Energy expenditure in adults living in developing compared with industrialized countries: a meta-analysis of doubly labeled water studies[1–3]

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ABSTRACT

Background: There is an assumption that people in developing countries have a higher total energy expenditure (TEE) and physical activity level (PAL) than do people in developed nations, but few objective data for this assertion exist.

Objective: We conducted a meta-analysis of TEE and PAL by using data from countries that have a low or middle human development index (HDI) compared with those with a high HDI to better understand how energy-expenditure variables are associated with development status and population differences in body size.

Design: We performed a literature search for studies in which energy expenditure was measured by using doubly labeled water. Mean data on age, weight, body mass index (BMI; in kg/m^2), TEE, and PAL were extracted, and HDI status was assessed. Pooled estimates of the mean effect by sex were obtained, and the extent to which age, weight, HDI status, and year of publication explained heterogeneity was assessed.

Results: A total of 98 studies (14 studies from low- or middle-HDI countries) that represented 183 cohorts and 4972 individuals were included. Mean (±SE) BMI was lower in countries with a low or middle HDI than in those with a high HDI for both men and women (22.7 ± 1.0 compared with 26.0 ± 0.7, respectively, in men and 24.3 ± 0.7 compared with 26.6 ± 0.4, respectively, in women). In meta-regression models, there was an inverse association of age ($P < 0.001$) and a positive association of weight ($P < 0.001$) with TEE for both sexes; there was an association of age only in men with PAL ($P < 0.001$). There was no association of HDI status with either TEE or PAL.

Conclusion: TEE adjusted for weight and age or PAL did not differ significantly between developing and industrialized countries, which calls into question the role of energy expenditure in the cause of obesity at the population level. *Am J Clin Nutr* 2011;93:427–41.

INTRODUCTION

The World Health Organization projects that 2.3 billion adults worldwide will be overweight and >700 million will be obese by 2015 (1). Increasingly, low- and middle-income countries are experiencing rapidly rising rates of overweight and obesity (2–7). As more countries face the consequences of obesity, public health organizations will adopt strategies to combat excess weight gain. Almost certainly, these strategies will include the reduction of energy intake and an increase of energy expenditure through physical activity (1, 8), but a clear understanding of how both factors contribute to excess weight gain at the population level will be essential for the design and implementation of appropriate public health policies.

Worldwide increases in urbanization with accompanying changes in patterns of dietary intake and energy expenditure have been implicated as the primary environmental drivers of the "obesity pandemic" (4, 6, 7). A lower mean body mass index (BMI; in kg/m^2) and lower prevalence of obesity in most developing compared with industrialized societies has led to the assumption that energy expenditure differs between populations at different stages of social and economic development. Popkin (7) proposed a number of causes for the likely decrease in energy expenditure associated with urbanization, including a change from agricultural to service sector occupations, reduced levels of occupational physical activity, and changes in the types of transportation used by urban residents. Although data on physical activity patterns and expenditure have been collected for decades by using subjective measures, objective measurements of free-living physical activity energy expenditure (PAEE) were not available until the mid-1980s with the application of the doubly labeled water (DLW) method to humans (9).

It is commonly assumed that populations in developing countries have a higher PAEE than in industrialized societies where people have more labor-saving devices and use more motor transportation (4, 6, 7), but in a 1996 review, Ferro-Luzzi and Martino (10) concluded that there was actually little objective evidence to support this assumption. On the other hand, they

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observed that energy expenditure in Western countries had been decreasing over the preceding decades with populations becoming more sedentary as a result of declines in activities of daily life (10). Most of the data presented in the Ferro-Luzzi and Martino review (10) were collected by using questionnaires and physical activity diaries or recalls, with only a limited number of DLW studies included. In contrast, results of a compilation of DLW studies by Westerterp and Speakman (11) suggested no measureable decrease in the PAEE in Western populations between the 1980s and 2005. In addition, a study by Ebersole et al (12) reported no significant differences in DLW-measured PAEE between a cohort of women in rural Nigeria and one in suburban Chicago, and a subsequent longitudinal analysis showed no association between weight change over time and any variable of energy expenditure in either cohort (13). These studies provided indirect evidence that reduced energy expenditure may not be the primary determinant of excess weight gain or of differing rates of obesity between populations. To test our hypothesis that objectively measured free-living energy expenditure does not differ significantly between developing and industrialized countries, we conducted a meta-analysis of studies that used DLW for the measurement of total energy expenditure (TEE) and physical activity level (PAL) in adults.

METHODS

Study selection

Studies were chosen for inclusion in these analyses if they were energy-expenditure studies that used the DLW technique. Weight-loss and postobese studies were excluded; intervention studies were included only if the preintervention measures were available. Also, studies of children, athletes, military personnel, and pregnant or lactating women were excluded. With the exception of one master's thesis (14), all data were retrieved from studies published in English-language journals. Articles were collected via a comprehensive literature search of Medline from 1986 to 30 June 2009. The keywords doubly labeled water (or doubly labelled water) and energy expenditure were used. Additional studies were found in the reference lists of identified articles. When data were not reported in articles as required for the meta-analysis (eg, if the data for both sexes were combined), attempts were made to contact the corresponding authors directly; in 8 cases, clarifications were received, and these studies were included. Studies with Eric Poehlman as a coinvestigator were excluded because of potential concerns regarding the authenticity of some data. The selection process for studies included in this meta-analysis is illustrated in **Figure 1**. Studies for which we could not break out mean data by sex, and studies with missing age, weight, or TEE data were excluded from the analyses ($n = 30$). Studies for which only PAL data were missing were included in the TEE analyses ($n = 26$). A total of 98 studies were included. Details of the cohorts and studies are shown in **Appendix A**.

Data extraction

We collected the year of publication, country of origin, sample size, sex, ethnicity (where available), cohort description, laboratory where the stable isotope analyses were conducted, and the mean (±SD) of age, weight, BMI, TEE (in MJ/d), and PAL (defined as the ratio of TEE to the resting energy expenditure). In all but 5 studies, the resting energy expenditure was measured with indirect calorimetry, and it was calculated by the original study investigators in the remaining studies by using Schofield's equations (15, 16), Mifflin's equations (17), or ethnic-specific equations (18, 19), and in one study PAL was estimated as

$$\text{TEE} \div (\text{BMR} + 0.1\ \text{TEE})\ (20) \qquad (1)$$

The human development index (HDI) developed by the United Nations Development Program was used to categorize the country of origin for each cohort as developing or middle income (ie, low or middle HDI) or developed (ie, high HDI) (21). Alternatively, cohorts were classified on the basis of on whether the country of origin had membership in the Organization for Economic and Community Development (OECD) (22).

Statistical analyses

With the METAN module of Stata (version 11; StataCorp, College Station, TX), meta-analyses were performed to obtain pooled estimates of mean effects and corresponding SEs for age, weight, BMI, TEE, and PAL after stratification by sex and age group (ie, <65 or ≥65 y). We used a random effects approach to estimate the summary effect size; this model incorporated an estimate of between-study heterogeneity into the study weights (23). The restricted maximum likelihood method was used to estimate the variance between studies. The I^2 statistic was computed to estimate the proportion of total variance that was due to differences in effect sizes. Under this model, the τ^2 statistic measured the amount of variability because of differences of the true effect sizes apart from random variation across studies. Meta-regression analyses allowed us to determine the extent to which the heterogeneity observed between studies was due to individual covariates or combinations of covariates. Concern over differing DLW analytic techniques prompted us to include the laboratory of analysis as a covariate in the meta-regression. We used dummy variables for the 4 most frequently cited laboratories (the Department of Human Biology, Maastricht University, Maastricht, Netherlands; the Medical Research Council Collaborative Centre for Human Nutrition Research, Cambridge, United Kingdom; the Department of Nutritional Sciences, University of Wisconsin, Madison, WI; and the Human Nutrition Research Center, US Department of Agriculture, Beltsville, MD) with the remainder combined in a fifth dummy variable.

The Q statistic was used to test for heterogeneity in TEE and PAL between studies. Meta-regression analyses were performed with the METAREG module of Stata (version 11; StataCorp) to determine the extent to which age, weight, BMI, and HDI (or OECD) status and year of study publication explained the heterogeneity observed in the meta-analyses. All meta-regression analyses were conducted separately for male and female cohorts.

