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ESTIMATIONS OF THE DAILY ENERGY EXPENDITURE OF WOMEN FROM RECORDS OF ACTIVITY AND OF PULSE RATE

by

Evelyn Hollen

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Nutrition

Approved:

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1963

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INTRODUCTION

When the energy expenditure of an individual is less than the energy value of the diet, the excess is stored in the body as fat. For this reason, it is important to be able to assess precisely the daily calorific requirement. A positive energy balance of only 200 Calories per day will cause a small unnoticeable increase in weight at the start, and if continued through the years, obesity will develop. In the etiology of degenerative diseases, obesity is considered a predisposing factor. The development of fat in the cells is a part of the degeneration that takes place in the aging body, Bourne (1). The FAO Nutritional Studies (2) stated that present knowledge of the influence of aging on energy expenditure is deficient, and further investigations are needed.

The knowledge of precise calorific requirements is desirable not only from the standpoint of weight control and health, but for economic reasons as well. World population is increasing at the rate of 2 1/2 per cent each year and conditions in the future will necessitate greater conservation of our food resources and an equitable distribution in order to provide adequate nutrition for all. Van Gehuchten (3, p. 63), a distinguished Belgian scientist, states:

> Statisticians assure us that, in a matter of decades, world population will have reached a level of overcrowding. When that time comes, every acre of land will be needed to grow cereals or graze cattle to feed the swarming population. Cotton

> may have to give way to wheat .... This is hard to visualize in an era of restricted acreage.

Energy requirements for the older woman engaged in homemaking have been determined from 24-hour diaries of activities calculated by factors based on Calories per kilogram, of body weight, per hour expended for each activity. This was not an exact measure but an estimation. To increase the validity of this estimation, it was necessary to study a large number of homemakers.

Brody (4, p. 383) stated that basal metabolism varies directly with 'metabolically effective body weight.' Therefore, confidence in the estimation of caloric need might be still greater if the factors for the calculation were based on Calories per kilogram of metabolically active body weight ($kg.^{0.73}$) per hour of activity.

Recent developments in electronic equipment have made possible the estimation of pulse rate for an extended period of time. A possible relationship of increment in pulse rate to increment in energy expenditure was suggested in 1910 by Benedict and Carpenter (5, p. 135), who noted that the pulse rate was parallel to total metabolism and that, "with the same subject under like conditions of muscular activity, the pulse rate during a 7-day fast appeared to be an excellent index of total metabolism." In 1913, Benedict and Cathcart (6, p. 24) studied the pulse rate and metabolism during exercise using the stethoscope and radial pulse. They concluded that some other technique would be necessary for the study of the pulse rate during muscular work. At the present time, equipment is available for obtaining a continuous record of pulse rate. Rowley *et al*. (7) developed a small portable pulse counter. Harten and Koroncai (8) described a small portable instrument for obtaining the heart rate of the human body and transmitting the impulse by a radio link. Holter (9) described instruments which function in a similar manner. Webb *et al*. (10) have successfully radio-telemetered electrocardiograph voltages of animals using portable equipment. This electronic equipment would make possible a study of the method for predicting 24-hour expenditure from a continuous record of the pulse rate.

This study is an investigation of the energy expended by older homemakers in the performance of daily household tasks. Part I deals with the collection of two 24-hour diaries of activities as performed by 46 homemakers and subsequent estimation of expended energy by two separate calculations which used data of energy expenditure for similar activities as compiled from the available literature. The first calculation was based on the unit 'Calories per kilogram per hour per activity.' The second calculation used the same research data recalculated on the unit 'Calories per kilogram to the 0.73 power per hour per activity.' Part II of the study concerns the development of a method for obtaining a continuous 24-hour energy expenditure based on a relationship between pulse rate and oxygen consumption expressed as Calories per minute, and the test-use of this method in determining the energy expended by the older homemaker. Comparisons were drawn among the three methods of obtaining energy expenditure of homemakers.

PART I. A STUDY OF THE ENERGY EXPENDED BY 46 OLDER HOMEMAKERS DETERMINED FROM 24-HOUR ACTIVITY RECORDS

REVIEW OF LITERATURE

The energy expenditure during homemaking activities has been estimated from the energy costs of separate household tasks. In 1910, Benedict and Carpenter (5) concluded that the best method of estimating a 24-hour energy expenditure was to total the energy costs of the muscular activities that make up the daily life. This method was still in use in 1961. Durnin et al. (11), for example, used this method in the stimation of the daily caloric requirement of homemakers in Scotland.

Factors for the evaluation of energy expenditure required for household tasks have been obtained from studies with a relatively small number of subjects. Langworthy in 1922 (12) reported 102 experiments of one subject as she performed six different kinds of work. Swartz in 1933 (13) studied seven subjects who duplicated each of several tests two to 14 times. Droese in 1949 (14) reported results of energy costs on three subjects who did 60 different household tasks. The above studies were conducted in the laboratory under controlled conditions because of the complicated nature of the testing equipment and of the analysis of the samples.

Durnin et al. (15) in 1957 and also in 1961 (11) tested subjects in the home situation using a portable apparatus for the collection of expired air. These workers measured the energy expenditure of each subject in her own home as she did a 'typical activity.' However, the number of subjects tested was still small, four to 21, and the energy costs of activities were totaled to estimate the daily expenditure of energy.

Estimation of 24-hour energy expenditure by summation of the Calorie cost of the daily activities as proposed by Benedict and Carpenter (5) required records of the energy cost of many household tasks. The compilation of data by Passmore and Durnin (16) from studies reported on the energy expenditure during various kinds of activity included values for women who performed different types of work. In several instances, however, marked differences in experimental design of the studies might be expected to contribute to variations in the values which were obtained. Values reported by Passmore and Durnin were expressed as Calories per minute. Since body weight may affect the total energy expenditure during activity, it was considered desirable to re-evaluate data on energy costs of activity by women for the purpose of comparing values on the basis of body weight per unit of time. Table 1 presents a compilation of the energy costs of specific household tasks arranged in categories according to the nature of the activity.

