

Activity, Adiposity and Weight Change in Jamaican Adults

A Luke¹, RA Durazo-Arvizu¹, G Cao¹, TE Forrester², RJ Wilks², DA Schoeller³, RS Cooper¹

ABSTRACT

Objective: Populations in developing countries are particularly vulnerable to the development of obesity in the period of rapid transition to a more modernized lifestyle. We sought to determine the relationship between activity energy expenditure (AEE), adiposity and weight change in an adult population undergoing rapid socio-economic transition.

Methods: Total daily energy expenditure (TDEE) was measured using the doubly labelled water method, resting energy expenditure (REE) using indirect calorimetry and AEE calculated as the difference between TDEE and REE, in adults from a working class community in Spanish Town, Jamaica. During six years of follow-up, weight was measured between one and four times. Mixed effects regression modelling was used to test for association between components of the energy budget and weight change.

Results: Men ($n = 17$) weighed more but women ($n = 18$), had significantly more body fat, 38.5% vs 24.5%, respectively ($p < 0.01$). Men had higher levels of EE, particularly AEE after adjustment for body weight, 66.3 versus 46.4 kJ/kg.d for men and women, respectively ($p < 0.001$). At baseline, adjusted AEE was inversely associated with body fat in men and women, $r = -0.46$ and $r = -0.48$, respectively ($p < 0.05$). Mean rate of weight change was +1.1 and +1.2 kg/year for men and women, respectively. No component of EE, ie TDEE, REE or AEE, significantly predicted weight change in this small sample.

Conclusions: These results suggest an important role for AEE in maintaining low levels of adiposity. The lack of association between EE and weight change, however, suggests populations in transition are at risk of obesity from environmental factors (eg dietary) other than simply declining physical activity levels.

Actividad, Adiposidad y Cambio de Peso en los Adultos Jamaicanos

A Luke¹, RA Durazo-Arvizu¹, G Cao¹, TE Forrester², RJ Wilks², DA Schoeller³, RS Cooper¹

RESUMEN

Objetivo: Las poblaciones en los países en vía de desarrollo son particularmente vulnerables al desarrollo de la obesidad en el período de rápida transición a un estilo de vida más moderno. Buscamos determinar la relación entre el gasto energético por actividad (GEA), la adiposidad y el cambio de peso en una población adulta en proceso de rápida transición socio-económica.

Métodos: El gasto energético total diario (GETD) fue medido usando el método del agua doblemente marcada, gasto energético en reposo (GER) usando calorimetría indirecta y el GEA calculado como la diferencia entre GETD y GER, en adultos de una comunidad de clase obrera en Spanish Town, Jamaica. Durante seis años de seguimiento, el peso fue medido entre una y cuatro veces. Un modelo de regresión de efectos mixtos fue usado para probar la asociación entre los componentes del presupuesto de la energía y el cambio de peso.

Resultados: Los hombres ($n = 17$) pesaron más pero las mujeres ($n = 18$) tenían significativamente más grasa corporal, 38.5% frente a 24.5%, respectivamente ($p < 0.01$). Los hombres tenían niveles más altos de GE, particularmente GEA después del ajuste por peso corporal, 66.3 frente a 46.4 kJ/kg.d para los hombres y mujeres, respectivamente ($p < 0.001$). Al inicio, el GEA ajustado estaba inversamente

From: Departments of Preventive Medicine and Epidemiology¹, Loyola University Medical Centre, Maywood, IL, USA, Tropical Medicine Research Institute², The University of the West Indies, Kingston 7, Jamaica and Nutritional Sciences³, University of Wisconsin, Madison, WI, USA.

Correspondence: Dr A Luke, Department of Preventive Medicine and Epidemiology, Loyola University Medical Centre, Maywood, IL, 60153, USA. Fax: 708-327-9009, e-mail: aluke@lumc.edu.

asociado con la grasa del cuerpo en los hombres y mujeres, $r = -0.46$ y $r = -0.48$, respectivamente ($p < 0.05$). La tasa media de cambio de peso fue $+1.1$ y $+1.2$ kg/año para los hombres y mujeres, respectivamente. Ningún componente de GE, es decir, GETD, GER o GEA, predijo significativamente el cambio de peso en esta muestra pequeña.