RESULTS

Ninety-eight studies were included in the meta-analysis and represented 183 cohorts and 4972 individual men and women (details of studies included are shown in Appendix A). Of the 98 studies, 14 studies that represented 21 cohorts and 483

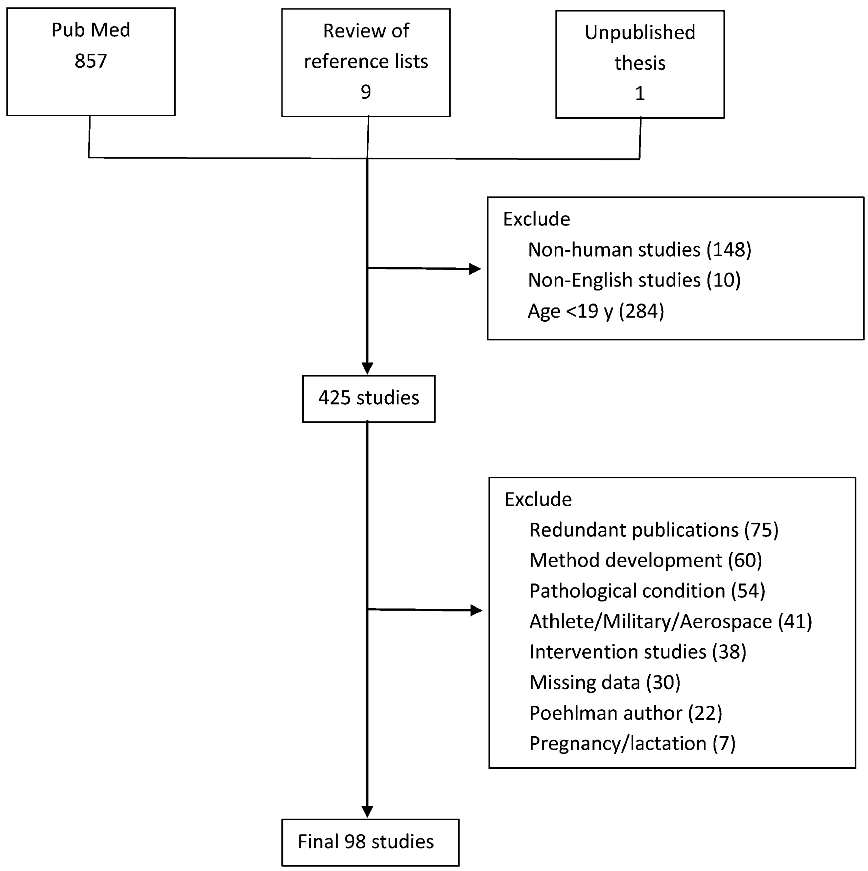

FIGURE 1. Study selection flowchart.

individuals were conducted in low- or middle-income countries as defined by HDI, specifically, Bolivia (24), Cameroon (25), China (18), Gambia (26–28), Guatemala (16), India (29), Jamaica (30), Nigeria (12, 31), Russia (remote Siberian herders) (32), South Africa (33), and Swaziland (15). The bulk of high-HDI studies were conducted in European countries (19, 34–59) and the United States (12, 14, 17, 20, 31, 59–100), with additions from Canada (101, 102), Mexico (103, 104), Cuba (104), Chile (104, 105), Brazil (106), Japan (107, 108), Australia (109–111), and New Zealand (112, 113). There were no cohorts in the low- or middle-HDI studies in which the mean age of the participants was ≥65 y; however, there were 30 such cohorts from 14 studies in the high-HDI group. Therefore, we presented the results of the meta-analysis with and without the studies with the older mean age of participants (**Table 1**). To make the low- or middle-HDI and high-HDI groups more comparable in terms of age, the 30 cohorts with a mean age ≥65 y were excluded from the meta-regression. The primary results of interest (ie, whether or not TEE

TABLE 1
Results of meta-analysis by sex, human development index (HDI) status, and age group[1]

	Men				Women			
	All	Low or middle HDI	High HDI	High HDI <65 y of age[2]	All	Low or middle HDI	High HDI	High HDI <65 y of age[2]
No. of studies	53	9	44	35	81	12	69	62
No. of cohorts	68	10	58	42	115	13	102	87
No. of subjects	1719	144	1575	1135	3253	339	2914	2462
Age (y)	43.2 ± 2.3[3]	32.5 ± 3.3	45.0 ± 2.6	34.5 ± 1.7	39.3 ± 1.9	33.2 ± 2.7	40.1 ± 2.1	35.1 ± 1.3
Weight (kg)	78.1 ± 1.5	66.1 ± 2.7	80.0 ± 1.6	81.3 ± 2.0	70.4 ± 2.8	59.3 ± 2.0	71.8 ± 3.0	72.6 ± 3.2
BMI (kg/m^2)	25.5 ± 0.4	22.7 ± 1.0	26.0 ± 0.7	26.0 ± 0.6	26.3 ± 0.4	24.3 ± 0.7	26.6 ± 0.4	26.6 ± 0.4
Total energy expenditure (MJ/d)	12.7 ± 0.2	12.3 ± 0.4	12.7 ± 0.3	13.5 ± 0.3	9.9 ± 0.1	9.3 ± 0.2	10.0 ± 0.1	10.3 ± 0.1
Physical activity level	1.80 ± 0.03	1.88 ± 0.06	1.79 ± 0.02	1.81 ± 0.03	1.71 ± 0.01	1.70 ± 0.03	1.71 ± 0.02	1.72 ± 0.02

[1] HDI is a composite statistic developed by the United Nations Development Program to rank countries by level of development. In our model, HDI status values were 0 (low or middle HDI) and 1 (high HDI).

[2] Cohorts were restricted to those in which the mean age of participants was <65 y of age.

[3] Mean ± SE (all such values).

or PAL differed between low- or middle-HDI and high-HDI countries) were not affected by the exclusion of these older cohorts.

As shown in Table 1, once the older cohorts were excluded from the meta-analysis, the mean ages for both men and women between the low- or middle-HDI and high-HDI groups were similar (32.5 compared with 34.5 y for men; 33.2 compared with 35.1 y for women). As expected, the mean body weight was lower in men in the low- or middle-HDI group than in men in the high-HDI group (66.1 compared with 81.3 kg, respectively); the same pattern was observed for women (59.3 compared with 72.6 kg, respectively). Mean BMI was also lower in the low- or middle-HDI group for both men (22.7 compared with 26.0 for men in the high-HDI group) and women (24.3 compared with 26.6 for women in the high-HDI group). TEE, unadjusted for body size or weight, was ≈1 MJ/d lower for both men and women in the low- or middle-HDI group than in the high HDI group. The I^2 statistic for sex- and HDI-stratified studies ranged between 83.1% for men in low- or middle-HDI countries to 91.1% for men in high-HDI countries, which indicated that 83.1% and 91.1% of the variance in TEE was due to differences in the true means for the respective groups of studies. The I^2 values were similar for PAL (data not shown). The τ^2 was 1.14 for men and 1.18 for the women, whereas the I^2 statistic was 90.2% and 93.9% for men and women, respectively. The forest plots for TEE by sex and HDI status are presented in **Figure 2**, A–D. In contrast, PAL, which can be considered modestly adjusted for body size (10), was higher in the low- or middle-HDI men than in high-HDI men [1.88 (95% CI: 1.77, 2.00) compared with 1.79 (95% CI: 1.74, 1.84), respectively] but slightly lower in low- or middle-HDI women than in high-HDI women [1.70 (95% CI: 1.63, 1.77) compared with 1.72 (95% CI: 1.68, 1.76), respectively] (forest plots of PAL by sex and HDI were not included).

With the use of meta-regression, we showed age was significantly and inversely associated and weight positively associated with TEE for both men and women in all models tested, except for women in model 1 (**Table 2**). The coefficients for age and weight were roughly similar to those measured for the 2003 Dietary Reference Intake equations (114). In contrast, HDI status was not associated with TEE (ie, after adjustment for age and body weight, TEE did not differ between low- or middle-development and high-development countries). The year of publication was marginally inversely associated ($P = 0.05$) with TEE in men but not in women, which suggested that TEE in men decreased modestly between 1989 (the first year of publication for a male cohort) and 2009. None of the laboratories exerted a significant effect on TEE, and inclusion of laboratory did not explain >1% of the residual heterogeneity observed between studies (data not shown). In addition, results were virtually identical when studies were classified by using HDI status or OECD membership (6 cohorts were reclassified); therefore, only the results for HDI are presented.

The results of the meta-regression analyses for PAL differed from those for TEE (**Table 3**). In women, none of the covariates examined were shown to be associated with PAL, whereas in men, only age was significantly inversely associated in all models tested. Because PAL was nominally adjusted for body size through the inclusion of the resting energy expenditure term, it was not surprising that weight did not explain any of the heterogeneity between studies. As with TEE, PAL did not differ by HDI status. In the full model after adjustment for age, weight, HDI status, and year of publication, there remained a relatively large degree of residual heterogeneity between studies (66.3% for men and 86.7% for women), which indicated that there were influences on TEE that we did not capture with this analysis. With PAL, the residual heterogeneity between studies was also high (88.0% for men and 90.1% for women).

DISCUSSION

Energy expenditure is a critical component of energy balance, but uncertainty remains over its direct effect on body weight in normal adult populations and the role it should play in public health policies for the prevention of overweight and obesity (115, 116). It has been hypothesized that lower BMIs observed in most developing compared with more-developed societies are due, in part, to higher levels of TEE and PAEE (10), which are assumed to be protective against excess weight gain.