Data presented in Table 1 were taken only from reports of research on women who had eaten food in the form of a light meal a short interval before performing an activity and who were in good health. Data have been included only for women

Table 1. Reported[a] values for energy expended during activity

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average[b]	Range	Average[b]	Range
Resting				
Lying down (19,20,13,23)	0.93	0.86- 1.01	2.90	2.60- 3.20
Standing at rest (14,13,15,23)	1.09	1.04- 1.15	3.17	2.95- 3.25
Preparing meals				
Moderate[c]				
Paring potatoes (13)	1.31	1.25- 1.37	3.86	3.73- 4.15
Cooking, sitting (14)	1.32	1.24- 1.37	4.19	4.11- 4.48
Beating batter (13)	1.39	1.25- 1.56	4.28	3.84- 4.45
Kneading dough (13,16)	2.08	1.97- 2.24	6.23	6.67- 6.49
Strenuous				
Cooking, standing (14,15)	2.37	2.27- 2.46	7.50	7.42- 7.58
Cooking, walking (14)	2.54	2.04- 3.03	7.30	7.18- 7.42
Stirring food (14,16)	2.68	2.17- 3.19	8.52	7.18- 9.86
Very strenuous				
Serving food in canteen (11)	2.96		9.50	
Grinding coffee (14)	3.84		11.85	

[a]Values as reported were re-calculated to provide for expression on common bases.

[b]Average represents median or mean.

[c]Light, moderate, strenuous and very strenuous are terms used to denote relative degree of work involved in activity.

Table 1. (Continued)

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Eating				
Sitting (14,16)	1.50	1.37- 1.63	4.75	4.48- 5.01
Standing (14)	1.93	1.81- 2.05	6.35	6.00- 6.69
Washing dishes				
Moderate				
Washing dishes (12,21)	1.59	1.43- 1.75	4.47	4.17- 4.89
Storing 1 3/4 lb. fry pan (22)	1.59	1.50- 1.69	4.87	4.58- 5.19
Washing dishes (14,15)	2.22	2.03- 2.35	6.82	6.70- 7.01
Strenuous				
Cleaning gas cooker (11)	3.00		8.63	
Very strenuous				
Scouring (14)	3.75	2.45- 4.50	12.41	8.12-15.26
Care of house				
Light				
Sweeping bare floor (12,20,16)	1.87	1.81- 1.90	5.51	5.23- 5.79
Cleaning windows (14,16)	2.55	2.53- 2.57	8.37	8.36- 8.38
Tidying up, walking about (14)	2.59	2.50- 2.67	8.57	8.16- 8.83
Wash floor by hand (11)	2.72		8.73	
Moderate				
Mopping (14)	3.28	3.24- 3.32	10.79	10.72-10.85
Heavy work tidying up and cleaning (14,16)	3.34	3.25- 3.46	11.02	10.60-11.43
Dusting with cloth (14,10)	3.44	3.32- 3.56	10.93	10.85-11.00
Polish furniture (14)	3.58	2.31- 4.67		
Small tasks in utility room (14)	3.60	3.10- 4.10	11.57	9.57-13.56

Table 1. (Continued)

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Strenuous				
Brushing carpet and mattresses (14)	3.71	2.53- 4.76	13.63	12.56-14.70
Wash floor with scrub brush with handle (14)	3.75	2.53- 6.02	13.54	12.38-14.70
Wiping furniture with damp cloth (14)	3.78	3.10- 3.85	13.06	12.56-13.56
Very strenuous				
Airing beds (14)	4.16	4.22- 4.10	13.68	13.56-13.79
Waxing with mop (14)	4.23	3.22- 5.13	14.94	14.03-15.84
Making beds (14)	4.36	4.22- 4.49	13.82	13.79-13.85
Carpet beating with hanging and brushing (14)	4.44	2.52- 4.76	17.19	14.70-19.67
Rubbing floor with a polish wax (14)	4.47	4.45- 4.49	14.04	13.56-14.52
Clean laundry room (14)	4.60	4.52- 4.67	15.11	14.77-15.45
Wash floor with kneeling and stooping (14)	5.10	4.97- 5.22	16.18	16.13-16.24
Scrubbing (14)	5.17	5.03- 5.22	16.37	16.13-16.62
Running carpet sweeper (14)	5.50		16.98	
Washing clothes, machine				
Wringing clothes, electric (13)	1.85	1.66- 2.06	5.64	5.20- 6.18
Hanging clothes basket on table (13)	1.95	1.84- 2.08	5.98	5.84- 6.72
Wringing clothes, extractor (13)	2.04	1.94- 2.13	6.29	6.00- 6.59
Put up and take down line (13)	2.27	2.12- 2.41	6.66	6.06- 7.26

Table 1. (Continued)

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Washing clothes, machine				
Emptying washing machine (13)	2.32	2.12- 2.51	6.80	6.06- 7.53
Rinsing clothes (13)	2.36	2.28- 2.45	7.21	6.91- 7.53
Hanging clothes, basket on floor (13)	2.44	2.38- 2.48	7.59	7.12- 8.25
Hanging up and taking down laundry (14)	3.63	3.55- 3.75	11.68	11.57-11.90
Clean laundry room (14)	4.60	4.52- 4.67	15.11	14.77-15.45
Rinse laundry (14)	5.20	4.67- 5.88	15.41	15.26-15.56
Folding and sorting clothes (14)			8.64	7.41- 9.86
Washing clothes, hand				
Light				
Washing clothes, hand (14,13,16)	2.20	2.05- 2.34	6.65	6.37- 7.08
Wringing clothes, hand (13)	2.23	2.05- 2.37	6.51	6.42- 6.63
Put up and take down clothes line (13,16)	2.27	2.12- 2.41	6.66	6.06- 7.26
Rinsing clothes (13)	2.36	2.28- 2.45		
Hang up and take down clothes (14)	3.63	3.55- 3.75	11.68	11.57-11.90
Strenuous				
Hand wash on board (14)	4.73	4.49- 4.97	15.05	13.85-16.24
Rinse laundry (14)	5.20	4.67- 5.88	15.41	15.26-15.56
Rub laundry (14)	5.20		16.97	
Turning washing machine (14)	5.28	4.82- 5.74	17.37	15.75-18.99
Hand wringing washing (14)	3.72	3.17- 4.30	12.67	12.07-13.27

