2020	76.9 (70.8-83.1)	62.3 (59.0-65.7)	72.4 (68.6-76.2)	49.6 (43.1-56.0)	40.3 (36.4-44.2)	57.3 (53.7-60.9)
Prevalence change†	14.1 (4.7-23.6)	16.2 (9.7-22.7)	8.3 (2.5-14.0)	9.8 (-0.6-20.1)	10.0 (3.9-16.1)	8.1 (0.8-15.4)
P for non-linearity‡	0.026	0.77	0.34	0.76	0.12	0.71
P value for trend‡	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Men	n=4,212	n=9,981	n=5,256	n=4,212	n=9,981	n=5,256
Prevalence, % (95% CI)						
1999-2000	42.9 (39.4-46.5)	33.2 (28.6-37.7)	27.5 (23.1-31.9)	29.1 (24.6-33.6)	26.8 (22.9-30.6)	26.8 (23.0-30.6)
2001-2002	40.6 (34.7-46.4)	34.1 (30.9-37.4)	25.8 (21.4-30.1)	25.9 (21.9-29.9)	28.3 (25.3-31.4)	26.5 (22.8-30.1)
2003-2004	47.1 (39.3-54.8)	38.9 (35.5-42.4)	31.2 (27.2-35.2)	31.7 (25.0-38.3)	30.9 (27.0-34.7)	34.2 (27.7-40.7)
2005-2006	40.8 (34.1-47.4)	40.0 (35.1-44.9)	34.1 (28.3-39.9)	27.4 (22.7-32.1)	33.3 (28.7-37.9)	37.2 (31.2-43.2)
2007-2008	50.9 (43.3-58.4)	38.8 (34.7-42.9)	33.8 (28.8-38.9)	35.1 (28.0-42.1)	32.0 (27.9-36.0)	36.9 (31.0-42.7)
2009-2010	47.8 (44.6-51.0)	39.4 (34.6-44.3)	35.4 (31.4-39.5)	36.3 (30.9-41.6)	36.1 (30.8-41.3)	38.6 (33.1-44.0)
2011-2012	52.5 (45.6-59.4)	37.6 (34.3-40.9)	36.4 (32.3-40.5)	42.7 (36.0-49.5)	32.5 (29.7-35.3)	37.5 (32.8-42.2)
2013-2014	52.4 (48.6-56.3)	41.7 (38.1-45.3)	35.2 (28.6-41.8)	43.6 (38.2-49.1)	35.6 (31.6-39.5)	37.9 (32.5-43.4)
2015-2016	55.9 (50.9-60.8)	42.3 (36.5-48.1)	38.1 (31.9-44.2)	45.3 (38.5-52.1)	38.4 (32.5-44.3)	38.9 (33.5-44.2)
2017-2020	61.2 (55.8-66.6)	45.8 (40.3-51.2)	39.1 (35.4-42.8)	50.3 (46.1-54.5)	43.1 (36.9-49.2)	41.2 (36.7-45.7)
Prevalence change†	18.3 (12.0-24.5)	12.6 (5.7-19.5)	11.6 (6.1-17.1)	21.2 (15.3-27.1)	16.3 (9.3-23.3)	14.4 (8.7-20.1)
P for non-linearity‡	0.21	0.80	0.50	0.24	0.45	0.08
P value for trend‡	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

* Prevalence estimates represent weighted data. The relative fat mass (RFM) was calculated as follows: RFM = 64 - (20 × height/waist circumference) + (12 × sex); sex equals 0 for men and 1 for women. Obesity was diagnosed if RFM was 40% or higher for women and RFM was 30% or higher for men. CI denotes confidence interval.
† Absolute difference (prevalence in 2017-2020 minus the prevalence in 1999-2000).
‡ Adjusted for age and sex.
§ Adjusted for age.

