

ENERGY COST OF ACTIVITIES AND TASKS OF WOMEN FROM A RURAL REGION OF GUATEMALA

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ABSTRACT

The energy costs of various domestic and agricultural activities were measured by indirect calorimetry in 56 women, 16-49 years old, from a small rural village. Mean energy expenditures (kcal/kg/min) were 0.021 - 0.035 for fourteen activities ("light occupations"), 0.038 - 0.064 for thirteen ("moderately active" occupations) and 0.072 - 0.089 for four ("very active" occupations). There were no differences per kg of weight between pregnant, lactating and non-pregnant, non-lactating women. The results were compared with other studies and weighted averages were calculated. The values reported can be used in combination with measurements of time to estimate energy expenditure in time-motion studies.

KEY WORDS: energy expenditure; rural population; task performance; time and motion studies; women.

INTRODUCTION

There is little information on the energy requirements of women in rural, developing countries. Estimates have been based mainly on the requirements of urban women in industrialized regions, after taking into account the larger energy expenditure usually observed in rural women (1). The accuracy of such estimates must be established by gathering more information directly from rural women. The measurements of energy expenditure are of utmost importance to achieve this, since they are a major determinant of a person's dietary energy needs. One way of making those measurements is by time-motion studies (2,3). These entail two components: a) determination of the energy cost (i.e., the energy expended per unit of time) of the activities or tasks performed by a person, and b) measurements or estimations of the time devoted to the performance of such activities. Sometimes the measurement of energy costs is impractical or beyond the technical facilities of the investigator, or only the time estimates are available. Under those circumstances the values reported by other researchers for the energy cost of similar activities can be used. However, most of the information currently available on energy costs is from studies in men or in urban women. Few investigators have measured the energy expended during the usual activities of peasant women in rural regions (4-7), and measurements were usually performed only in small numbers of subjects. Furthermore, some of the activities measured have been defined in too general terms without considering that certain characteristics may influence energy demands.

This study provides actual estimates of the energy costs of the house-hold and agricultural activities most frequently performed by women in a rural region of Guatemala, describes how each activity was measured and compares the data with the results of other studies on women.

METHODS

Location: The study was made in Cacahuito, Taxisco, a village of 1043 inhabitants located 113 kms southeast of Guatemala City, at 616 m above sea level. It is in an area devoted mainly to the growing of coffee, corn, black beans and rice. Its population is an ethnic mixture of Spaniards and Maya Indians with western cultural patterns ("ladinos"). Energy expenditure was measured in August-September, January-March and June-July. Environmental temperature ranged from 21 to 33°C, relative humidity from 41 to 96% and barometric pressure from 718 to 730 mm Hg.

Women: Fifty-eight healthy women between 16 and 49 years (mean \pm S.D.: 27 ± 6), who accounted for about 30% of that age group in the village, participated in the study. Twelve were in the second or third trimester of pregnancy and 30 were lactating. Average weight was 49.1 ± 8.0 kg (range: 36.2 - 75.6) and average height was 150 ± 6 cm. They engaged mainly in child care and household-related activities and in chores such as gleaning, winnowing or chopping wood with a machete. Many women picked coffee during the harvest season.

Energy expenditure: Energy expenditure was measured by open-circuit indirect calorimetry, using a respiratory face mask with a low-resistance, small Rudolph valve. A portable respirometer of the Kofranyi-Michaelis type was used initially (8). It was substituted by a modification of the Douglas bag method (9), because most of the chores performed by the women produced low ventilation rates and required long periods to collect enough exhaled air in the rubber bag of the portable respirometer for an accurate analysis of its oxygen content. Briefly, it consisted of using a 3-way aluminum stopcock which connected a hose from the respiratory valve outlet to a 30-100 liter latex rubber balloon. After 2 minutes for light tasks and 3-5 minutes for more strenuous tasks, all exhaled air was collected for 2-5 minutes; immediately afterwards the exhaled air was mixed by shaking the balloon, oxygen concentration was measured using a portable microfuel cell oxygen analyzer (Model 320-B, Teledyne Instruments, San Gabriel, Ca.) calibrated with certified gas mixtures, and volume was measured using a dry gas meter (Model 802, Singer, American Meter Division) or a Wright respirometer (Model P.M., British Oxygen Company) calibrated with a Tissot gas meter. The two methods and the similarity of the results obtained with them are described elsewhere (10). All women were accustomed to using the respiratory face mask and all other equipment prior to the actual measurements. Energy expenditure was calculated from oxygen consumption at standardized temperature and pressure (STPD), using 4.92 kcal/liter as the energy equivalent of oxygen.