Although it is indisputable that patterns of physical activity are different between countries at differing levels of industrialization, we could not detect differences in TEE or PAL, as measured by

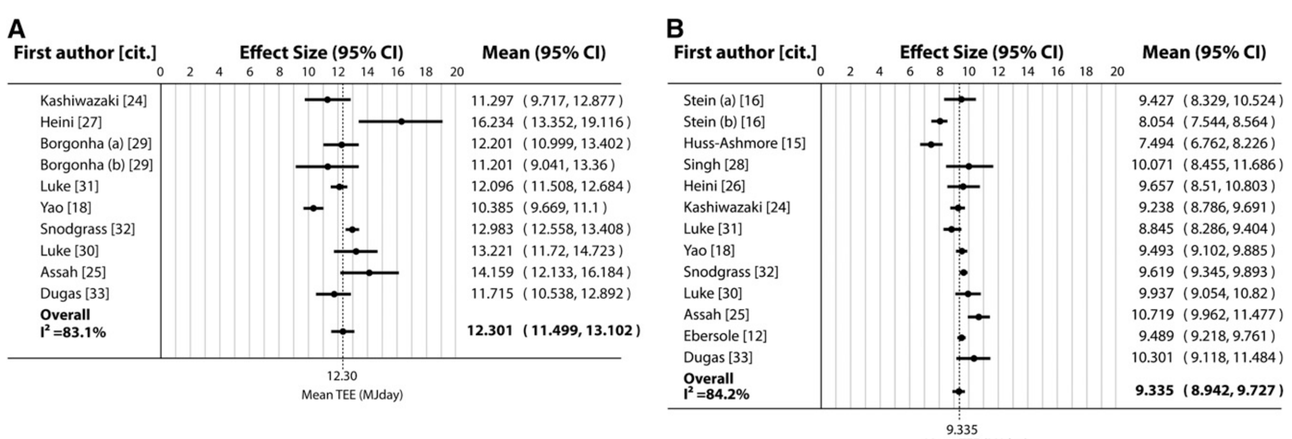

FIGURE 2. Forest plots of means (circles) and 95% CIs (horizontal lines) of total energy expenditure (TEE; in MJ/d) for men (<65 y of age) representing low– or middle–human development index (HDI) countries (A), for women (<65 y of age) representing low- or middle-HDI countries (B), for men (<65 y of age) representing high-HDI countries (C), and for women (<65 y of age) representing high-HDI countries (D). (*Continued*)

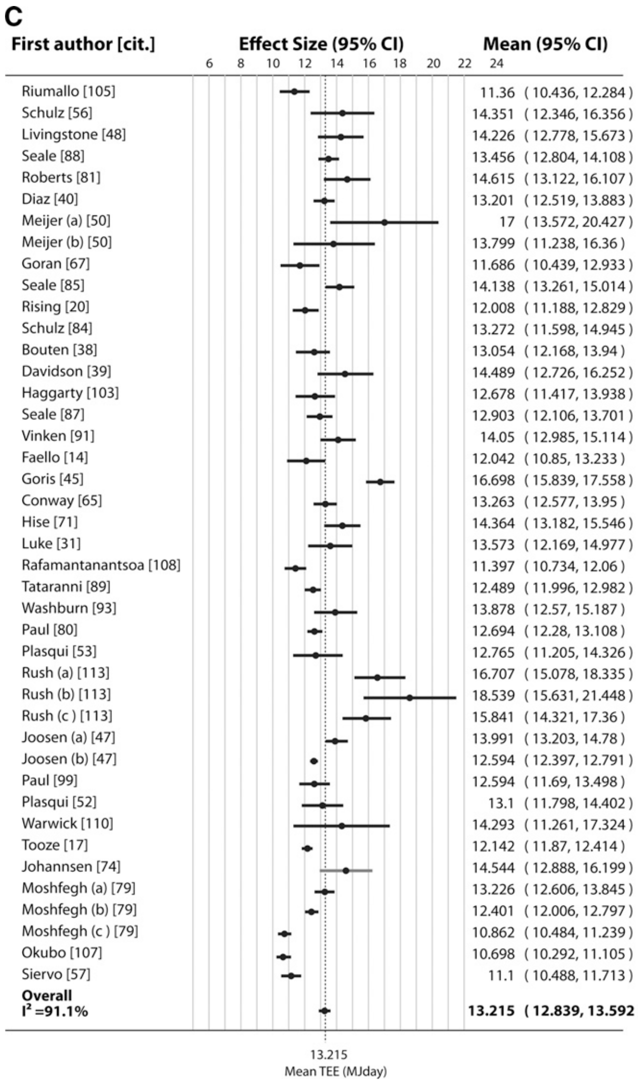

FIGURE 2. (*Continued*)

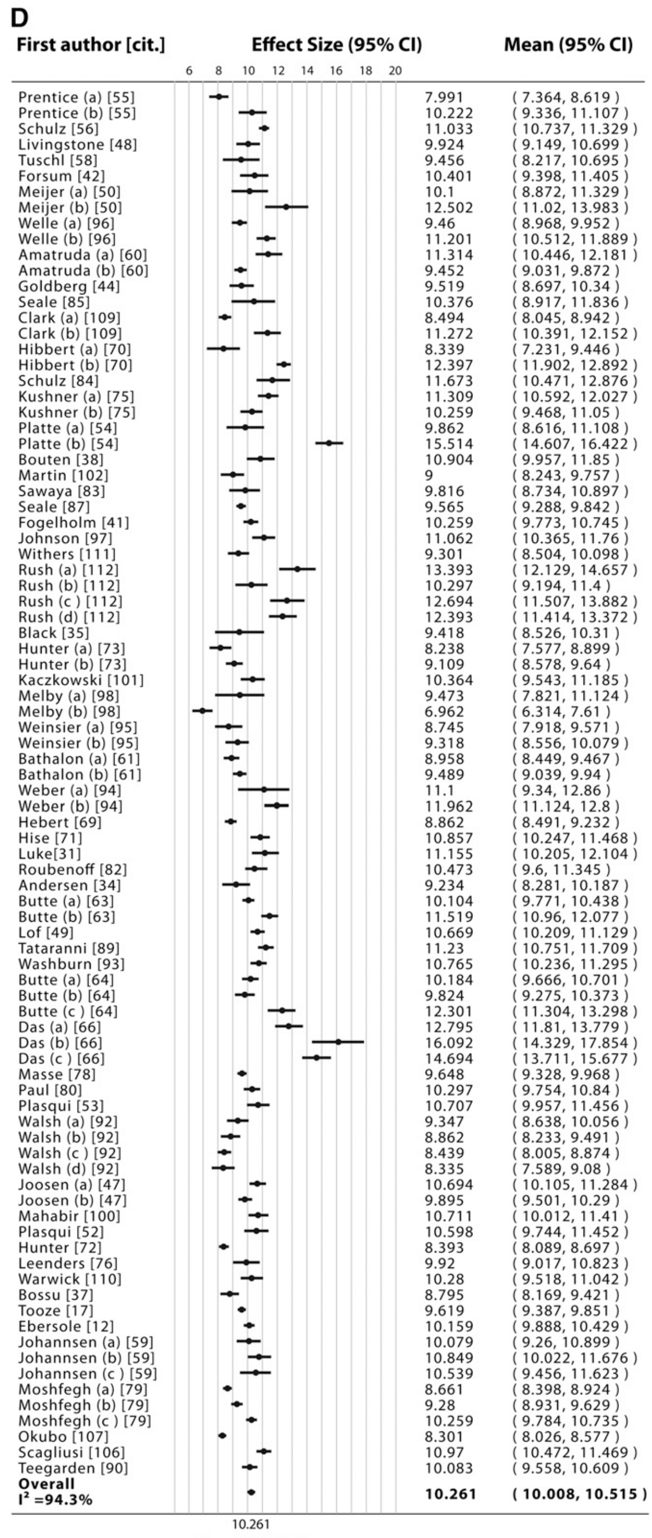

FIGURE 2. (*Continued*)

using DLW, between subjects from low- or middle-HDI and high-HDI countries. In our meta-regression analyses, age, weight, and sex were significant determinants of TEE, whereas only age was predictive of PAL in men. Once adjusted for age and weight, TEE and PAL did not differ by HDI status. This result conflicts with reports that implicated decreased levels of TEE (including PAEE) as a driver of the obesity epidemic (6, 7). These investigators and others have postulated that developing countries are at increased risk of the development of obesity because of decreases in the energy expenditure of occupational and transportation activities associated with increased mechanization and automation (3, 4, 117, 118).

There are relatively few published reports in which TEE or PAL is compared between populations (13, 119); most reports are compilations or reviews of existing literature (11, 120, 121). The findings of the current meta-analysis support the conclusions of Westerterp and Speakman (11), who collected data from multiple sources (some included in this meta-analysis) and examined TEE and PAL trends in industrialized societies and compared these to data from developing countries by using generalized linear regression models. The focus of their study was the change in energy expenditure over the 20-y period during which there was a marked increase in the prevalence of obesity in the US and most European countries (122). Interestingly, their analysis showed a slight increase in PAEE between 1988 and 2006 in industrialized countries, whereas PAL remained stable. The

TABLE 2
Results of meta-regression models with total energy expenditure (in kJ/d) as the outcome in cohorts with a mean age of <65 y[1]

Model and independent variable	Men (n = 1279) Values	P	Women (n = 2801) Values	P
Model 1				
Age	−50 (−90, −10)	0.02	−20 (−49, 8)	0.16
Model 2				
Weight	72 (44, 99)	<0.001	65 (54, 77)	<0.001
Model 3				
Age	−74 (−99, −48)	<0.001	−25 (−43, −7)	0.008
Weight	88 (66, 109)	<0.001	66 (55, 77)	<0.001
Model 4				
Age	−74 (−100, −48)	<0.001	−25 (−43, −7)	0.008
Weight	90 (66, 114)	<0.001	65 (54, 77)	<0.001
HDI status[2]	−190 (−950, 569)	0.62	130 (−438, 697)	0.65
Model 5				
Age	−69 (−94, −43)	<0.001	−24 (−42, 5)	0.02
Weight	93 (70, 116)	<0.001	66 (55, 78)	<0.001
HDI status[2]	−348 (−1090, 706)	0.35	139 (−428, 706)	0.63
Year of publication	−45 (−89, −1)	0.05	−17 (−48, 14)	0.28

[1] All values are coefficients; 95% CIs in parentheses. HDI, human development index.
[2] HDI is a composite statistic developed by the United Nations Development Program to rank countries by level of development. In our model, HDI status values were 0 (low or middle HDI) and 1 (high HDI).

investigators concluded it was unlikely that decreased energy expenditure was the primary cause of the current obesity epidemic.