Supplemental Table 4. Age-adjusted U.S. adult prevalence temporal trends in RFM-defined obesity by age group: 1999-2000 through 2017-March 2020.*

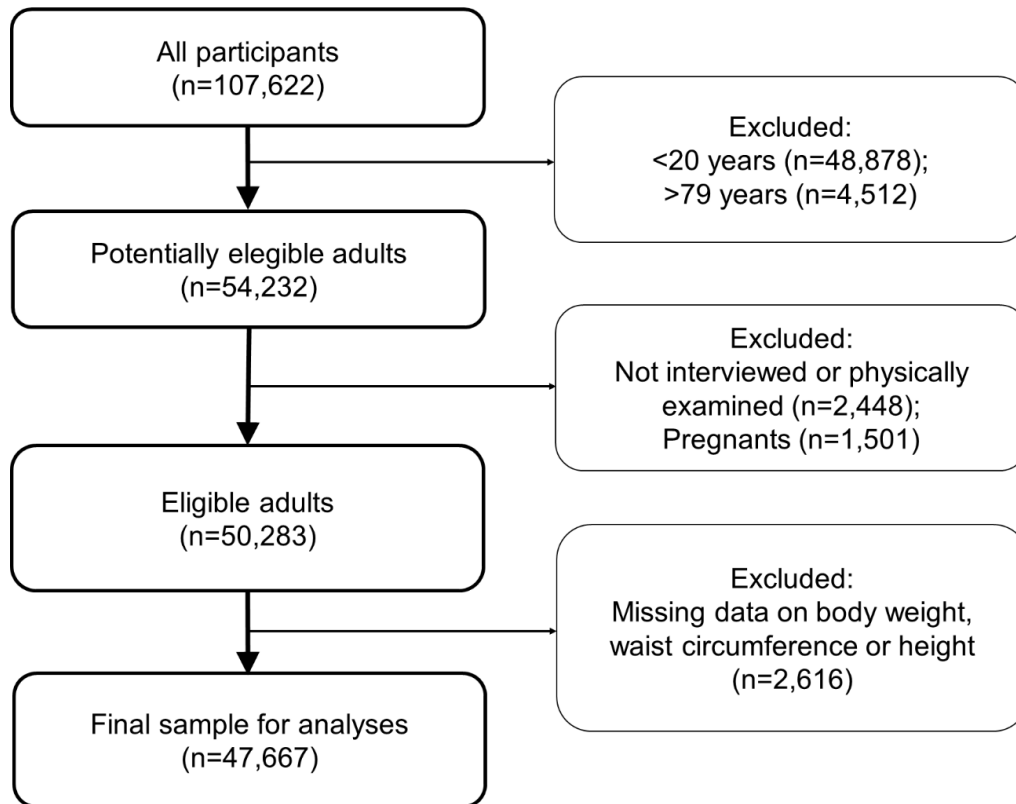
	RFM-defined obesity			BMI-defined obesity		
	20-39 years old n=16,747	40-59 years old n=16,912	60-79 years old n=14,008	20-39 years old n=16,747	40-59 years old n=16,912	60-79 years old n=14,008
All participants						
Prevalence, 95% CI						
1999-2000	29.0 (24.5-33.6)	46.9 (40.5-53.4)	61.8 (58.1-65.6)	25.4 (21.5-29.3)	33.2 (26.9-39.4)	35.4 (31.3-39.5)
2001-2002	30.2 (27.2-33.1)	45.0 (42.2-47.8)	63.8 (61.3-66.3)	25.3 (22.4-28.1)	33.2 (29.9-36.4)	33.7 (30.7-36.8)
2003-2004	34.2 (31.2-37.1)	51.2 (47.8-54.6)	65.8 (62.5-69.0)	28.1 (24.6-31.7)	35.9 (32.1-39.7)	33.0 (29.4-36.5)
2005-2006	32.6 (28.7-36.5)	53.2 (47.9-58.5)	66.0 (62.2-69.8)	28.5 (24.1-32.9)	40.1 (35.6-44.6)	34.9 (31.5-38.3)
2007-2008	35.5 (31.1-39.9)	51.6 (48.5-54.7)	66.1 (62.4-69.8)	30.2 (26.2-34.3)	35.7 (32.4-39.1)	37.4 (33.8-40.9)
2009-2010	37.2 (32.8-41.6)	50.5 (47.7-53.4)	68.5 (65.2-71.8)	32.5 (28.7-36.3)	36.0 (33.9-38.2)	41.8 (38.0-45.7)
2011-2012	37.7 (33.1-42.3)	53.6 (49.9-57.3)	68.0 (62.9-73.1)	30.4 (26.2-34.5)	39.3 (36.1-42.5)	38.3 (33.8-42.9)
2013-2014	40.0 (36.2-43.9)	54.5 (50.3-58.7)	68.8 (64.6-73.0)	34.4 (31.3-37.5)	40.6 (36.2-45.1)	39.3 (35.2-43.5)
2015-2016	43.0 (39.0-47.0)	57.1 (50.6-63.6)	69.8 (64.7-74.9)	36.0 (32.2-39.8)	42.8 (37.5-48.2)	42.8 (37.5-48.2)
2017-2020	44.6 (40.5-48.6)	59.4 (56.2-62.7)	70.6 (67.2-74.0)	39.8 (35.6-44.0)	44.3 (41.2-47.4)	42.7 (39.1-46.3)
Prevalence change†	15.5 (9.7-21.3)	12.5 (5.6-19.4)	8.8 (3.9-13.6)	14.5 (8.9-20.0)	11.2 (4.5-17.8)	7.3 (2.0-12.5)
P for non-linearity‡	0.65	0.94	0.25	0.48	0.21	0.46