Table 1. (Continued)

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Ironing clothes, hand				
Sitting				
Ironing clothes (13)	1.53	1.52- 1.54	4.78	4.57- 5.06
Ironing clothes (11,16)	2.15		6.69	
Standing				
Ironing clothes (18,21,13)	1.64	1.57- 1.69	5.00	4.95- 5.10
Ironing laundry (14)	2.33	2.24- 2.42	7.66	7.41- 7.91
Ironing clothes, mangle				
Light				
Ironing, electric rotary (13)	1.37	1.27- 1.41	4.11	3.80- 4.38
Ironing, electric flat press (13)	1.47		4.41	
Strenuous				
Mangle laundry (14)	4.60		15.01	
Sewing				
Electric machine (12,20)	1.21	1.15- 1.24	3.64	3.51- 3.76
Treadle machine (14,12)	1.44	1.38- 1.67	5.00	4.37- 5.58
Simple needle work (14,16)	1.35	1.24- 1.45	4.42	4.10- 4.73
Hand sewing (12,21,20,16)	1.20	1.17- 1.25	3.58	3.35- 4.03
Walking				
Marketing (14)	1.86	1.81- 1.90	6.10	6.00- 6.20
Walking in house (14)	2.42	2.35- 2.46	7.90	7.67- 8.12
Cooking, walking (14)	2.55	2.53- 2.57	7.30	7.18- 7.42
Tidying up, walking about (14)	2.59	2.50- 2.67	8.57	8.16- 8.83
Pushing baby pram (11)	3.23		9.39	

Table 1. (Continued)

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Walking				
Walking 2 mi./hr. 4% grade (19)	3.50	3.38- 3.64	10.49	10.20-10.79
Walking at 77 meters/min. (17)	3.59		10.78	10.20-11.42
Walking 3 mi./hr. 4% grade (19)	4.34	4.17- 4.48	13.04	12.69-13.26
Walking 87.5 meters/min. (17)	4.39		12.37	
Climbing stairs				
Ascending stairs (14)	7.65		22.11	
Ascending stairs with load (14)	10.26		29.23	
Descending stairs				
Descending stairs (14)	4.26		12.14	
Descending stairs with load (14)	6.86		19.54	
Walking up and down stairs				
Climbing up and down stairs (14)	5.82	5.74- 5.87	18.56	18.12-18.99
Climbing up and down stairs with load (14)	7.68	7.62- 7.74	24.57	23.52-25.61
Sitting activities				
Sitting quietly (14,12,20, 13,15,9)	1.01	0.99- 1.10	3.15	2.89- 3.40
Sitting activities with moderate hand and arm movement				
Sitting, playing music (14)	1.16	0.96- 1.35	3.66	3.16- 4.16
Sewing, hand (12,21,20,16)	1.20	1.17- 1.25	3.58	3.35- 4.03
Sitting, simple work (14,16)	1.31	1.22- 1.44	4.51	4.44- 4.58

Table 1. (Continued)

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Sitting activities with moderate hand and arm movement				
Sitting, cooking (14)	1.32	1.24- 1.37	4.19	4.11- 4.48
Sitting, simple needle work (14,16)	1.35	1.24- 1.45	4.42	4.10- 4.73
Sitting, crocheting (21)	1.38		3.97	
Sitting, knitting (21)			4.05	
Sitting activities with body movement				
Sewing machine, treadle (14,12)	1.44	1.38- 1.67	5.00	4.37- 5.58
Ironing, rotary (13)	1.37	1.27- 1.41	4.11	3.80- 4.38
Ironing, flat press (13)	1.47		4.41	
Ironing, hand sitting (13)	1.53	1.52- 1.54	4.78	4.57- 5.06
Ironing, hand sitting (11)			6.69	
Standing activities with some arm and body motion				
Washing dishes (12,21)	1.59	1.43- 1.75	4.47	4.17- 4.89
Ironing, standing (18,21,13)	1.64	1.57- 1.69	5.00	4.95- 5.10
Storing 1 3/4 lb. fry pan (22)	1.59	1.50- 1.69	4.87	4.58- 5.19
Wringing clothes, electric (13)	1.85	1.66- 2.06	5.64	5.20- 6.18
Eating, standing (14)	1.93	1.81- 2.05	6.35	6.00- 6.69
Hanging clothes, basket on table (13)	1.95	1.84- 2.08	5.98	5.84- 6.72
Wringing clothes, extractor (13)	2.04	1.94- 2.13	6.29	6.00- 6.59
Kneading dough (13,16)	2.08	1.97- 2.24	6.23	6.07- 6.49

Table 1. (Continued)