A recent anthropologic review of farmers in developing countries reported considerable variation in PAL between groups of farmers, an, although the data generally supported the hypothesis that energy expenditure was high among farmers in developing countries, it was not as high as anticipated by the investigators (121). This review included 26 studies of both men and women, which used either objective or subjective data-collection techniques (ie, DLW, heart-rate monitoring, and questionnaires). The PAL for both men and women was in the range of moderate activity (for men: 1.36–2.40 with a mean of 1.90; for women: 1.47–2.36 with a mean of 1.74). The mean PAL reported in the review was somewhat higher than the PAL for the low- or middle-HDI samples in the current meta-analysis (ie, 1.88 for men and 1.70 for women) and likely reflect the effect of the different methodologies used by the studies included in the review. In this review of energy expenditure in farmers in developing countries, a significant variability in expenditure over

TABLE 3
Results of meta-regression models with physical activity level as the outcome in cohorts with a mean age of <65 y[1]

Model and independent variable	Men (n = 1279) Values	P	Women (n = 2801) Values	P
Model 1				
Age	−0.010 (−0.014, −0.004)	0.001	0.0001 (−0.004, 0.004)	0.94
Model 2				
Weight	−0.002 (−0.007, 0.004)	0.51	−0.001 (−0.003, 0.001)	0.32
Model 3				
Age	−0.009 (−0.014, −0.004)	0.002	0.0002 (−0.003, 0.004)	0.93
Weight	0.0004 (−0.005, 0.004)	0.88	−0.001 (−0.003, 0.001)	0.33
Model 4				
Age	−0.010 (−0.015, −0.004)	0.001	0.0001 (−0.004, 0.004)	0.94
Weight	0.001 (−0.004, 0.007)	0.59	−0.002 (−0.003, 0.001)	0.27
HDI status[2]	−0.112 (−0.268, 0.044)	0.15	0.032 (−0.071, 0.136)	0.54
Model 5				
Age	−0.010 (−0.016, −0.004)	0.001	−0.0001 (−0.004, 0.004)	0.95
Weight	0.001 (−0.005, 0.007)	0.70	−0.001 (−0.003, 0.001)	0.21
HDI status[2]	−0.105 (−0.264, 0.055)	0.19	0.029 (−0.074, 0.133)	0.57
Year of publication	0.003 (−0.008, 0.014)	0.60	0.003 (−0.003, 0.009)	0.31

[1] All values are coefficients; 95% CIs in parentheses. HDI, human development index.
[2] HDI is a composite statistic developed by the United Nations Development Program to rank countries by level of development. In our model, HDI status values were 0 (low or middle HDI) and 1 (high HDI).

the course of different seasons was also suggested (eg, the only studies that reported mean PAL in the vigorous range were conducted during the peak harvesting season).

For differences in energy expenditure between populations to be considered important for differences in obesity prevalence, some association between expenditure and excess weight gain must be shown. To our knowledge, this has not occurred. In several relatively large cross-sectional studies of individuals encompassing wide ranges of body weights and BMI, positive or null associations have been described between PAEE or PAL and BMI (55, 123, 124), rather than the anticipated negative association. The few prospective studies in adults that used objective measures have also showed no significant inverse relation between energy expenditure and weight gain (13, 89, 125, 126). Previous studies by Luke et al showed no difference in PAEE between Nigerian and African American women (12) and no association between PAEE and weight gain over 3 y (13). Although Ravussin et al (127) and Tataranni et al (89) reported that resting energy expenditure was a significant predictor of weight gain in adult Pima Indians, PAEE was not (89). Recent prospective work by Plasqui and Westerterp (128), suggested that high PAEE at baseline was not protective against subsequent weight gain and that a decrease in energy expenditure over time was predictive of gains in body fat. Although the results of studies that used self-reported physical activity were equivocal regarding subsequent weight gain (129, 130), in a large sample of healthy women, Lee et al (131) showed that high levels of self-reported physical activity (>21 metabolic equivalent task h/wk or >60 min/d) were associated with decreased weight gain.

The lack of observed differences in TEE and PAL in the current study suggested that the difference in mean BMI between low- or middle-HDI and high-HDI countries was due to energy intake rather than energy expenditure. Two recent articles (132, 133) provide further support that an increased food supply may be more important than a decrease in physical activity. Swinburn et al (132) estimated changes in body weight for both US children and adults between the 1970s and 2000s by using energy-intake data inserted into DLW-derived equations to estimate body weight. The predicted weight gain in children was identical to the measured weight gain, whereas for adults, the predicted weight gain was actually higher than the measured weight gain, which indicated that current increases in energy intake were sufficient to explain the significant increase in obesity prevalence. In the second article, also by Swinburn et al (133), an equation for relating energy flux to body weight was investigated by using DLW data from the past 3 decades. Energy flux was positively related to weight after adjustment for height, age, and sex, and the authors concluded that an increase in energy intake was primarily responsible for increases in body weight over the past 3 decades (133).

As with any analysis of data from multiple sources, there were limitations to the current study. Research that used DLW for the measurement of TEE has been hampered by the high cost of isotopes and the isotopic analysis; thus, most studies included in this meta-analysis were of a relatively small size. In addition, few of the studies were population-based or had randomly selected participants, and therefore most samples were not truly representative of the population from which they were drawn. Another potential limitation was the use of TEE adjusted for body weight via meta-regression and the use of PAL rather than examining PAEE directly. These expenditure variables were chosen for inclusion because of availability in the largest number of studies; in a majority of studies, either PAEE, or resting energy expenditure for the calculation of PAEE, were not presented or the method of calculation was not explicit in the text. PAL calculated as the ratio of TEE to resting energy expenditure is not an optimal measure of physical activity expenditure; however, it is the metric used most often for comparisons between countries (10). In addition, we did not ascertain occupation or site of residence (ie, rural or urban) of the cohorts within each country; thus, simply identifying a country as low or high HDI may have overgeneralized important individual study characteristics.

The statistical method of a meta-analysis has its own set of limitations. Meta-analysis of observational data often produces spurious results because of unadjusted for confounding factors (134, 135), and these cannot be ruled out as an explanation of our findings. Unlike a typical meta-analysis, we did not focus on an exposure-disease relation but instead summarized mean levels of TEE and PAL in studies that have been conducted around the world. The heterogeneity in populations observed in these analyses might also seem a limitation; however, we argue that it is a strength. Explanation of heterogeneity should be regarded as a goal of the review of observational studies, which may be carried out by using a meta-regression (135). To our surprise, the meta-regression revealed that HDI explained none of the heterogeneity between studies, whereas the mean body weight of the study populations was explanatory.

In conclusion, we showed no differences for DLW-measured TEE or PAL between populations living in countries with a high- compared with low- or middle-development index despite significant differences in body size. These data draw into question the commonly held belief that energy expenditure differs between populations living in developing and industrialized countries, thereby accounting for much of observed disparities in obesity prevalence.

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APPENDIX A

Details of 98 studies and 183 cohorts[1]