Activities measured: The activities accounting for most of the women's day-time occupation were investigated. They are listed in Tables 1 and 2 and described in the Appendix. Most activities were measured in at least 4 women. The energy cost of the occupations described in Table 2 were estimated from direct observations of their activity components and calculations of the energy cost of those components.

RESULTS AND DISCUSSION

Table 1 shows the energy cost of the activities per unit of body weight and the corresponding average expenditures for the FAO/WHO "reference 55-kg woman" (1). Based on the classification of occupations suggested by the FAO/WHO Committee of Experts on Protein and Energy Requirements (1), activities 3 to 14 correspond to "light" occupations, activities 15 to 27 were "moderately active" and activities 28 to 32 were "very active". As might

TABLE 1

Energy Cost of Tasks Performed by Guatemalan Rural Women

Activity or task ^a	n ^b	Energy cost, kcal/kg/min			CV, %	Energy expended by 55-kg woman ^c kcal/min
		Mean	+ S. D.	Range		
1. Lying down	23	.021	+ .003	.017 - .026	13	1.14
2. Standing	8	.021	+ .005	.015 - .029	23	1.15
3. Buying or selling	d	.021				1.15
4-5. Sitting or sewing	20	.022	+ .044	.014 - .029	19	1.20
6. Nursing	d	.022				1.20
7. Eating	d	.022				1.20
8. Ironing clothes	1	.026				1.44
*9. Picking coffee	6	.027	+ .004	.023 - .033	14	1.50
*10. Winnowing or dekernelizing corn	15	.030	+ .006	.014 - .037	19	1.63
11. Washing dishes	1	.030				1.68
12. Cooking	19	.032	+ .008	.018 - .049	27	1.75
13. Personal necessities	d	.035				1.94
14. Hanging clothes	d	.035				1.94
15. Making tortillas	48	.038	+ .009	.017 - .056	23	2.08
16. Housecleaning	16	.040	+ .016	.020 - .077	40	2.20
17. Child care	4	.040	+ .010	.033 - .055	26	2.22
*18. Picking fruits	d	.044				2.42
*19. Weeding	d	.047				2.58
20. Washing clothes	16	.049	+ .010	.036 - .067	21	2.69
21. Walking on a flat terrain or downhill, with or without a load ^e	31	.050	+ .012	.032 - .078	24	2.73 (3.22) ^f
*22. Tending animals	d	.050				2.73
*23. Raking and burning	d	.050				2.77
24. Sweeping	33	.057	+ .010	.038 - .077	18	3.12
*25. Staking a fence	d	.058				3.18
*26. Cutting fruit with a pole	1	.061				3.34
*27. Light work with machete	d	.064				3.52
*28. Gleaning	5	.072	+ .026	.039 - .106	36	3.95
*29. Lifting and moving objects	4	.074	+ .018	.049 - .087	25	4.04
30. Walking uphill	18	.077	+ .019	.054 - .117	24	4.25
*31. Chopping wood with machete	6	.078	+ .013	.057 - .093	16	4.32
32. Carrying a load uphill ^e	24	.089	+ .016	.058 - .134	18	4.88 (5.77) ^f

^a The tasks are described in detail in the Appendix. ^bn= number of observations; CV. = coefficient of variation. ^cWHO/FAO "reference woman" (1). ^dEstimated as described in Table 2. ^eWeight of the load must be added to the woman's weight to calculate energy expenditure. ^fIn parentheses: energy expended while carrying a 10-kg load. *Tasks related mainly to agricultural activities.