Conclusiones: *Estos resultados sugieren un papel importante del GEA en cuanto a mantener niveles bajos de adiposidad. Sin embargo, la falta de asociación entre GE y cambio de peso, sugiere que las poblaciones en transición corren el riesgo de obesidad debido a factores ambientales (p.ej. dietéticos) distintos de la mera disminución de los niveles de actividad física.*

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INTRODUCTION

Obesity has emerged as a major health problem for societies all over the world. A particularly rapid rise in obesity prevalence has been common in countries that have undergone a recent and abrupt transition to a more western lifestyle, with increased access to motorized transport and less manual labour both for employment and at home (1, 2). For most individuals, accumulation of excess energy stores results from a subtle imbalance between intake and expenditure. While it is self-evident that either excess intake or reduced expenditure, or a combination of the two, must be the cause of positive energy balance, quantifying the causal role of these factors in free-living individuals is very difficult. While randomized trials can readily verify the assumptions of the energy budget, the inference from clinical experiments to mechanisms underlying age-related weight gain in the population is limited given the controlled nature of such interventions. Measurements of habitual patterns of physical activity among individuals engaged in their normal activities of life, if accurate, should be uniquely informative about processes that result in gradual weight gain. However, total caloric intake cannot be reliably assessed in free-living individuals using survey methods (3, 4) and while questionnaires can capture information about patterns of activity, quantitatively they account for only 10–20% of the variance when compared to objective measures (5). Stable isotopes, in the form of doubly labelled water (DLW), provide a robust means of quantifying activity energy expenditure (AEE) although their use has been limited in epidemiologic studies.

Jamaica is a middle-income country in which the epidemiologic and nutritional transitions are well underway (6). Obesity and chronic diseases such as diabetes mellitus, cancer and cardiovascular diseases coexist with disorders related to undernutrition (7, 8). As part of the abrupt transition to a more industrialized lifestyle, with relocation from rural areas to urban centres, traditional patterns of physical activity for much of the Jamaican working class have been disrupted. As part of an ongoing community-based survey in Spanish Town, Jamaica, we examined the associations between the energy budget, adiposity and weight change among adults. We were interested in determining whether adults with relatively low levels of EE at baseline, specifically AEE, had higher levels of body fat and gained more weight over time than those with higher levels of energy expenditure.

METHODS

The International Collaborative Study of Hypertension in Blacks (ICSHIB) is an on-going study of hypertension and associated risk factors among populations of West African origin; the data presented here comprised an ancillary study. The ICSHIB study design and methods have been described in detail elsewhere (8, 9). In brief, a “probability proportional to size” age-and-sex stratified sampling method was used to recruit a total of 2660 adults, aged 25–74 years, in Spanish Town between September 1993 and March 2001. Of this total, 35 younger adults (aged 25–55 years) were randomly selected and asked to participate in this ancillary study of EE. After a baseline measurement of EE, participants were recalled for measurement of weight between one and four times over the subsequent six years (range 4.0–8.5 years).

At baseline and subsequent examinations, body weight was measured to the nearest 0.2 kg using a calibrated electronic scale. Height was measured using a stadiometer consisting of a steel tape fastened to a straight wall and a wooden headboard; height was recorded to the nearest 0.1 cm. Body composition was measured at baseline using the stable isotope dilution method carried out concurrently with the doubly labelled water (DLW) procedure described below. This body composition method is based upon the dilution principle and has been described in detail elsewhere (10). Total body water was calculated for both of the stable isotopes, deuterium and 18 -oxygen and the two values were averaged. Fat-free mass (FFM) was calculated by dividing the average total body water by a hydration constant (0.73) (11). Fat mass (FM) was calculated as the difference between body weight and FFM.