First author, year	Population or cohort description	HDI status[2]	OECD member[3]	No. of subjects	Sex[4]	Age	Weight	BMI	TEE	PAL	Laboratory[5]	Reference no.
						y	*kg*	*kg/m²*	*MJ/d*			
Low or middle HDI: men <65 y of age												
Kashiwazaki, 1995	Bolivia, Aymara, average	1	1	6	0	45.8 ± 4.7[6]	54.6 ± 1.3	21.2 ± 0.7	11.30 ± 0.81	2.02 ± 0.09	1	24
Heini, 1996	Gambia, average	1	1	8	0	25.0 ± 1.4	61.2 ± 3.6	21.2 ± 0.9	16.23 ± 1.47	2.40 ± 0.14	1	27
Borgonha, 2000 (a)	India, rural	1	1	6	0	23.0 ± 0.9	55.3 ± 1.1	18.1 ± 0.2	12.20 ± 0.61	1.90 ± 0.08	5	29
Borgonha, 2000 (b)	India, urban control subjects	1	1	6	0	20.2 ± 0.8	64.7 ± 2.3	22.7 ± 0.7	11.20 ± 1.10	1.79 ± 0.11	5	29
Luke, 2002	Nigeria, average	1	1	30	0	39.9 ± 2.3	60.8 ± 2.3	20.9 ± 0.5	10.38 ± 0.37	1.70 ± 0.05	2	31
Yao, 2002	China, urban average	1	1	33	0	43.1 ± 0.7	73.4 ± 2.2	24.7 ± 0.6	12.10 ± 0.30	1.77 ± 0.04	5	18
Snodgrass, 2006	Sakha Republic (Russia), average	1	1	14	0	33.3 ± 2.6	72.2 ± 3.9	25.1 ± 1.3	12.98 ± 0.22	1.68 ± 0.09	2	32
Luke, 2007	Jamaica, average	1	1	17	0	38.2 ± 1.7	83.1 ± 5.2	27 ± 1.6	13.22 ± 0.77	2.03 ± 0.08	2	30
Assah, 2009	Cameroon, average	1	1	16	0	32.8 ± 1.8	78.2 ± 3.3	25.6 ± 0.9	14.23 ± 1.03	1.87 ± 0.12	5	25
Dugas, 2009	South Africa, average	1	1	8	0	26.5 ± 1.1	64.1 ± 2.7	21.6 ± 0.9	11.72 ± 0.60	—	2	33
Low or middle HDI: women <65 y of age												
Stein, 1988 (a)	Guatemala, urban high SES	1	1	7	1	36.9 ± 2.3	59.8 ± 5.5	26.9 ± 2.0	9.43 ± 0.56	1.68 ± 0.07	5	16
Stein, 1988 (b)	Guatemala, urban low SES	1	1	8	1	34.6 ± 2.7	49.1 ± 2.8	21.8 ± 1.3	8.05 ± 0.26	1.62 ± 0.06	5	16
Huss-Ashmore, 1989	Swaziland, young, students	1	1	14	1	21.0 ± 0.7	54.2 ± 1.0	21.3 ± 0.3	7.49 ± 0.37	1.39 ± 0.07	5	15
Singh, 1989	Gambia, rural	1	1	10	1	30.0 ± 2.2	49.4 ± 1.7	—	10.07 ± 0.82	1.98 ± 0.13	1	28
Heini, 1991	Gambia, rural	1	1	7	1	26.0 ± 1.3	50.2 ± 2.3	20 ± 0.9	9.66 ± 0.59	1.90 ± 0.15	1	26
Kashiwazaki, 1995	Bolivia, Aymara, average	1	1	7	1	41.0 ± 6.1	50.0 ± 2.9	21.9 ± 1.5	9.24 ± 0.23	1.90 ± 0.09	1	24
Luke, 2002	Nigeria, average	1	1	28	1	42.4 ± 1.6	53.1 ± 1.9	21.3 ± 0.7	8.84 ± 0.29	1.78 ± 0.06	2	31
Yao, 2002	China, urban, average	1	1	40	1	42.6 ± 0.6	65.5 ± 2.0	25.3 ± 0.6	9.49 ± 0.20	1.66 ± 0.02	5	18
Snodgrass, 2006	Sakha Republic (Russia), average	1	1	14	1	31.4 ± 2.6	65.2 ± 5.2	26.9 ± 1.9	9.62 ± 0.14	1.50 ± 0.05	2	32
Luke, 2007	Jamaica, average	1	1	18	1	37.7 ± 1.6	76.0 ± 4.9	29 ± 1.7	9.94 ± 0.45	1.76 ± 0.05	2	30
Assah, 2009	Cameroon, average	1	1	17	1	35.6 ± 1.8	76.7 ± 3.2	28.4 ± 1.2	10.76 ± 0.39	1.71 ± 0.06	5	25
Ebersole, 2008	Nigeria, average	1	1	149	1	31.9 ± 1.0	57.8 ± 1.0	22.6 ± 0.4	9.49 ± 0.14	1.77 ± 0.02	2	12
Dugas, 2009	South Africa, average	1	1	20	1	23.5 ± 0.7	77.1 ± 4.7	31 ± 1.7	10.30 ± 0.60	—	2	33
High HDI: men <65 y of age												
Riumallo, 1989	Chile, average	2	1	6	0	26.8 ± 1.8	55.0 ± 1.6	19.6 ± 0.2	11.36 ± 0.47	1.81[7]	2	105
Schulz, 1989	Netherlands, average	2	2	4	0	23.7[7]	74.6 ± 5.1	—	14.35 ± 1.02	1.92 ± 0.14	3	56
Livingstone, 1990	United Kingdom, average	2	2	16	0	31.5 ± 1.8	79.7 ± 3.0	25.8 ± 0.8	14.23 ± 0.74	1.88 ± 0.08	1	48
Seale, 1990	United States, average	2	2	4	0	41.0 ± 4.0	84.6 ± 3.6	26.5 ± 1.1	13.46 ± 0.33	—	4	88
Roberts, 1991	United States, sedentary students	2	2	14	0	22.3 ± 0.5	72.6 ± 3.2	23.2 ± 0.7	14.61 ± 0.76	1.98 ± 0.08	5	81
Diaz, 1992	United Kingdom, overfeeding subjects at baseline	2	2	10	0	29.6 ± 2.5	73.4 ± 2.7	23.2 ± 0.8	13.20 ± 0.35	1.80 ± 0.06	1	40
Meijer, 1992 (a)	Netherlands, obese	2	2	4	0	37.0 ± 2.0	109.2 ± 10.1	32.4 ± 2.1	17.00 ± 1.75	—	3	50
Meijer, 1992 (b)	Netherlands, lean	2	2	6	0	37.0 ± 1.2	74.0 ± 3.4	24 ± 0.6	13.80 ± 1.31	—	3	50
Goran, 1993	United States, average	2	2	17	0	22.0 ± 0.9	68.3 ± 2.0	22.1[7]	11.69 ± 0.64	1.70 ± 0.09	5	67
Seale, 1993	United States, average	2	2	5	0	41.8 ± 3.9	87.3 ± 3.5	27.4 ± 1.1	14.14 ± 0.45	—	4	85
Rising, 1994	United States, Pima Indians	2	2	30	0	42.0 ± 2.9	83.6 ± 3.7	28.6[7]	12.01 ± 0.42	1.39 ± 0.04	5	20
Schulz, 1994	United States, Pima Indians	2	2	12	0	35.4 ± 4.0	97.0 ± 10.0	32.3 ± 2.7	13.27 ± 0.85	1.66 ± 0.08	5	84

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APPENDIX A (*Continued*)