TABLE 2
Energy Cost of Tasks Estimated from their Component Activities

Task ^a	Energy cost kcal/kg/min	Estimated as
Buying or selling	.021	- similar to standing
Nursing	.022	- similar to sitting or sewing
Eating	.022	- similar to sitting or sewing
Personal necessities	.035	- mean between standing and walking
Hanging clothes	.035	- mean between standing and walking
Picking fruits	.044	- mean of picking coffee and cutting fruit with a pole
Weeding	.047	- mean between sitting and gleaning
Tending animals	.050	- similar to walking
Raking and burning	.050	- mean of standing, sweeping and lifting
Staking a fence	.058	- mean of sitting or crouching, light work with machete and lifting
Light work with machete	.064	- mean between walking and chopping wood with machete

^aThe tasks are described in detail in the Appendix.

TABLE 3
Energy Cost of Activities Performed by Lactating, Pregnant and Non-Pregnant, Non-Lactating Women (NPNL), kcal/kg/min

	Lactating	Pregnant	NPNL
Lying down	.022 + .003 ^{a,b} (12)	.020 + .002 (8)	.018 + .001 ^b (3)
Making tortillas	.040 + .007 (28)	.037 + .008 (11)	.036 + .007 (8)
Sweeping	.059 + .010 (16)	.055 + .011 (12)	.055 + .005 (5)

^a Mean + standard deviation. Number of women in parenthesis
^b Mean values differ, p < 0.05

be expected, tasks related mainly to agricultural activities required more energy than those related to child care and household maintenance.

The energy costs per kg body weight of activities measured in several pregnant, lactating and non-pregnant, non-lactating women did not differ (Table 3). This was probably due to the fact that there were few or no changes in these women's patterns of activities related to their physiological status (10) and their fitness and efficiency to perform routine tasks remained unchanged. The contribution of an increased basal metabolic rate in the last stages of pregnancy was not detected in the energy expenditure measurements. Pregnant women, however, do expend more energy per unit of time in those activities which require body displacement due to their greater weight.

The mean coefficient of variation of the 17 activities that were measured in 4 or more women was 22% (range 13-40%). The variability did not correlate with the number of observations nor with the energy expended in each activity, although the "light" occupations tended to have smaller variabilities. This could be, at least in part, because most activities entailed only one action (e.g., lying down, standing still) or a few actions which involved similar physical effort (e.g., sitting or sewing, picking coffee, winnowing).

The energy cost of carrying a load on a flat terrain or downhill, expressed per kg body weight, did not seem to differ from walking without the load (Student's $t = 0.691$). However, the total weight displaced by a 55-kg woman becomes 60 or 65 kg when she carries a 5- or 10-kg load, respectively, corresponding to an energy expenditure of 2.98 or 3.22 kcal/min compared to the 2.73 kcal/min that she would expend when walking without a load. More energy was expended per kg of body weight walking uphill with than without a load (Student's $t = 2.164$, $p < 0.05$) and the difference becomes greater when the total mass displaced is 60 or 65 kg (5.33 or 5.77 kcal/min, respectively) instead of 55 kg (4.25 kcal/min).

Table 4 compares the present study with similar or equivalent activities evaluated in other parts of the world. The results are usually similar and, with a few exceptions, the mean values reported by other investigators fall within the ranges shown in Table 1. The differences can be explained by the small number of measurements (sometimes made on one woman only), difference in methods, environmental conditions and inadequate description or lack of standardization of the activities involved. The latter can account for the large array of energy costs of washing clothes (type of clothes, body position, intensity of scrubbing), walking (gait and speed, inclinations and other characteristics of the terrain) and carrying a load (weight and volume of the load, how it is carried and the variables mentioned for walking), and for the discrepancies in many agricultural tasks (weight and type of rhythm, technique, inclusion of several actions or pauses within an activity, and so on).

The values shown in Table 1 can be applied to time-motion determinations in most of rural Central America and in other regions where the activities performed are similar to those described in the Appendix. The descriptions of the tasks in the references cited in Table 4 might apply better to other situations. As an alternative, the weighted averages shown in the last column of Table 4 can be used when the observed activities do not exactly coincide with those described in the sources for that Table. The data of Banerjee et al. (13) were not used to calculate the weighted averages, since they were usually lower than all others and the large number of observations would weigh markedly on the average. Data appended in the FAO/WHO 1973 report (1) are shown for comparison.