P value for trend§	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Women	n=8,295	n=8,684	n=6,952	n=8,295	n=8,684	n=6,952
Prevalence, 95% CI						
1999-2000	36.9 (30.9-42.9)	56.2 (48.9-63.5)	67.7 (63.3-72.2)	28.7 (23.6-33.7)	37.4 (30.2-44.5)	37.4 (31.6-43.2)
2001-2002	39.9 (35.3-44.5)	52.9 (48.1-57.6)	72.0 (69.3-74.7)	28.9 (24.1-33.6)	35.0 (30.2-39.8)	36.6 (32.0-41.2)
2003-2004	42.0 (35.8-48.2)	59.7 (54.9-64.5)	73.0 (68.3-77.7)	29.0 (23.8-34.1)	38.1 (32.3-43.9)	33.6 (28.5-38.7)
2005-2006	40.3 (35.3-45.4)	58.7 (53.5-63.8)	71.3 (66.4-76.2)	29.2 (24.1-34.3)	40.7 (35.9-45.6)	34.8 (28.4-41.2)
2007-2008	46.1 (40.4-51.7)	60.0 (56.2-63.8)	69.8 (64.5-75.1)	33.0 (27.3-38.6)	37.6 (32.6-42.5)	36.0 (30.0-41.9)
2009-2010	46.4 (40.6-52.2)	59.3 (55.5-63.1)	78.5 (75.8-81.3)	31.8 (28.2-35.4)	35.5 (31.7-39.3)	45.1 (40.7-49.5)
2011-2012	47.6 (42.1-53.1)	64.6 (60.1-69.0)	76.7 (69.8-83.5)	31.9 (28.0-35.9)	39.4 (35.1-43.6)	42.1 (34.4-49.7)
2013-2014	50.8 (46.6-55.1)	63.3 (58.1-68.5)	78.0 (74.6-81.4)	36.6 (33.9-39.3)	43.6 (38.2-48.9)	40.2 (34.1-46.2)
2015-2016	53.3 (48.9-57.8)	69.1 (62.7-75.5)	77.1 (70.6-83.6)	37.1 (33.5-40.7)	44.8 (38.4-51.1)	45.0 (37.3-52.8)
2017-2020	53.3 (48.5-58.0)	67.9 (63.6-72.3)	81.0 (76.4-85.6)	39.9 (35.3-44.4)	42.8 (38.9-46.7)	45.4 (40.9-49.8)
Prevalence change†	16.4 (9.1-23.7)	11.7 (3.6-19.9)	13.3 (7.1-19.5)	11.2 (4.7-17.7)	5.5 (-2.3-13.2)	8.0 (1.0-15.0)
P for non-linearity‡	0.16	0.39	0.99	0.44	0.42	0.97
P value for trend§	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Men	n=8,452	n=8,228	n=7,056	n=8,452	n=8,228	n=7,056
Prevalence, 95% CI						
1999-2000	22.4 (18.0-26.8)	36.8 (30.4-43.2)	54.7 (49.9-59.5)	22.7 (18.3-27.0)	28.8 (22.8-34.8)	33.2 (28.2-38.1)
2001-2002	20.8 (17.4-24.1)	37.1 (33.5-40.7)	53.5 (49.8-57.1)	21.7 (18.5-24.9)	31.2 (28.0-34.5)	30.4 (26.0-34.8)