First author, year	Population or cohort description	HDI status[2]	OECD member[3]	No. of subjects	Sex[4]	Age	Weight	BMI	TEE	PAL	Laboratory[5]	Reference no.
						y	*kg*	*kg/m²*	*MJ/d*			
Bouten, 1996	Netherlands, average	2	2	16	0	28.4 ± 1.2	79.9 ± 2.1	24.6 ± 0.6	13.05 ± 0.45	1.71 ± 0.05	3	38
Davidson, 1997	Scotland, average	2	2	9	0	38.0 ± 3.0	66.6 ± 2.1	21.6 ± 0.5	14.49 ± 0.90	2.01 ± 0.10	5	39
Haggarty, 1997	Mexico, construction workers	2	2	13	0	21.0 ± 0.8	63.9 ± 3.1	22.5 ± 1.1	12.68 ± 0.64	1.78 ± 0.06	5	103
Seale, 1997	United States, nonobese	2	2	8	0	49.5 ± 2.5	82.4 ± 2.5	25.7 ± 0.5	12.90 ± 0.41	—	4	87
Vinken, 1999	United States, young	2	2	24	0	23.1 ± 0.5	71.7 ± 2.1	22.6 ± 0.5	14.05 ± 0.54	1.94 ± 0.06	5	91
Faello, 2000	United States, average	2	2	9	0	56.3 ± 1.7	88.5 ± 4.8	28.2 ± 1.1	12.04 ± 0.61	1.64 ± 0.09	5	14
Goris, 2000	Netherlands, obese	2	2	30	0	44.0 ± 1.3	108.8 ± 2.7	34.1 ± 0.7	16.70 ± 0.44	—	3	45
Conway, 2002	United States, average	2	2	24	0	41.2 ± 2.0	79.5 ± 1.8	25.1 ± 0.5	13.26 ± 0.35	1.81 ± 0.03	4	65
Hise, 2002	United States, average	2	2	22	0	22.7 ± 0.8	97.5 ± 2.2	30.3 ± 0.6	14.36 ± 0.60	1.63 ± 0.07	5	71
Luke, 2002	United States, African American, average	2	2	12	0	30.8 ± 2.4	86.4 ± 5.5	27.3 ± 1.8	13.57 ± 0.72	1.85 ± 0.07	2	31
Rafamantanantsoa, 2002	Japan, average	2	2	24	0	48.0 ± 2.0	65.5 ± 2.2	23.1 ± 0.6	11.40 ± 0.34	—	5	108
Tataranni, 2003	United States, Pima Indians	2	2	64	0	37.0 ± 1.6	88.0 ± 2.4	30[7]	12.49 ± 0.25	1.58 ± 0.03	5	89
Washburn, 2003	United States, sedentary	2	2	17	0	23.9 ± 0.9	95.1 ± 2.9	29.8 ± 0.7	13.88 ± 0.67	—	5	93
Paul, 2004	United States, average	2	2	44	0	47.0 ± 1.7	83.2 ± 1.9	26.4 ± 0.6	12.69 ± 0.21	1.64 ± 0.03	4	80
Plasqui, 2004	Netherlands, urban, winter	2	2	9	0	26.0 ± 0.7	70.1 ± 3.3	20.8 ± 0.7	12.77 ± 0.80	1.80 ± 0.06	3	53
Rush, 2004 (a)	New Zealand, Maori, average	2	2	10	0	22.1 ± 1.0	100.3 ± 9.2	30.4 ± 2.5	16.71 ± 0.83	2.14 ± 0.09	1	113
Rush, 2004 (b)	New Zealand, Pacific Islander, average	2	2	9	0	23.2 ± 0.6	103.1 ± 4.7	31.8 ± 1.5	18.54 ± 1.48	2.29 ± 0.14	1	113
Rush, 2004 (c)	New Zealand, European, average	2	2	10	0	22.6 ± 0.9	82.6 ± 3.7	25.9 ± 1.3	15.84 ± 0.78	2.33 ± 0.08	1	113
Joosen, 2005 (a)	Netherlands, monozygotic twins	2	2	10	0	25.0 ± 2.5	75.2 ± 3.4	22.9 ± 0.8	13.99 ± 0.40	1.97[7]	3	47
Joosen, 2005 (b)	Netherlands, dizygotic twins	2	2	2	0	20.0 ± 0.0	70.2 ± 0.4	21 ± 0.3	12.59 ± 0.10	1.83[7]	3	47
Paul, 2005	United States, average	2	2	12	0	39.0 ± 2.6	79.9 ± 2.4	24.1 ± 0.4	12.59 ± 0.46	—	4	99
Plasqui, 2005	Netherlands, average	2	2	10	0	24.0 ± 2.6	71.9 ± 2.5	22.4 ± 0.8	13.10 ± 0.66	1.90 ± 0.04	3	52
Warwick, 2006	Australia, average	2	2	7	0	29.6 ± 1.6	73.2 ± 3.3	22.9 ± 0.6	14.29 ± 1.55	1.90 ± 0.13	5	110
Tooze, 2007	United States, middle-aged	2	2	259	0	53.9 ± 0.5	88.0 ± 1.0	28.1 ± 0.3	12.14 ± 0.14	1.77 ± 0.01	2	17
Johannsen, 2008	United States, average young	2	2	19	0	27.0 ± 1.0	88.0 ± 4.1	28 ± 1.0	14.54 ± 0.84	1.88 ± 0.06	5	74
Moshfegh, 2008 (a)	United States, obese	2	2	54	0	52.0 ± 1.5	103.7 ± 1.6	33.1 ± 0.4	13.23 ± 0.32	1.64 ± 0.05	4	79
Moshfegh, 2008 (b)	United States, overweight	2	2	114	0	50.0 ± 1.0	84.8 ± 0.6	27.3 ± 0.1	12.40 ± 0.20	1.68 ± 0.03	4	79
Moshfegh, 2008 (c)	United States, normal weight	2	2	94	0	49.0 ± 1.1	72.6 ± 0.7	23.1 ± 0.2	10.86 ± 0.19	1.64 ± 0.03	4	79
Okubo, 2008	Japan, average	2	2	67	0	39.4 ± 1.4	67.3 ± 1.2	23.3 ± 0.4	10.70 ± 0.21	1.70 ± 0.03	5	107
Siervo, 2008	United Kingdom, average	2	2	5	0	44.2 ± 5.2	68.7 ± 4.4	21.6 ± 0.9	11.10 ± 0.31	1.62 ± 0.09	1	57
High HDI: women <65 y of age												
Prentice, 1986 (a)	United Kingdom, average	2	2	13	1	29.0 ± 1.4	57.5 ± 1.7	22.1 ± 0.7	7.99 ± 0.32	1.42 ± 0.04	1	55
Prentice, 1986 (b)	United Kingdom, obese	2	2	9	1	35.0 ± 1.7	87.9 ± 4.8	32.9 ± 1.5	10.22 ± 0.45	1.54 ± 0.06	1	55
Schulz, 1989	Netherlands, average	2	2	2	1	23.7[7]	62.0 ± 0.1	—	11.03 ± 0.15	1.99 ± 0.19	3	56
Livingstone, 1990	United Kingdom, average	2	2	15	1	35.5 ± 2.9	62.4 ± 2.1	24.3 ± 0.8	9.92 ± 0.40	1.76 ± 0.04	1	48
Tuschl, 1990	Germany, unrestrained eaters	2	2	11	1	24.0[7]	57.5 ± 1.5	20 ± 0.4	9.46 ± 0.63	—	5	58
Forsum, 1992	Sweden, subgroup 1 prepregnancy	2	2	22	1	29.0 ± 0.9	61.0 ± 2.1	22.3 ± 0.7	10.40 ± 0.51	1.87 ± 0.10	3	42
Meijer, 1992 (a)	Netherlands, lean	2	2	5	1	28.0 ± 3.1	53.8 ± 0.9	19.6 ± 0.6	10.10 ± 0.63	—	3	50
Meijer, 1992 (b)	Netherlands, obese	2	2	7	1	33.0 ± 2.6	83.0 ± 5.0	29.9 ± 1.1	12.50 ± 0.76	—	3	50
Welle, 1992 (a)	United States, normal weight	2	2	12	1	33.0 ± 1.7	59.6 ± 1.2	21.2 ± 0.2	9.46 ± 0.25	1.67 ± 0.05	5	96

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APPENDIX A (*Continued*)

First author, year	Population or cohort description	HDI status[2]	OECD member[3]	No. of subjects	Sex[4]	Age	Weight	BMI	TEE	PAL	Laboratory[5]	Reference no.
						y	*kg*	*kg/m²*	*MJ/d*			
Welle, 1992 (b)	United States, overweight	2	2	26	1	36.0 ± 1.4	85.2 ± 2.1	31.8 ± 0.5	11.20 ± 0.35	1.76 ± 0.05	5	96
Amatruda, 1993 (a)	United States, obese before weight loss	2	2	18	1	39.5 ± 1.2	83.7 ± 2.0	31.1[7]	11.31 ± 0.44	1.81[7]	5	60
Amatruda, 1993 (b)	United States, lean/control subjects	2	2	14	1	34.0 ± 1.7	58.2 ± 1.5	21.1[7]	9.45 ± 0.21	1.68[7]	5	60
Goldberg, 1993	United Kingdom, average	2	2	12	1	28.8 ± 1.0	61.7 ± 2.5	23 ± 1.0	9.52 ± 0.42	1.58 ± 0.05	1	44
Seale, 1993	United States, average	2	2	4	1	29.3 ± 4.0	52.4 ± 2.4	20.4 ± 1.0	10.38 ± 0.74	—	4	85
Clark, 1994 (a)	Australia, large eater	2	2	6	1	37.3 ± 1.5	50.9 ± 1.0	18.6 ± 0.7	8.49 ± 0.23	1.56 ± 0.03	5	109
Clark, 1994 (b)	Australia, small eater	2	2	6	1	39.7 ± 0.8	59.9 ± 1.3	22.8 ± 0.9	11.27 ± 0.45	2.11 ± 0.04	5	109
Hibbert, 1994 (a)	United States, lean	2	2	9	1	31.0 ± 1.9	60.0 ± 2.2	22 ± 0.3	8.34 ± 0.56	1.64 ± 0.11	5	70
Hibbert, 1994 (b)	United States, obese	2	2	5	1	29.0 ± 1.8	101.0 ± 7.6	36 ± 1.8	12.40 ± 0.25	1.95 ± 0.20	5	70
Schulz, 1994	United States, Pima Indians	2	2	9	1	31.3 ± 4.3	106.2 ± 10.9	42.2 ± 4.2	11.67 ± 0.61	1.58 ± 0.05	5	84
Kushner, 1995 (a)	United States, obese white	2	2	15	1	38.7 ± 1.5	91.0 ± 2.6	32.9 ± 0.6	11.31 ± 0.37	1.78 ± 0.05	2	75
Kushner, 1995 (b)	United States, obese black	2	2	14	1	39.8 ± 1.3	93.5 ± 2.3	35.3 ± 0.8	10.26 ± 0.40	1.66 ± 0.05	2	75
Platte, 1995 (a)	Germany, control students	2	2	11	1	24.5 ± 1.3	57.5 ± 1.5	20.1 ± 0.4	9.86 ± 0.64	—	5	54
Platte, 1995 (b)	Germany, obese	2	2	11	1	32.6 ± 2.3	100.7 ± 5.3	37.4 ± 2.4	15.51 ± 0.46	—	5	54
Bouten, 1996	Netherlands, average	2	2	14	1	25.6 ± 1.3	63.5 ± 1.7	23.4 ± 0.5	10.90 ± 0.48	1.78 ± 0.07	3	38
Martin, 1996	Canada, validation sample	2	2	29	1	48.7 ± 0.9	61.9 ± 1.2	23.3 ± 0.5	9.00 ± 0.39	1.44 ± 0.02	5	102
Sawaya, 1996	United States, young	2	2	10	1	25.2 ± 1.1	54.8 ± 1.3	20.9 ± 0.6	9.82 ± 0.55	—	5	83
Seale, 1997	United States, nonobese	2	2	11	1	51.9 ± 1.5	62.4 ± 1.9	22.6 ± 0.8	9.56 ± 0.14	—	4	87
Fogelholm, 1998	Finland, overweight	2	2	20	1	40.0 ± 0.9	79.8 ± 1.8	29.2 ± 0.7	10.26 ± 0.25	1.66 ± 0.03	3	41
Johnson, 1998	United States, low-income average	2	2	35	1	30.2 ± 1.1	70.5 ± 3.6	28.3 ± 1.3	11.06 ± 0.36	—	5	97
Withers, 1998	Australia, sedentary	2	2	8	1	57.5 ± 1.4	61.7 ± 1.7	22.5 ± 0.6	9.30 ± 0.41	1.87 ± 0.07	5	111
Rush, 1999 (a)	New Zealand, obese Polynesian	2	2	15	1	21.9 ± 0.5	104.6 ± 3.9	38.8 ± 1.8	13.39 ± 0.64	1.71 ± 0.08	5	112
Rush, 1999 (b)	New Zealand, nonobese European	2	2	23	1	21.8 ± 0.5	63.7 ± 2.6	23.4 ± 0.8	10.30 ± 0.56	1.58 ± 0.06	5	112
Rush, 1999 (c)	New Zealand, obese European	2	2	17	1	23.0 ± 0.5	97.6 ± 4.2	36.2 ± 1.4	12.69 ± 0.61	1.71 ± 0.06	5	112
Rush, 1999 (d)	New Zealand, nonobese Polynesian	2	2	25	1	21.5 ± 0.4	74.5 ± 2.2	26.6 ± 0.8	12.39 ± 0.50	1.88 ± 0.08	5	112
Black, 2000	United Kingdom, average	2	2	16	1	57.5 ± 1.2	68.7 ± 2.5	25.1 ± 1.1	9.42 ± 0.46	1.65 ± 0.07	5	35
Hunter, 2000 (a)	United States, black	2	2	18	1	35.6 ± 1.6	63.3 ± 1.6	23.9 ± 0.3	8.24 ± 0.34	1.60[7]	5	73
Hunter, 2000 (b)	United States, white	2	2	17	1	35.2 ± 1.8	65.1 ± 1.4	23.6 ± 0.3	9.11 ± 0.27	1.61[7]	5	73
Kaczkowski, 2000	Canada, weight stable	2	2	53	1	65.0 ± 1.5	63.0 ± 1.6	24.4 ± 0.5	10.36 ± 0.42	—	5	101
Melby, 2000 (a)	United States, white	2	2	11	1	21.5 ± 0.9	59.3 ± 2.2	23 ± 0.8	9.47 ± 0.84	1.80 ± 0.12	5	98
Melby, 2000 (b)	United States, black	2	2	13	1	22.5 ± 0.7	60.1 ± 2.4	22.5 ± 0.8	6.96 ± 0.33	1.39 ± 0.05	5	98
Weinsier, 2000 (a)	United States, overweight black	2	2	14	1	37.9 ± 1.9	78.0 ± 2.2	28.9 ± 0.6	8.74 ± 0.42	1.52[7]	5	95
Weinsier, 2000 (b)	United States, overweight white	2	2	18	1	38.1 ± 1.6	79.5 ± 1.2	29.1 ± 0.4	9.32 ± 0.39	1.46[7]	5	95
Bathalon, 2001 (a)	United States, restrained eaters	2	2	34	1	59.4 ± 0.6	64.0 ± 1.5	24.8 ± 0.5	8.96 ± 0.26	1.72 ± 0.04	5	61
Bathalon, 2001 (b)	United States, unrestrained eaters	2	2	26	1	60.3 ± 0.6	63.8 ± 1.7	23.6 ± 0.6	9.49 ± 0.23	1.84 ± 0.04	5	61
Weber, 2001 (a)	United States, college, lean	2	2	8	1	22.8 ± 1.1	56.6 ± 2.4	21.4 ± 0.8	11.10 ± 0.90	—	5	94
Weber, 2001 (b)	United States, college, obese	2	2	8	1	25.1 ± 2.3	83.9 ± 3.4	32 ± 1.2	11.96 ± 0.43	—	5	94
Hebert, 2002	United States, average	2	2	80	1	49.1 ± 0.8	69.9 ± 1.2	27 ± 0.4	8.86 ± 0.19	—	5	69
Hise, 2002	United States, average	2	2	32	1	22.1 ± 0.8	80.7 ± 1.7	29.5 ± 0.5	10.86 ± 0.31	1.65 ± 0.04	5	71
Luke, 2002	United States, African American average	2	2	22	1	31.8 ± 1.7	81.6 ± 4.8	30.9 ± 1.5	11.15 ± 0.48	1.91 ± 0.07	2	31