Resting energy expenditure was measured on an out-patient basis using respiratory gas exchange. Several participants had multiple measurements of REE made over the follow-up period. Certified staff made all measurements in a clinic setting in Spanish Town using two indirect calorimeters over the 6 years of follow-up (Delta Trac and DeltaTrac II Metabolic Monitors, Viasys Medical Systems, Palm Springs, CA). Both of the metabolic monitors were open circuit canopy systems with a paramagnetic oxygen sensor, infrared CO₂ analyzer and onboard computer. The DeltaTrac II was a newer model with the same basic design. Rates of oxygen consumption and CO₂ production were

calculated as the difference between inspired and expired gas concentrations using a known, fixed flow rate. Using the modified Weir equation (12), REE was calculated from oxygen consumption and CO₂ production values.

The examination room was the same temperature as the outside environment; air circulation was maintained by overhead fans. All measurements were done in the morning, the coolest part of each day. In order to control for the thermic effect of food during the REE measurement, participants were asked to fast from 10 *pm* the previous evening. Compliance with the request for fasting was assessed by monitoring respiratory quotient (RQ) during the REE measurement; no participant had a RQ greater than 0.90. Upon arrival at the clinic, the participant was allowed to sit quietly for at least 30 minutes prior to the measurement; they then rested in a supine position for at least 15 minutes to become acclimated to the examination room and bed. A clear Lucite hood was placed over the participant's head and respiratory gas rates, REE and RQ were recorded each minute for 30 to 45 minutes. In all participants, REE was stable (< 10% variability) for at least 20 minutes. The first 10 to 15 minutes of recorded data were not used in the calculation of average REE. The instrument was calibrated daily using an external gas of known composition. Alcohol burn tests conducted monthly indicated that the two instruments were both accurate to within 3% at all times. The average environmental temperature was about 28°C and no seasonal variation in mean REE was noted.

For those participants with replicate REE measurements over a mean of six years of follow-up, the intra-individual coefficient of variation of REE was 4.7%: 14 participants had two measurements, seven participants had three measurements and three participants had four measurements while nine of the remaining eleven had only a single measurement. The final two participants did not complete a REE measurement at baseline and were not available for any subsequent follow-up examination, therefore, their REE values were predicted from the Cunningham equation using FFM derived from isotope dilution, $REE = 0.09FFM + 1.46$ (REE in MJ/d, FFM in kg) (13). These two participants were excluded from the longitudinal analysis of weight change.

The DLW method for the measurement of TDEE and the principles upon which it is based are described in detail elsewhere (14). Briefly, the DLW method is based on the differential elimination of the two stable isotopes, deuterium and 18-oxygen. Participants are given an oral dose of water labelled with the two stable isotopes based upon their body weight and composition. Because the isotopes are naturally occurring, a baseline sample from each participant was obtained by collecting a urine sample prior to consumption of the labelled water. After the water was consumed, three post-dose urine samples were collected to confirm that the isotopes had equilibrated with the participant's total body water. Subsequently, midpoint and endpoint samples were

collected at five days and ten days, respectively, after the dosing day. For this study, deuterium and 18-oxygen elimination rates were calculated by the two-point method, using the isotopic enrichment relative to baseline and the time difference between the third post-dose and the final urine samples and used to calculate TDEE (15). The midpoint urine sample was used as an internal quality control.

Active energy expenditure was calculated as: $AEE = TDEE - REE - (0.1 * TDEE)$ and expressed as MJ/d. The equation term (0.1*TDEE) represents the estimated 10% of TDEE expended as the thermic effect of food (16). To allow for comparison between individuals of differing body sizes, AEE was adjusted for body size in three ways: AEE divided by body weight (kJ/kg.d), AEE adjusted using the residuals of the regression of AEE on weight and gender (AEE, MJ/d) and physical activity level (PAL) calculated as the ratio of TDEE to REE.

Student's t-tests were used to assess differences in mean values between men and women. The cross-sectional association of AEE to adiposity, by gender, was assessed by correlation analysis. The association between EE and weight change was tested using mixed effects regression modelling, with weight determinations over time nested within participants (17). In separate mixed effects models, TDEE, REE, AEE and AEE per kg weight represented the fixed effects with participant and time from baseline representing the random effects. TDEE, REE and AEE were adjusted for body size and/or composition before inclusion in the mixed effects models. The use of mixed effects models allowed modelling of participant-specific weight trends and the incorporation of all weight determinations for each participant regardless of the number of follow-up measurements or the time between exams.