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Standing activities with some arm and body motion				
Washing clothes, hand (13,14,16)	2.20	2.05- 2.43	6.65	6.37- 7.08
Cooking, standing (14,16)	2.37	2.27- 2.46	7.50	7.42- 7.58
Standing activities with arm and bending and lifting motion				
Put up and take down clothes line (13)	2.27	2.12- 2.41	6.66	6.06- 7.26
Lifting 5 lb. load to shelf (22,23)	2.32	1.76- 3.21	6.17	5.23- 6.81
Empting washing machine (13)	2.32	2.12- 2.51	6.80	6.06- 7.53
Rinsing clothes (13)	2.36	2.28- 2.45	7.21	6.91- 7.53
Polishing shoes (14)	2.42	1.87- 3.36	6.69	6.68- 6.70
Hanging clothes, basket on floor (13)	2.44	2.38- 2.48	7.59	7.12- 8.25
Sprinkling clothes (14)	2.44	2.38- 2.50	8.54	7.89- 9.57
Dressing, undressing, and washing up (14,16)	2.48	2.38- 2.57	8.15	7.89- 8.40
Cleaning windows (14,16)	2.55	2.53- 2.57	8.37	8.36- 8.38
Stirring food (14,16)	2.68	2.17- 3.19	8.52	7.18- 9.86
Folding and sorting clothes (14)	2.69	2.24-3.19	8.64	7.41- 9.86
Removing ashes and firing stove (14)	2.74	2.65- 2.82	8.69	8.65- 8.72
Wringing clothes, hand power (14)	2.84	2.66- 3.02	8.35	7.64- 9.06
Clean gas cooker (11)	3.00		8.63	

Table 1. (Continued)

Category, activity reported, and literature reference	Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Standing activities with bending and pushing or pulling motion				
Mopping (14)	3.28	3.24- 3.32	10.79	10.72-10.85
Kneading dough (14)	3.29		10.14	
Heavy work tidying up, cleaning (14,23)	3.34	3.25- 3.46	11.02	10.60-11.43
Dusting with cloth (14)	3.44	3.32- 3.56	10.93	10.85-11.00
Polish furniture (14)	3.58	2.31- 4.67	13.37	12.32-14.42
Hang up and take down laundry (14)	3.63	3.55- 3.75	11.68	11.57-11.90
Brushing carpets and mattresses (14)	3.71	2.53- 4.76	13.63	12.56-14.70
Waxing with mop (14)	4.23	3.32- 5.13		
Making beds (14,15)	4.36	4.22- 4.49	14.94	14.03-15.84
Carpet beating with hanging and brushing (14)	4.44	2.53- 4.76	17.19	14.70-19.67
Scrubbing floor with a polish wax (14)	4.47	4.54- 4.49	14.04	13.56-14.52
Hand wash on board (14)	4.73	4.49- 4.97	15.05	13.85-16.24
Running carpet sweeper (14)	5.50		16.98	
Pushing baby pram (11)	3.23			
Walking and carrying load				
Serving in a canteen and tidying up (11)	2.96		9.50	
Walking with a load (23)	4.33	3.72- 4.62	13.20	11.43-14.09

for whom body weights were reported or for whom sufficient information was given that the body weight could be calculated in order to express values as Calories per kilogram per hour. Data from the reports of the following investigators were used: Droese et al. (14), Durnin et al. (15), Durnin et al. (11), Gairns and O'Brien (17), Knowles (18), Langford (19), Langworthy (12), Langworthy and Barott (20), Langworthy and Barott (21), McCracken and Richardson (22), Passmore and Durnin (16), Richardson and McCracken (23), and Swartz (13).

Values reported for the metabolic cost of different activities represented results obtained from multiple approaches to the study of energy metabolism. Variable factors included the number of subjects, the number of replications, the kinds of activity performed by each subject, and methods of calculation of energy expenditures. The following bases were established for deriving both the average and the range of values given in Table 1: (a) When energy expenditures were reported for the same activity by more than three subjects, these data were plotted on a scattergram. The Calories of energy expended by the greatest number of the subjects was the value selected for the average figure. The range was set between those caloric values which included a concentration of the subjects. (b) When a study, Droese 1949 (14), reported data listing all of its subjects expending energy at much higher caloric values than the scope of the scattergram, these data were recorded separately as a duplication of the activity. (c) When the energy expenditure values were reported for the same activity for only three subjects, the two values which were very similar were set for the range and the average of these two values was recorded as the average. (d) When the data for all three subjects listed unlike values, the extreme values were set for the range and the average of the three values was recorded. (e) When values for energy expenditure were reported for the same activity for only two subjects, these values were set for the range and the average of the two values was taken. (f) When energy expenditure was reported for an activity by only one subject, this value was used and no range was set.

Metabolically Effective Body Weight

Research workers frequently have reported energy cost of activities in terms of Calories per kilogram of body weight. However, Brody (4) stated that basal metabolism varied directly with what he designated "metabolically effective body weight." To determine this weight, he plotted the logarithm of the kilogram weight of homeotherms ranging from mice to elephants against the logarithm of their total basal metabolism and calculated the value of the slope to be 0.73. He found that this agreed with Benedict's data. As a result of his studies, he expressed the metabolically effective body weight as $W^{0.73}$.

The rate of total heat production also may vary directly with the amount of tissues active in the metabolic processes. Kleiber (24) stated in 1947 that once the unit of metabolic body size is established, the metabolic rate can be predicted by multiplying the metabolic body size by a given factor. His research results approximated those of Brody. He recommended the body weight in kilograms raised to the 3/4 power as a measure of metabolic size. He also stated that the metabolic body size is useful for expressing levels of food intake and the rate of metabolism in the cell.

A wide variation in the amount of active metabolic tissue among individuals of the same species, as for example, women living in southern India, ranged from $W^{0.44}$ to $W^{0.70}$ was reported by Miller (25) in a review article published in 1954.

In 1960, Langford (19) compared values for energy metabolism based on units of metabolic body size, $W^{0.73}$ and with values based on total body mass, W^{1}. She reported (19, p. 94):

> When this parameter was used for expression of energy expenditures of subjects of less and more than desirable body weight, total values for energy expenditure were affected differently than when reduced to Calories per kilogram of body weight.

The second committee on Calorie requirements of the Food and Agriculture Organization of the United Nations (2) reported in 1957 that the total energy expenditure was considered as the sum of three components; namely, resting energy expenditure, energy expenditure related to the ingestion of food, and the energy expenditure involved in physical activities.