(Continued)

APPENDIX A (*Continued*)

First author, year	Population or cohort description	HDI status[2]	OECD member[3]	No. of subjects	Sex[4]	Age	Weight	BMI	TEE	PAL	Laboratory[5]	Reference no.
						y	*kg*	*kg/m²*	*MJ/d*			
Roubenoff, 2002	United States, no rheumatoid arthritis	2	2	20	1	48.0 ± 3.1	68.1 ± 2.5	24.2 ± 0.7	10.47 ± 0.45	1.89 ± 0.08	5	82
Anderson, 2003	Norway, average	2	2	17	1	23.7 ± 0.6	62.0 ± 1.8	21.8 ± 0.5	9.23 ± 0.49	—	5	34
Butte, 2003 (a)	United States, normal weight	2	2	70	1	31.0 ± 0.5	57.5 ± 0.7	21.2 ± 0.2	10.10 ± 0.17	1.87 ± 0.03	5	63
Butte, 2003 (b)	United States, overweight	2	2	33	1	31.0 ± 0.7	80.8 ± 1.8	29.6 ± 0.6	11.52 ± 0.28	1.86 ± 0.05	5	63
Lof, 2003	Sweden, average	2	2	34	1	30.0 ± 0.7	67.0 ± 1.7	24 ± 0.7	10.67 ± 0.23	1.98 ± 0.04	5	49
Tataranni, 2003	United States, Pima Indians	2	2	28	1	32.0 ± 1.9	95.0 ± 2.5	37[7]	11.23 ± 0.24	1.58 ± 0.03	5	89
Washburn, 2003	United States, sedentary	2	2	29	1	23.3 ± 0.9	79.1 ± 1.8	29.4 ± 0.5	10.77 ± 0.27	—	5	93
Butte, 2004 (a)	United States, prepregnancy, normal-weight	2	2	34	1	30.3 ± 0.7	59.3 ± 10.2	22.1 ± 0.3	10.18 ± 0.26	1.84 ± 0.04	5	64
Butte, 2004 (b)	United States, prepregnancy, underweight	2	2	17	1	30.8 ± 0.9	49.9 ± 0.9	18.9 ± 0.2	9.82 ± 0.28	1.97 ± 0.06	5	64
Butte, 2004 (c)	United States, prepregnancy, overweight	2	2	12	1	31.2 ± 1.3	77.3 ± 2.9	28.8 ± 0.8	12.30 ± 0.51	1.96 ± 0.06	5	64
Das, 2004 (a)	United States, obese, BMI (in kg/m²) ≈41	2	2	12	1	36.2 ± 0.5	106.7 ± 0.2	40.8 ± 0.7	12.79 ± 0.50	1.61 ± 0.06	5	66
Das, 2004 (b)	United States, obese, BMI ≈60	2	2	8	1	35.4 ± 0.9	162.0 ± 0.6	60.3 ± 2.2	16.09 ± 0.90	1.62 ± 0.05	5	66
Das, 2004 (c)	United States, obese, BMI ≈49	2	2	10	1	40.1 ± 0.5	134.3 ± 0.3	49.5 ± 1.0	14.69 ± 0.50	1.67 ± 0.04	5	66
Masse, 2004	United States, black and Hispanic	2	2	136	1	49.7 ± 0.6	76.0 ± 1.4	29.9 ± 0.6	9.65 ± 0.16	1.70 ± 0.03	5	78
Paul, 2004	United States, average	2	2	47	1	48.0 ± 1.5	74.2 ± 2.6	27.4 ± 0.9	10.30 ± 0.28	1.69 ± 0.03	4	80
Plasqui, 2004	Netherlands, urban, average, summer	2	2	15	1	25.0 ± 0.5	64.4 ± 1.5	21.9 ± 0.5	10.71 ± 0.38	1.79 ± 0.05	3	53
Walsh, 2004 (a)	United States, white overweight	2	2	21	1	36.5 ± 1.3	78.7 ± 1.2	29.1 ± 0.4	9.35 ± 0.36	—	5	92
Walsh, 2004 (b)	United States, black overweight	2	2	20	1	36.0 ± 1.3	78.0 ± 2.1	28.6 ± 0.4	8.86 ± 0.32	—	5	92
Walsh, 2004 (c)	United States, white control subjects	2	2	20	1	31.8 ± 1.2	62.3 ± 1.1	23.1 ± 0.2	8.44 ± 0.22	—	5	92
Walsh, 2004 (d)	United States, black control subjects	2	2	14	1	31.9 ± 1.3	59.9 ± 1.5	23 ± 0.4	8.33 ± 0.38	—	5	92
Joosen, 2005 (a)	Netherlands, dizygotic twins	2	2	14	1	21.6 ± 0.5	65.9 ± 3.4	23.1 ± 1.3	10.69 ± 0.30	1.78[7]	3	47
Joosen, 2005 (b)	Netherlands, monozygotic twins	2	2	14	1	28.3 ± 2.1	67.2 ± 4.1	24.2 ± 1.6	9.90 ± 0.20	1.62[7]	3	47
Mahabir, 2006	United States, postmenopausal	2	2	65	1	59.9 ± 0.9	74.0 ± 2.0	27.7 ± 0.7	10.71 ± 0.36	—	5	100
Plasqui, 2005	Netherlands, average	2	2	19	1	25.5 ± 1.6	66.8 ± 3.5	23.7 ± 1.3	10.60 ± 0.44	1.77 ± 0.05	3	52
Hunter, 2006	United States, average	2	2	71	1	33.9 ± 0.7	63.9 ± 0.7	23.4 ± 0.1	8.39 ± 0.15	1.56[7]	5	72
Leenders, 2006	United States, average	2	2	13	1	25.8 ± 1.6	65.5 ± 1.5	23.5 ± 0.6	9.92 ± 0.46	1.77[7]	5	76
Warwick, 2006	Australia, average	2	2	10	1	26.6 ± 2.1	61.0 ± 1.2	21.7 ± 0.5	10.28 ± 0.39	1.84 ± 0.05	5	110
Bossu, 2007	France, healthy control subjects	2	2	7	1	22.0[7]	54.1 ± 1.7	21.2 ± 0.3	8.79 ± 0.32	1.57 ± 0.03	5	37
Tooze, 2007	United States, middle-aged	2	2	222	1	52.7 ± 0.5	73.2 ± 1.1	27.6 ± 0.4	9.62 ± 0.12	1.79 ± 0.02	2	17
Ebersole, 2008	United States, African American average	2	2	172	1	34.6 ± 0.8	83.5 ± 1.6	30.8 ± 0.6	10.16 ± 0.14	1.75 ± 0.02	2	12
Johannsen, 2008 (a)	United States, average young	2	2	33	1	28.0 ± 1.0	73.0 ± 4.0	27 ± 1.0	10.08 ± 0.42	1.70 ± 0.04	5	74
Johannsen, 2008 (b)	United States, obese	2	2	10	1	38.5 ± 1.9	91.2 ± 3.0	32.7 ± 1.0	10.85 ± 0.42	1.56[7]	5	59
Johannsen, 2008 (c)	United States, lean	2	2	10	1	39.6 ± 1.9	65.7 ± 1.5	23 ± 0.5	10.54 ± 0.55	1.75[7]	5	59
Moshfegh, 2008 (a)	United States, normal weight	2	2	127	1	48.0 ± 1.0	59.9 ± 0.5	22.4 ± 0.2	8.66 ± 0.13	1.57 ± 0.02	4	79
Moshfegh, 2008 (b)	United States, overweight	2	2	79	1	51.0 ± 1.2	71.5 ± 0.8	27 ± 0.1	9.28 ± 0.18	1.59 ± 0.04	4	79
Moshfegh, 2008 (c)	United States, obese	2	2	56	1	49.0 ± 1.3	89.0 ± 1.5	34 ± 0.5	10.26 ± 0.24	1.58 ± 0.05	4	79
Okubo, 2008	Japan, average	2	2	73	1	38.5 ± 1.2	53.9 ± 0.9	21.6 ± 0.3	8.30 ± 0.14	1.69 ± 0.03	5	107
Scagliusi, 2008	Brazil, average	2	1	65	1	33.7 ± 1.3	73.7 ± 2.2	27.9 ± 0.8	10.97 ± 0.25	—	5	106