RESULTS

Participant baseline characteristics are presented in Table 1. Although mean BMIs for men and women were not significantly different in this sample, women had significantly greater levels of body fat, as expected ($p < 0.01$). All measures of EE were significantly higher among men ($p < 0.05$). The gender difference in REE disappeared once the values were adjusted for body composition and age. The mean length of follow-up was 6.0 years, with a maximum of 8.5 years between the baseline and final follow-up examination. Men gained, on average, 6.1 kg or 1.1 kg/year and women gained 7.4 kg or 1.2 kg/year during the follow-up period. Individual trends in body weight are presented in Figs. 1a (males) and 1b (females). As can be observed in Figs. 1a and 1b, almost all individual participants exhibited weight gain from baseline across the follow-up examinations, however, a few individuals were able to maintain their weight (three men and one woman) or lose weight on average (two men and one woman) over this time frame.

Table 1: Participant characteristics at baseline – mean (SD)

	Men (n = 17)	Women (n = 18)	Total (n = 35)
Age (y)	38.2 (7.2)	37.7 (6.6)	37.9 (6.8)
Weight (kg)	83.1 (21.4)	76.0 (20.9)	79.4 (21.1)
Body mass index (kg/m ²)	27.0 (6.8)	29.0 (7.4)	28.0 (7.1)
Body fat (%)	24.5 (8.6)**	38.5 (6.8)	31.7 (10.4)
Total daily expenditure (MJ/d)	13.23 (3.16)**	9.94 (1.91)	11.54 (3.05)
Resting expenditure (MJ/d)	6.56 (1.03)*	5.50 (0.79)	6.02 (1.05)
Activity expenditure [§] (MJ/d)	5.42 (2.32)**	3.32 (1.16)	4.34 (2.09)
Activity expenditure [‡] (kJ/kg.d)	66.3 (32.2)**	46.4 (15.3)	56.1 (26.6)
Physical activity level [†]	2.03 (0.33)*	1.76 (0.23)	1.89 (0.31)
Weight change (kg)	6.1 (8.5)	7.4 (7.1)	6.8 (7.7)
Weight change per yr (kg/y)	1.1 (1.2)	1.2 (1.6)	1.1 (1.4)

Mean values significantly different between men & women; **p* < 0.05, ***p* < 0.01

[§] Activity expenditure calculated as AEE = TDEE - REE - (0.1*TDEE)

[‡] Activity expenditure divided by body weight

[†] Physical activity level calculated as TDEE/REE

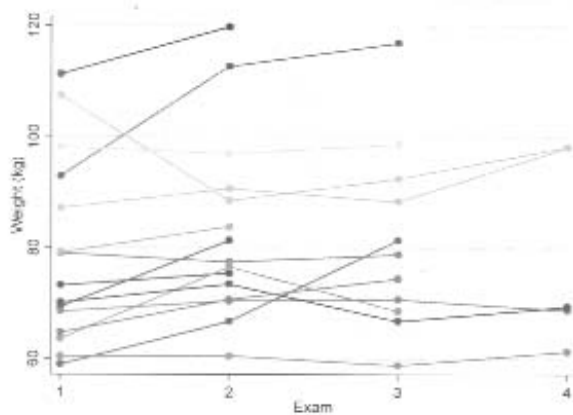


Fig. 1a: Trends in body weight for adults from Spanish Town, Jamaica, men (n = 17). Examination number indicates only the sequence of follow-up examinations, the time between examinations was not consistent. There were 2 participants, 1 man and 1 woman, who did not return for any follow-up examinations.