TABLE 4
Energy Cost of Equivalent Activities Performed by Women in Various Parts of the World
(kcal/kg/min)

	Present study	Machiguenga, Peru(4)	Mafia, Peru(5)	New Guinea (6)	China (11)	Various countries (12)	Negev, Israel (7)	Malaysia (13)	Marikina, Philippines (14)	Glasgow, Scotland (15)	Glasgow, older women (16)	Weighted mean ^a	FAO/WHO ref woman (1)
Setting	rural	rural	rural	rural	rural	rural	rural	urban	urban	urban	urban		
Altitude, m	616	700	3950	coastal and highland		varied	150	20	20				
Age, years	16-49	16-41	20-66	18-49		young adult	20-30	18-42 ^b	26-50	young adult	54-66	36	20-39
Occupation	H, A ^b	H, A	H, A	H, A	H, A	H, A	H, A	H	H	H	H		
Mean weight, kg	49.1	43.5	52.0	48.6			55.7	53.4 ^a	54.0	60.0	60.6	50.6	55.0
Women studied	56	4	8	78			8	79	10	4	17		
Lying down	.021(23) ^c		.021(8)					.018(79) ^a				.021	.016
Standing	.021(8)		.023(8)					.021(79) ^a	.024(10)	.023(8)		.023	.025
Sitting/sewing	.022(20)		.023(8)	.025(3)	.026	.024(5)	.024(2)	.019(79) ^a	.023(10)	.018(8)	.022(1)	.022	.021
Ironing	.026(1)							.030(79) ^a			.036(1)	.031	
Picking coffee	.027(6)		.033(8)	.061(10) ^d								.030	
Washing dishes	.030(1)									.049(8)	.041(17)	.043	
Cooking	.032(19)						.036(1)		.036(10)	.042(8)	.038(17)	.036	.031
Housecleaning	.040(16)						.045(3)					.041	
Caring for children	.040(4)								.038(8)			.039	
Weeding	.047	.055(2)	.040(8)	.049(20)	.056	.064(1)	.060(2)					.048	
Washing clothes	.049(16)	.060(3)		.050(3)		.047(3)		.032(79) ^a	.044(3)	.051(8)		.050	
Walking on flat terrain	.050(31)		.055(8)	.054(13)	.059		.074(2)	.031(79) ^a	.046(10)	.075(8)		.054	.055
Tending animals	.050						.056(1)					.053	
Sweeping	.057(33)	.065(1)		.046(7)		.038(5)					.055(17)	.054	
Light work with machete	.064			.065(3)	.053							.062	
Gleaning	.072(5)	.077(2)				.070(1)						.073	
Lifting and moving objects	.074(4)		.085(8)		.087		.081(2)					.082	
Walking uphill	.077(18)			.101(17)								.089	
Chopping wood	.078(8)		.071(16)									.073	.069 - .100
Carrying a load uphill ^e	.089(24)			.109(10)								.095	

^aWhen n was not available, a weight of 1 was given. Data with ^a were not used to calculate the weighted mean. ^bH = household activities; A = agricultural chores.
^cMean and number of measurements, when available. ^dWorking on steep terrain. ^eThe load's weight must be added to the woman's weight to calculate energy expenditure.

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APPENDIX

Energy expenditure was measured or estimated for the following activities and tasks, listed in alphabetical order:

Buying and selling: carrying out negotiations while standing; it often included walking a few steps.

Carrying loads: on the head, with the arms, or both; energy differences in the manner of carrying the load were minimal and values were therefore combined. The weight carried was added to the woman's weight to calculate energy expenditure per kg of body weight.

Child care: bathing, diapering, and dressing children and helping them to move about.

Chopping wood: wood 2-4 inches in diameter and dried tree branches were chopped with a machete (long-blade knife weighing 2-3 pounds); only the actual cost of chopping was measured.

Cooking: over wood fires using virtually no labor-saving devices. Typical activities included cutting of vegetables or meat; preparing and cooking rice, beans or corn (which entailed walking within the house to get the grain, walking to an outside faucet to draw water, apportioning grain or water, carrying the pot to the fire, stoking and poking the fire; and cleaning counters or a table. Environmental temperature in the kitchen was usually 27°C or higher.