(*Continued*)

APPENDIX A (*Continued*)

First author, year	Population or cohort description	HDI status[2]	OECD member[3]	No. of subjects	Sex[4]	Age	Weight	BMI	TEE	PAL	Laboratory[5]	Reference no.
						y	*kg*	*kg/m²*	*MJ/d*			
Teegarden, 2008	United States, white	2	2	24	1	22.2 ± 0.7	72.4 ± 0.4	27.7 ± 0.4	10.08 ± 0.27	1.77 ± 0.04	5	90
High HDI: men ≥65 y of age												
Fuller, 1996	United Kingdom, elderly	2	2	23	0	82.0 ± 0.6	72.4 ± 2.2	24.8 ± 0.6	9.20 ± 0.29	1.50 ± 0.04	1	43
Morio, 1997	France, elderly	2	2	6	0	68.8 ± 1.0	74.9 ± 5.1	26.9 ± 1.6	12.80 ± 1.27	—	5	51
Rothenberg, 1998	Sweden, elderly	2	2	3	0	73.0[7]	74.0 ± 7.6	23.7 ± 1.8	10.79 ± 1.18	1.74 ± 0.09	5	19
Vinken, 1999	United States, older	2	2	20	0	67.8 ± 1.4	78.3 ± 2.9	25.1 ± 0.8	10.80 ± 0.53	1.74 ± 0.06	5	91
Bonnefoy, 2001	France, healthy elderly	2	2	19	0	73.4 ± 0.9	74.3 ± 2.2	—	10.62 ± 0.56	1.71 ± 0.07	5	36
Seale, 2002	United States, rural elderly	2	2	14	0	74.1 ± 1.1	83.6 ± 2.1	28.2 ± 0.6	12.42 ± 0.44	1.83[7]	4	86
Blanc, 2004	United States, elderly white	2	2	72	0	75.1 ± 0.4	83.5 ± 1.5	27.6 ± 0.5	10.55 ± 0.20	1.74 ± 0.03	2	62
Blanc, 2004	United States, elderly black	2	2	72	0	74.8 ± 0.3	81.6 ± 1.7	27.1 ± 0.5	9.72 ± 0.21	1.71 ± 0.03	2	62
Aleman-Mateo, 2006	Chile, elderly	2	1	8	0	70.1 ± 1.9	70.0 ± 5.7	26.3 ± 1.6	9.98 ± 0.46	1.63 ± 0.07	5	104
Aleman-Mateo, 2006	Cuba, elderly	2	1	5	0	70.1 ± 2.4	55.8 ± 3.6	20.8 ± 0.8	9.38 ± 0.40	1.76 ± 0.07	5	104
Aleman-Mateo, 2006	Mexico, elderly	2	2	6	0	70.1 ± 2.2	69.0 ± 3.3	24.4 ± 1.6	10.39 ± 0.43	1.76 ± 0.04	5	104
Manini, 2006	United States, elderly, black	2	2	73	0	75.0 ± 0.4	81.6 ± 1.7	27.1 ± 0.5	9.76 ± 0.21	1.71 ± 0.03	2	77
Manini, 2006	United States, elderly, white	2	2	75	0	75.0 ± 0.4	83.2 ± 1.4	27.6 ± 0.5	10.48 ± 0.19	1.73 ± 0.02	2	77
Harris, 2007	United States, elderly	2	2	5	0	75.0 ± 1.6	74.4 ± 3.1	24 ± 0.5	11.23 ± 0.75	1.75 ± 0.07	5	68
Hertogh, 2008	Netherlands, elderly	2	2	10	0	70.6 ± 1.2	—	26.3 ± 0.7	12.00 ± 0.44	1.78 ± 0.07	5	46
Johannsen, 2008	United States, average 60–74 y of age	2	2	29	0	69.0 ± 1.0	90.0 ± 2.0	29 ± 1.0	12.43 ± 0.36	1.84 ± 0.03	5	74
High HDI: women ≥65 y of age												
Sawaya, 1996	United States, older	2	2	10	1	74.0 ± 1.4	58.7 ± 3.1	24.1 ± 0.9	7.52 ± 0.28	—	5	83
Morio, 1997	France, elderly	2	2	6	1	71.3 ± 1.0	67.7 ± 3.1	26.8 ± 0.6	9.60 ± 0.33	—	5	51
Rothenberg, 1998	Sweden, elderly	2	2	9	1	73.0[7]	65.7 ± 1.9	24.9 ± 1.1	9.60 ± 0.39	1.72 ± 0.10	5	19
Seale, 2002	United States, rural elderly	2	2	13	1	73.5 ± 1.2	69.8 ± 2.6	27.6 ± 0.9	9.43 ± 0.25	1.82[7]	4	86
Blanc, 2004	United States, elderly white	2	2	77	1	74.8 ± 0.3	67.2 ± 1.6	26.2 ± 0.6	7.89 ± 0.14	1.65 ± 0.02	2	62
Blanc, 2004	United States, elderly black	2	2	67	1	74.6 ± 0.4	73.5 ± 2.1	28.6 ± 0.7	7.97 ± 0.19	1.69 ± 0.03	2	62
Aleman-Mateo, 2006	Chile, elderly	2	1	8	1	69.9 ± 2.7	56.1 ± 2.1	25.1 ± 0.8	7.62 ± 0.33	1.54 ± 0.04	5	104
Aleman-Mateo, 2006	Cuba, elderly	2	1	5	1	69.9 ± 3.4	50.8 ± 5.2	22 ± 2.4	7.30 ± 0.32	1.57 ± 0.04	5	104
Aleman-Mateo, 2006	Mexico, elderly	2	2	8	1	69.9 ± 2.7	63.3 ± 3.4	26 ± 1.0	8.90 ± 0.51	1.74 ± 0.02	5	104
Manini, 2006	United States, elderly, black	2	2	71	1	75.0 ± 0.4	73.9 ± 1.9	28.8 ± 0.7	8.12 ± 0.20	1.72 ± 0.04	2	77
Manini, 2006	United States, elderly, white	2	2	80	1	74.9 ± 0.3	67.8 ± 1.6	26.3 ± 0.6	7.92 ± 0.13	1.65 ± 0.02	2	77
Harris, 2007	United States, elderly	2	2	5	1	76.6 ± 2.7	63.2 ± 2.8	23.5 ± 0.9	8.22 ± 0.19	1.66 ± 0.02	5	68
Hertogh, 2008	Netherlands, elderly	2	2	11	1	69.2 ± 1.4	—	24.3 ± 0.9	9.60 ± 0.18	1.85 ± 0.07	5	46
Johannsen, 2008	United States, average 60–74 y of age	2	2	29	1	69.0 ± 1.0	78.0 ± 3.0	30 ± 1.0	9.34 ± 0.31	1.72 ± 0.03	5	74

[1] HDI, human development index; OECD, Organization for Economic and Community Development; TEE, total energy expenditure; PAL, physical activity level; SES, socioeconomic status.

[2] 1, low or middle HDI; 2, high HDI.

[3] 1, no; 2, yes.

[4] 0, men; 1, women.

[5] 1, Medical Research Council Cambridge, United Kingdom; 2, University of Wisconsin, Madison, WI; 3, Maastricht University, Maastricht, Netherlands; 4, US Department of Agriculture, Beltsville, MD; 5, others or unknown.

[6] Mean ± SE (all such values).

[7] Mean.