The resting energy expenditure was believed to be estimated with reasonable accuracy from the body weight by an expression of the form: basal metabolism equals aW^n, where a is a constant determined by age, sex, and the units employed, W is the nude weight, and the exponent n is about 0.73. If it is considered that resting energy expenditure should include seated as well as supine rest, the same equation would hold but the constant would be somewhat larger. For any given person, the energy expenditure in the seated position is considered a multiple of that in the supine position.

The energy expenditure related to the ingestion of food, the committee reported, could be taken as about 10% of the total energy expenditure when the individual is in Calorie balance.

In the energy expenditure involved in physical activity, the major part is directly and linearly proportional to the body weight. The remaining part of the cost of activity is unrelated to body size. The committee proposed $E = 123.4\ W^{0.73}$ as an equation for total energy requirement for women of various weights but who are otherwise comparable to the reference women of 25 years.

Table 1 presents energy expenditure values, reported in the literature, of women in the performance of activities associated with family life and the maintenance of the home. These values were converted to units of Calories per kilogram to the 0.73 power of body weight. To facilitate this procedure, a conversion table was set up for use in the calculation. See Appendix, p. 151. Table 1 also contains the average and range of values expressed in units of Calories per $kilogram^{0.73}$.

METHOD OF PROCEDURE

Experimental Plan

Part I of the study is an investigation of the energy expenditure of older homemakers as estimated from diaries of the activities they performed in their daily life. Forty-six women, whose ages ranged from 33 to 85 years, participated as subjects. They kept records of their activities for two days, as they carried on their usual homemaking duties. The energy expenditures of the women were summated from estimations of the metabolic costs of various activities. Values were expressed as Calories per kilogram per hour and also as Calories per kilogram$^{0.73}$ per hour. The average daily energy expenditures of the subjects were evaluated as to the effects of the following variables: age, body weight, metabolically active body weight, and health status. The possible influence of the size of the family, the size of the house, the efficiency, and temperament of the subject on the average daily energy expenditure was investigated also. A subjective method of evaluation was used to obtain ratings for the efficiency and the temperament of each subject.

Subjects

This study represented one phase of research on the nutritional status of older women which was conducted as a project of the Iowa Home Economics and Agricultural Experiment Station under the direction of Dr. Pearl P. Swanson.*

The subjects were homemakers who lived in Ames, Iowa and outlying districts. Households were selected at random from an area sample prepared by the Department of Statistics of the Iowa State University. Personal interviews with occupants of these homes revealed whether any of the members of the family were over 30 years of age and were willing to take part in the project. Fifty subjects were chosen at random from the group of 100 women who agreed to cooperate.

The number of women in each decade of age was approximately the same; however, during the period of investigation, some of the women dropped out making it necessary to fill in with others drawn from the above-mentioned list of 100 women. The subjects who asked to be released from the project were, in the main, older women, and since there were fewer older women on the list, replacements were usually made with younger subjects. Thus at the close of the study, the groups comprising the sixth and seventh decades of age were smaller in number of subjects than the other groups.

*Acknowledgment is made to Dr. Pearl P. Swanson and the members of her research staff for the selection of the subjects of this study.

Diaries of Activities

As a participant in the overall research project, the author visited the subjects in their homes. The method for keeping the diaries of activities was explained to each subject during a home visit. The diaries were to be representative of the usual homemaking activities. The subject was to select the two days to be recorded but was requested not to select a Sunday unless this day was devoted to the usual homemaking duties. The days selected did not need to be consecutive. If the work performed on certain days of the week was usually of a strenuous type, and on other days was of a lighter type of activity, the subject was asked to select a day of each type of work for her activity record. Copies of a form (see Table 2) were given to each woman for the completed day's record.

The form was designed to obtain complete information from each subject and also to provide for uniformity in the manner of recording the data. The second page of the form gave a description of activities to assist the homemaker in placing her 'light work' and 'strenuous work' in the correct categories.

Weight Groups

The women were placed in five weight groups as follows: -20 to -10% underweight, desirable weight, 0 to +10%, +10 to

Table 2. Form for record of activities - Subproject 1: Nutritional Status of Older Women (NC-5)

Subject: Number___Name______________________Date____Day____
Age subject___No. in family at home___No. adults___
No. children___
House: No. rooms___No. floors___Dimensions______________

Way time was spent	Amt. of time
Sleeping	________
Resting (during the day lying down)	________
Preparing meals: bkfst.___lunch___dinner___	________
Eating: bkfst.___lunch___dinner___	________
Washing dishes: bkfst.___lunch___dinner___	________
Care of house - Strenuous work	________
Care of house - Light work	________
Washing clothes (automatic washer, yes___no___)	________
Ironing clothes - sitting (hand iron___ mangle___)	________
Ironing clothes - standing (hand iron___ mangle___)	________
Sewing (electric machine___pedal machine___)	________
Sewing by hand or other hand work	________
Shopping (carrying bundles___no. bundles___)	________
Walking (not inside and not shopping)	________
Caring for children	________
Recreation: kind______________	________
Driving car	________
Outdoor work: kind______________	________
Other: List:______________________	________
Total (24 hrs.)	________

How many times did you go upstairs today?____

Table 2. (Continued)

DESCRIPTION OF ACTIVITIES
House Care - Strenuous Scrubbing floors Making beds Waxing floors Sweeping rugs Moving furniture Washing windows Etc.
House Care - Light Dusting furniture Dustmopping floors Straightening bookshelves or magazine racks General tidying of the house Etc.
Sewing by hand or other hand work Knitting Embroidering Crocheting Darning Patching Hand sewing in general Etc.
Recreation: Kind: Sitting listening to the radio Playing cards Visiting with friends Bowling Golfing Swimming Etc.
Outdoor work: Kind: Planting garden Raking yard Pulling weeds Mowing yard Taking care of chickens Chores Etc.