2003-2004	26.9 (23.3-30.4)	42.3 (36.7-47.9)	57.2 (52.5-62.0)	27.4 (22.5-32.3)	33.6 (28.4-38.9)	32.3 (27.4-37.2)
2005-2006	25.4 (20.1-30.7)	47.4 (40.5-54.2)	59.8 (54.8-64.7)	27.6 (22.0-33.1)	39.5 (33.1-45.9)	34.7 (29.9-39.5)
2007-2008	25.4 (21.2-29.5)	42.8 (37.8-47.8)	61.8 (57.7-65.9)	27.6 (23.8-31.4)	33.7 (28.8-38.5)	39.2 (34.8-43.5)
2009-2010	28.5 (23.6-33.3)	41.6 (37.7-45.5)	56.9 (51.1-62.7)	33.2 (27.2-39.2)	36.6 (33.0-40.2)	37.5 (32.3-42.8)
2011-2012	28.4 (23.9-33.0)	42.3 (38.0-46.6)	58.1 (52.1-64.2)	28.9 (23.5-34.2)	39.1 (35.6-42.5)	34.2 (29.2-39.2)
2013-2014	30.0 (25.5-34.5)	45.5 (40.3-50.7)	58.6 (51.6-65.5)	32.5 (28.1-36.8)	37.7 (32.2-43.3)	38.6 (30.7-46.4)
2015-2016	33.1 (28.3-38.0)	44.5 (36.5-52.6)	61.4 (55.4-67.5)	35.0 (29.0-41.0)	40.8 (34.6-47.1)	40.2 (34.9-45.5)
2017-2020	35.9 (30.2-41.5)	50.8 (46.2-55.4)	58.8 (54.3-63.3)	39.5 (33.1-46.0)	45.8 (41.1-50.6)	39.7 (34.0-45.4)
Prevalence change†	13.4 (6.5-20.4)	14.0 (6.4-21.6)	4.1 (-2.3-10.5)	16.8 (9.3-24.4)	17.0 (9.7-24.4)	6.5 (-0.7-13.8)
P for non-linearity‡	0.47	0.42	0.16	0.97	0.41	0.24
P value for trend§	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

* Prevalence estimates represent weighted data. The relative fat mass (RFM) was calculated as follows: RFM = 64 - (20 × height/waist circumference) + (12 × sex); sex equals 0 for men and 1 for women. Obesity was diagnosed if RFM was 40% or higher for women and RFM was 30% or higher for men. CI denotes confidence interval.

† Absolute difference (prevalence in 2017-2020 minus the prevalence in 1999-2000).

‡ Adjusted for sex and ethnicity.

§ Adjusted for ethnicity.

NHANES 1999-March 2020**Supplemental Figure 1.** Selection of study participants.