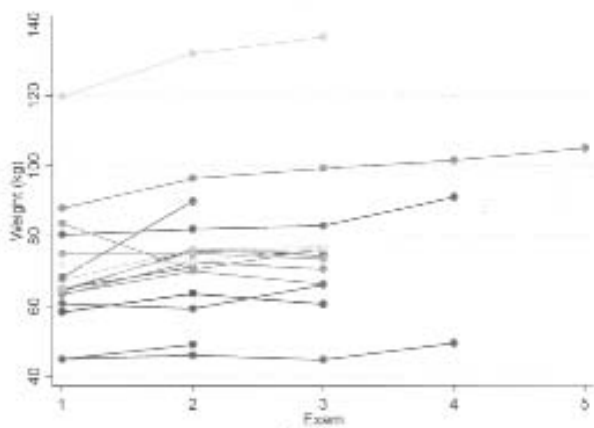


Fig. 1b: Trends in body weight for adults from Spanish Town, Jamaica, women (n = 18). Examination number indicates only the sequence of follow-up examinations, the time between examinations was not consistent. There were 2 participants, 1 man and 1 woman, who did not return for any follow-up examinations.

There were consistent inverse cross-sectional associations between AEE and measures of adiposity, regardless of the expression of AEE used (Table 2) with the exception of

Table 2: Pearson correlations between expressions of activity energy expenditure and measures of adiposity, by sex at baseline

	AEE*	AEE/kg wt	PAL
Men			
BMI	-0.08	-0.33	-0.10
Fat mass	-0.29	-0.50	-0.30
% body fat	-0.46	-0.63	-0.46
Women			
BMI	-0.21	-0.30	-0.06
Fat mass	-0.29	-0.37	-0.04
% body fat	-0.48	-0.57	-0.24

* AEE adjusted for body composition by regression analysis

the association between BMI and AEE adjusted for body size, which was minimal. In addition, the correlations between PAL and BMI and fat mass, particularly for women, were slight. In Figure 2, the gender-specific, cross-sectional

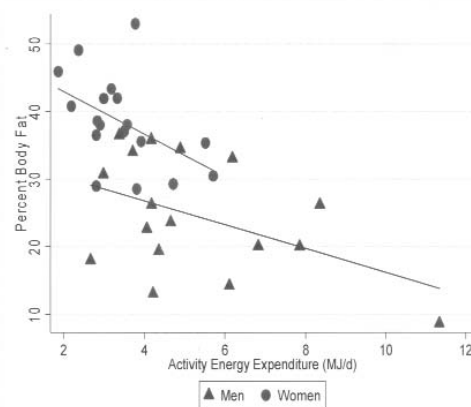


Fig. 2: There is a negative association between % body fat and activity energy expenditure (AEE) as measured using double labelled water in Jamaican men [s] (*r* = -0.46) (*p* = 0.05) and women [●] (*r* = -0.48) (*p* < 0.05). AEE was adjusted for body size using the residuals of the regression of AEE on body weight. The correlation for the combined sample was *r* = -0.60, *p* < 0.01.

relationship between per cent body fat and AEE, after adjustment for body size using the residuals of the regression of AEE on body weight, is illustrated; the correlation for the men was -0.46 and for the women -0.48 (*p* < 0.05). The mixed effects models used to test the association between parameters of EE and weight change over six years of follow-up indicated that no measure of EE was predictive of weight change in this small sample (as indicated by the α_1 estimate in Table 3), although each measure of EE was significantly associated with the average weight of individuals (as indicated by the γ_1 estimate).

Table 3: Parameter estimates resulting from mixed effects modelling

	Total Daily EE (MJ/d)		Resting EE (MJ/d)		Activity EE (MJ/d)		Activity EE/kg Wt (kJ/kg.d)	
	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value
γ_0	75.83 (2.21)	0.0001	75.82 (1.31)	0.0001	75.82 (2.85)	0.0001	75.82 (3.23)	0.0001
γ_1	6.29 (0.95)	0.0001	18.08 (1.33)	0.0001	8.27 (2.24)	0.001	-0.37 (0.20)	0.07
α_0	1.03 (0.22)	0.0001	1.04 (0.22)	0.0001	1.03 (0.22)	0.0001	1.03 (0.23)	0.0001
α_1	0.07 (0.10)	0.45	0.23 (0.25)	0.36	0.09 (0.17)	0.59	-0.01 (0.01)	0.65