+20%, and +20% overweight. The 1959 tables of weight standards for women constructed by the Metropolitan Life Insurance Company (26) were used to estimate the per cent deviation of body weight from desirable body weight. The weight divisions for structure of body frame were not used, but the entire range of weight for each inch of height given in the table was accepted as the desirable or standard body weight for that height.

Health Scores

The health scores for each subject that were used in this study were made available from the data of the project Nutritional Status of Older Women.* These scores were a composite of the summaries from the medical examinations and the health history schedules for each subject.

Temperament and Efficiency Rating

The temperament and efficiency of each subject were judged by a panel consisting of the author and two members** of the research staff who visited the subjects at stated times to collect the samples for the "balance study" in the nutri-

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*Appreciation is given to Dr. Pearl P. Swanson and the members of her research staff for the use of this data.

**Appreciation is given to Harriett Roberts Wilkinson and to Isabel Pesek for their assistance in establishing these ratings.

tion project. After the visits were terminated for the project, these staff members established the rating from a subjective evaluation based on their impressions of each subject for these two characteristics.

Calculation of Energy Expenditure

Various activities of the subjects were classified according to the different categories in Table 1 on the basis of bodily movements and apparent effort involved in performing the activities. Any activity reported by the subjects but not listed in Table 1 was assigned to a category as indicated below.

The sitting quietly activities were: reading, visiting with people, riding in a car, listening to a radio, attending a movie, attending meetings, sitting in a doctor's office, and wasting time.

Activities which were classified as sitting activities with moderate hand and arm movement included playing cards, Chinese Checkers, quiet games with children, work with church committees, desk work, watching sports, and writing letters. Activities classified as sitting activities with body movement were: playing the piano, milking cows, typing, and driving a car.

The activities which were assessed as standing activities with some arm and body motion were: weighing food, sweeping the porch, setting up a picnic table, picking flowers, reporting at a meeting, dressing and undressing and caring for children.

Tasks of the homemakers which were classified as standing activities with arm and bending and lifting motion were: fixing the furnace, gathering garden vegetables, planting garden, hanging up clothes, and putting up screens. Activities categorized as standing activities with bending and pushing or pulling motion were: hoeing garden, weeding the garden, raking the yard, and others of similar nature.

A summary of the metabolic cost of various activities was developed from the compilation of data taken from the available literature which was given in Table 1. The average energy expenditure in Calories per kilogram per hour for each category of activities was obtained by averaging values for all activities listed in the category. The range was established to include the low and high values for the activities. The average and range of energy expenditures expressed as Calories per kilogram$^{0.73}$ per hour were obtained in a similar manner for these categories of activities. Values based on total body weight and metabolically effective body weight are given in Table 3. Table 4 was prepared for use in calculating energy costs, on the basis of body weight, of the diaries of activities. Table 5 was developed for calculating energy costs of activities on the basis of body weight raised to the 0.73 power.

Table 3. Energy costs of activities

Categories of activities	Estimated energy cost per category Cal./kg./hr.		Cal./kg.$^{0.73}$/hr.	
	Average	Range	Average	Range
Resting lying down	0.9	0.9- 1.0	2.9	2.6- 3.2
Standing at rest	1.1	1.0- 1.2	3.2	3.0- 3.2
Preparing meals				
Moderate	1.3	1.3- 1.4	4.1	3.9- 4.3
Strenuous	2.4	2.1- 2.7	7.4	6.2- 8.5
Very strenuous	3.4	3.0- 3.8	10.7	9.5-11.9
Eating	1.7	1.5- 1.9	5.6	4.8- 6.4
Washing dishes				
Moderate	1.8	1.6- 2.2	5.4	4.5- 6.9
Strenuous	3.0		8.6	
Very strenuous	3.8	2.4- 4.5	12.4	8.1-15.3
Care of house				
Light	2.4	1.9- 2.7	7.8	5.5- 8.7
Moderate	3.4	3.3- 3.6	11.1	10.8-11.6
Strenuous	3.8	3.7- 3.8	13.4	13.1-13.6
Very strenuous	4.7	4.2- 5.5	15.4	13.7-17.2
Washing clothes, machine	2.9	1.8- 5.2	8.8	5.6-15.4
Washing clothes, hand				
Light	2.5	2.2- 3.6	7.9	6.5-11.7
Strenuous	4.8	3.7- 5.3	15.5	12.7-17.4
Ironing by hand				
Sitting	1.8	1.5- 2.2	5.7	4.8- 6.7
Standing	2.0	1.6- 2.3	6.8	5.0- 7.7
Ironing with mangle				
Light	1.4	1.4- 1.5	4.3	4.1- 4.4
Strenuous	4.6		15.0	
Sewing, electric machine	1.2	1.2- 1.2	3.6	3.5- 3.8
Sewing, pedal machine	1.4	1.4- 1.7	5.0	4.4- 5.6
Sewing, hand	1.3	1.2- 1.4	4.0	3.6- 4.4
Walking	3.2	1.9- 4.4	9.6	6.1-13.0
Walking upstairs	9.0	7.8-10.2	25.7	22.1-29.2
Walking downstairs	5.6	4.3- 6.9	15.8	12.1-19.5
Walking up and down stairs	7.5	5.8- 7.7	21.6	18.6-24.7
Sitting activity	1.0	1.0- 1.1	3.2	2.8- 3.4
Sitting, moderate hand and arm movement	1.3	1.2- 1.4	4.1	3.6- 4.5
Sitting, body movement	1.4	1.4- 1.5	5.0	4.1- 6.7
Standing activity, some arm and body motion	1.9	1.6- 2.4	5.9	4.5- 7.5
Standing: arm, bending and lifting motion	2.5	2.3- 3.0	7.8	6.2- 8.7
Standing with bending, pulling or pushing motion	3.9	3.2- 5.5	13.3	10.1-17.2
Walking and carrying load	3.6	2.9- 4.3	11.4	9.5-13.2