Cutting fruit with a pole: a long pole was lifted and swung at fruits hanging from high branches. The woman then picked the fallen fruits from the ground and placed them in a basket that was carried to the next tree.

Eating: seated at a table the majority of the time, occasionally getting up to serve food to family members.

Gleaning: encompassed several activities: gathering wild fruit in the woods, scavenging fallen coffee berries for the household and gleaning grains after thrashing rice, sorghum or beans. This activity also included the picking of low plants or chili peppers and involved frequent crouching.

Hanging clothes: draping wet clothes over a line, bushes or on rooftops and removing them when dry.

Housecleaning: this is a general category for household duties that

account for a large portion of the women's work day. It included dusting, folding clothes, shaking out straw sleeping mats, collecting clothes for washing and "putting things in order". It can be considered as "random standing", as more standing than walking was involved.

Ironing clothes: was performed while standing, using a coal-filled or coal-heated iron.

Lifting and moving: activities such as stacking firewood, placing beans to dry under the sun and moving furniture and other household objects.

Light work with a machete: cutting low brush, usually to clear a trail while walking through fields.

Lying down: energy expenditure was measured after 15 minutes in this position.

Making tortillas: included kneading of corn dough and adding water until smooth; rolling the dough on a grinding stone; patting a small amount of dough with both hands into a round, thin pancake; tending the tortillas while they cooked on a griddle, and poking and stoking the fire. The grinding stones and fire were often located on opposite sides of the room and the process included frequent walking across the kitchen.

Nursing: usually while seated. When performing simultaneously other activities such as cooking or housecleaning, the energy cost of the most demanding activity was used to calculate energy expenditure.

Personal necessities: dressing and undressing, hair-combing, bathing and walking to an "out-house" to urinate or defecate.

Picking coffee: coffee berries were picked from branches within arm's reach of women standing beside the trees. Berries were placed into a basket tied to the women's waists and carried from tree to tree until the basket was full. The contents of full baskets (about 35 lb) were dumped into a gunny sack. Generally, coffee plantations were located on fairly flat terrain. The measurements made in this study coincided with a poor coffee harvest; during good seasons coffee is picked faster and in larger amounts per working hour.

Picking fruits: fruits, nuts, and leaves from bushes and trees within reach were picked while standing.

Raking and burning: raking leaves, grass, litter and trash into a heap for burning.

Sitting and sewing: these activities were combined, as women sewed while seated and energy expenditure was similar to that of non-activity.

Standing: either unsupported or while leaning against a wall.

Staking a fence: cutting saplings with a machete, digging holes with a stick, securing poles into the ground and tying fence wires around the poles.

Sweeping: with a broom. Dirt floors of the houses were sprinkled with water prior to sweeping.

Tending animals: herding pigs and cows short distances; preparing a slop

of corn dough, water, and salt and dropping it into a trough, and scattering grain for fowl.

Walking: was measured on local terrain, while ascending and descending mild slopes or on a flat surface. Generally, the women walked at a pace of about 4 km per hour.

Washing dishes: included lifting full buckets of water and vigorous scrubbing with coarse sand to remove grease and particles from pans and dishes.

Washing clothes: by hand either in a cement sink with a textured scrubbing surface or at a river. The rinsing of clothes was performed at the sink by scooping water and pouring it over the soaped clothes, whereas at the river clothing was dunked several times into the current. The women worked less continuously at the sink to allow the re-filling of the reservoir. Nevertheless, there was no difference in the amounts of energy expended using either method. Dirt was removed from the clothes by the women's physical force and weight against the roughness of the sink's surface or the rocks at the river; virtually no detergent and only mild vegetable soaps were used. The procedure consisted of wetting the clothes, soaping, scrubbing (anchoring the cloth with one hand and scrubbing with a back-and-forth motion using the other), rinsing and wringing; with heavy or exceptionally dirty clothing, both hands were used to scrub and the procedure was akin to kneading a tough piece of dough.

Weeding: stooping to cut weeds with a small curved knife, between bean plants or rows of corn.

Winnowing and other grain preparation performed while seated. This included shucking corn and removing dried kernels, cleaning undesirable particles from the grain, shaking or blowing grains to remove extraneous matter, shelling beans, separating grains for planting from those for eating and winnowing by pouring the grain into the wind for cleaning.