γ_0 Estimated average weight predicted by model

γ_1 Effect of EE variable on average weight ie, weight difference between two individuals with EE variable 1 unit apart

α_0 Estimated average weight change per year predicted by model

α_1 Effect of EE variable on weight change per year ie, weight change difference between two individuals with EE variable 1 unit apart

DISCUSSION

To our knowledge, this study represents one of the first community-based adult samples in which AEE was measured using DLW in a country undergoing rapid socio-economic transition. This sample of Jamaican adults was relatively overweight at baseline and experienced, on average, a significant weight gain over the six-year follow-up period. These data suggest that the degree of adiposity was closely associated to habitual levels of energy expended in physical activity in these adults, however, weight gain over the six years of follow-up was not.

While previous cross-sectional surveys using questionnaire data have reported similar negative correlations between adiposity and physical activity, the associations have been weaker (18, 19). In addition, other community-based DLW studies have observed inverse associations between adiposity and AEE (20). In contrast, to date, there is only one other study using DLW to investigate the longitudinal relationship between EE and weight change in individuals not involved in weight loss or weight management schemes. Those investigators reported a non-significant outcome *ie* no association, either positive or negative, between AEE or TDEE and weight gain among adult Pima Indians of Arizona (21). Unlike the present study, however, a significant negative association was reported between REE and weight gain among the Pima Indians. Consequently, understanding the relationship between adiposity, weight change and the various components of the energy budget across various life stages continues to be an important focus for energy metabolism researchers.

Social contexts appear to have a profound effect on the risk of obesity at the population level. It has been shown that the social environment may impact the relative balance between energy intake and expenditure and, therefore, body composition (22). As a result of the lack of readily available comparative data, it is impossible to determine whether the strength of the relationship we observe is generalizable or specific to this social setting. For example, in settings where food intake is limited, it would seem plausible that expenditure would be the major determinant of adiposity among individuals. While at the other end of the spectrum, in populations exposed to greater pressures to consume more

calories, control of satiety and regulation of intake may have more impact. The relatively rapid rate of weight gain among these Jamaican adults, approximately twice the rate as in US adults (23) suggests additional environmental changes are negatively impacting body weight and, ultimately, health in Jamaica (24, 25). In the context of our study, AEE appears to be one modulator of cumulative energy balance and thus body composition but, due to the lack of a longitudinal association between AEE and weight change, it is clear that the other major component of the energy budget, energy intake, remains a primary determinant of weight gain in this population.

It should be observed that these data have inherent limitations mostly stemming from the small sample size. In spite of the small sample, the observed cross-sectional relationship between AEE *per kg* and adiposity appeared linear across the range of adiposity. Furthermore, the measurement interval is relatively short, only 10 days, and one may argue that without duplicate measures of total daily EE, there is little assurance that the DLW measurements were representative of habitual expenditure. However, previous reports have indicated that the intra-individual coefficient of variation for TDEE measured using DLW, in adults, is only about 5% for consecutive measurements (3) and 8% for measurements made six months apart (26) suggesting relative stability in EE. Within-person variability introduced by random error would bias the estimate to the null, however, and while physical activity habits will change over time it is difficult to see how bias would create the relationship that was observed. In conclusion, we may therefore infer from these data that habitual patterns of physical activity in this sample of free-living adult Jamaicans, whether imposed by requirements of work or the activities of daily living, strongly condition the risk of excess adiposity. However, we interpret these data cautiously as it does not necessarily follow, as illustrated by the lack of association observed in the longitudinal studies, that an intervention to increase AEE would have the long term consequence of decreasing body weight. Furthermore, the ecological niches within which individuals assort themselves may be determined by a variety of metabolic and social phenomena of which the individual is not directly conscious. It may therefore be difficult to alter the net

balance between intake and expenditure by simply changing one component *ie* either energy intake or expenditure. Nonetheless, further research documenting the components of the obesity syndrome should help illuminate both its physiologic causes and consequences.

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