Table 4. Energy cost of activities of Iowa women, 30-85 years old (inclusive of basal metabolism and influence of food)

Subject no._____
Ht. (cm.)_______
Wt. (kg.)_______
S.A. (M^2)_______

B.M.R./kg./hr.___________________
Total energy expended/24 hr._____
Energy expended/kg./24 hr._______
Energy expended/M^2/24 hr.________

Activity category	Cal./kg./hr. Mean	Cal./kg./hr. Range	Remarks	Adjusted Cal./kg./hr.	Activity hours	Cal./kg. for activity
Sleeping (B.M.R.)						
Resting - lying down	0.9	0.9-1.0				
Preparing meals - moderate	1.3	1.3-1.4				
Preparing meals - strenuous	2.4	2.1-2.7				
Eating	1.7	1.5-1.9				
Washing dishes	1.8	1.6-2.2				
Care of house - light	2.4	1.9-2.7				
Care of house						
Washing clothes - machine	2.9	1.9-5.2				
Washing clothes - hand						
Ironing - hand & sitting	1.8	1.5-2.2				
Ironing - hand & standing	2.0	1.6-2.3				
Ironing - mangle, light	1.4	1.4-1.5				
Sewing - electric machine	1.2	1.1-1.2				

Table 4. (Continued)

Activity category	Cal./kg./hr. Mean	Cal./kg./hr. Range	Remarks	Adjusted Cal./kg./hr.	Activity hours	Cal./kg. for activity
Sewing - pedal machine	1.4	1.4-1.5				
Sewing - hand	1.3	1.2-1.4				
Walking	3.2	1.9-4.4				
Walking - carrying load	3.6	2.9-4.3				
Walking upstairs	7.6					
Walking downstairs	4.3					
Sitting	1.0	1.0-1.1				
Sitting - moderate hand and arm motions	1.3	1.2-1.4				
Sitting with body movement	1.4	1.4-1.5				
Standing - some arm and body motions	1.9	1.6-2.4				
Standing - arm bending and lifting motions	2.5	2.3-3.0				
Standing - arm, leg, body bending, and pulling motions	3.9	3.2-5.5				
	Grand total					

Table 5. Energy cost of activities of Iowa women, 30-85 years old (inclusive of basal metabolism and influence of food)

Subject no._____
Ht. (cm.)_____
Wt. (kg.)_____
S.A. (M^2)_____

B.M.R./kg./hr._____
Total energy expended/24 hr._____
Energy expended/kg./24 hr._____
Energy expended/M^2/24 hr._____

Activity category	Cal./kg.$^{0.73}$/hr. Mean	Range	Remarks	Adjusted Cal./kg./hr.	Activity hours	Cal./kg.$^{0.73}$ for activity
Sleeping (B.M.R.)						
Resting - lying down	2.9	2.6-3.2				
Preparing meals - moderate	4.1	3.9-4.3				
Preparing meals - strenuous	7.4	6.2-8.5				
Eating	4.8	4.5-5.0				
Washing dishes	5.4	4.5-6.9				
Care of house - light	7.8	5.5-8.7				
Care of house						
Washing clothes - machine	8.8	5.6-15.4				
Washing clothes - hand						
Ironing - hand & sitting	5.7	4.8-6.7				
Ironing - hand & standing	6.8	5.0-7.7				
Ironing - mangle, light	4.3	4.1-4.4				
Sewing - electric machine	3.6	3.5-3.8				

Table 5. (Continued)

Activity category	Cal./kg.$^{0.73}$/hr. Mean	Cal./kg.$^{0.73}$/hr. Range	Remarks	Adjusted Cal./kg./hr.	Activity hours	Cal./kg.$^{0.73}$ for activity
Sewing - pedal machine	5.0	4.4-5.6				
Sewing - hand	4.0	3.6-4.4				
Walking	9.6	6.1-13.0				
Walking - carrying load	11.4	9.5-13.2				
Walking upstairs	22.1					
Walking downstairs	12.4					
Sitting	3.2	2.8-3.4				
Sitting - moderate hand and arm motions	4.0	3.6-4.5				
Sitting with body movement	5.0	4.1-6.7				
Standing - some arm and body motions	5.9	4.5-7.5				
Standing - arm bending and lifting motions	7.8	6.2-8.7				
Standing - arm, leg, body bending, and pulling motions	13.3	10.1-17.2				
	Grand total					

RESULTS AND DISCUSSION

Ninety-one diaries of activities for 24-hour periods that had been recorded by 46 homemakers were analyzed for the caloric equivalent of the daily energy expenditure. Daily energy expenditures were expressed as Calories per kilogram per hour of activity and also as Calories per kilogram, raised to the 0.73 power per hour of activity. The results of these analyses are evaluated according to the physical characteristics of the subjects in the following section. Statistical analyses were not applied to the data because the number of subjects was not adequate for isolation of the multiple interactions of the various factors which might influence energy expenditures.

Description of Subjects

The physical characteristics and basal metabolisms of the 46 women subjects are given in Table 6. The average age of the entire group of homemakers was 54 years and the range was 33 to 85 years. Twenty-three women were in the fifth and sixth decades. The women ranged in height from 150.5 to 178.0 cm. Sixteen of the subjects were within the range of desirable weight for height, from small to large frame, as given in the 1959 Metropolitan Life Insurance tables of standard weight (26). There were 15 women whose body weight exceeded the range of desirable body weight by 20 per cent or more.

Table 6. Description of subjects

Subject no.	Age yrs.	Height cm.	Body weight kg.	Body weight $kg.^{0.73}$	Desirable body weight kg.	Deviation group[a]	Basal metabolism Cal./hr.
1	40	157.8	72.6	22.8	59.6	O	59.8
2	65	163.8	74.2	23.2	62.7	O	57.5
4	47	163.8	59.9	19.8	59.9	DW	48.2
6	42	166.8	55.5	18.8	55.5	DW	54.8
7	35	158.3	46.5	16.5	46.5	DW	55.6
8	34	171.5	59.2	19.7	59.2	DW	63.3
9	49	159.5	71.7	22.6	60.9	O	55.5
10	76	153.0	70.3	22.3	56.8	O	55.5
11	52	164.3	72.9	22.9	64.6	MO	57.4
14	52	166.0	69.6	22.1	64.6	MO	59.1
15	49	165.3	59.4	19.7	59.4	DW	49.1
16	53	158.4	74.4	23.2	59.6	O	62.5
18	39	166.0	57.6	19.3	57.6	DW	48.5
20	33	178.0	76.9	23.8	74.0	MO	63.6
21	33	155.0	45.0	16.1	45.0	DW	41.0
22	40	164.6	95.0	27.8	64.6	O	61.0
23	62	159.0	53.2	18.2	53.2	DW	37.7
26	54	166.0	64.4	20.9	64.4	DW	52.1
27	54	162.5	78.2	24.1	62.7	O	52.1
28	72	160.0	65.8	21.2	60.9	MO	46.1
31	57	160.0	66.2	21.3	60.9	MO	56.1
32	52	165.5	70.3	22.3	64.6	MO	54.5
33	42	169.2	66.2	21.3	66.2	DW	47.7
34	71	160.2	55.1	18.7	55.1	DW	44.6
35	47	168.0	58.1	19.4	58.1	DW	54.6

[a]DW = desirable weight, includes the entire range for height, from small to large frame, as given in the 1959 Metropolitan Life Insurance tables of standard weight;

MO = moderate overweight, includes weights 19% over range of desirable weight for height;

O = overweight, includes weights 20% and over the range of desirable weight for height;

UW = underweight, includes weights 19% under range of desirable weight for height.

Table 6. (Continued)

Subject no.	Age yrs.	Height cm.	Body weight kg.	Body weight $kg.^{0.73}$	Desirable body weight kg.	Desirable body weight Deviation group	Basal metabolism Cal./hr.
37	54	157.6	54.4	18.5	54.5	DW	48.8
38	59	173.5	91.2	27.0	70.0	O	59.1
39	39	174.8	74.2	23.2	70.0	MO	54.6
40	58	158.4	65.5	21.2	59.6	MO	52.6
43	46	165.5	94.8	27.7	64.6	O	67.5
45	47	161.0	88.2	26.3	62.7	O	56.7
46	36	155.9	56.7	19.1	58.2	DW	48.2
47	46	164.8	61.5	20.2	61.5	DW	54.3
49	68	173.5	82.8	25.1	70.0	MO	68.5
50	67	161.8	79.6	24.4	62.7	O	63.3
51	65	150.5	69.6	22.1	55.4	O	57.4
52	74	166.8	68.5	21.9	66.4	MO	45.0
53	62	177.3	82.4	25.0	74.1	MO	57.5
54	85	154.1	38.6	14.4	45.0	UM	44.1
55	71	162.7	64.3	20.9	62.7	MO	46.4
56	70	156.8	76.7	23.8	59.6	O	58.4
57	63	157.2	91.4	27.0	58.2	O	64.9
58	60	162.0	68.0	21.8	62.7	MO	49.0
59	49	163.0	74.4	23.2	62.7	O	59.0
60	71	160.0	62.6	20.5	60.9	MO	49.3
100	56	173.0	70.1	22.2	70.0	DW	50.4

The range of deviation from desirable body weight was from -6.4 to +33.2 kg. Only one of the subjects, no. 54, was underweight. This subject, who was 85 years old, was the only subject studied who was in the ninth decade of age.

Basal metabolisms for all of the women ranged from 41.0 to 68.5 Calories per hour. The basal metabolic rate of 38 women was within the range usually considered as standard, -15% to +15%, as given by Guyton (27, p. 926). Eleven of the subjects were in the positive area and 27 were in the negative area of the range. Eight women had basal metabolic rates between -15% and -26%.

Table 7 presents additional characteristics which are descriptive of the subjects. These include the composition of the family, the nature of the dwelling, and the health scores which were evaluated from laboratory findings, case histories, and clinical appraisals of the subjects.

The composition of the family may be expected to influence the dietary habits and/or energy expenditures of the adult women. The woman who lives alone, for example, may be a compulsive eater as a compensation for loneliness. The older person who lives alone may eat an insufficient amount of food since there is little incentive to have organized meals and the impetus from sharing food with others is lacking. There were six women who participated in the study who lived alone. They ranged in age from 58 to 74 years. One woman was of desirable weight, and one was more than 20% over the range for desirable weight. Twenty-two women lived in families with adult members only. Eighteen of the subjects were from families with children in the home. Seven of the women who lived in families of adult members were of desirable weight, and eight of the women in families with children were

Table 7. Description of subjects

Subject no.	Family members		House size		Health score[a]	Efficiency level[b]	Temperament[c]
	Adults	Children	Rooms	Floors			
1	2	1	5	2	P	L	R
2	1	-	5	1	G-F	L	P
4	3	-	9	2	G	A	R
6	2	-	5	1	F-P	H	N-T
7	2	3	10	2	G	A	N-T
8	2	3	7	2	F-P	A	N-T
9	3	1	9	3	F-P	H	P
10	2	-	6	1	F	A	R
11	2	-	7	2	G-F	H	R
14	4	-	11	3	G	H	R
15	2	-	5	2	G-F	A	N-T
16	1	2	6	2	F	L	N-T
18	2	2	7	2	G-F	H	N-T
20	3	2	3	1	F	L	P
21	2	2	5	1	G	A	N-T
22	2	3	6	2	P	H	R
23	2	-	8	2	G-F	A	R
26	3	-	7	2	G-F	H	P
27	2	-	7	2	F	A	R
28	1	-	5	1	F	A	P
31	3	1	7	2	F	H	R
32	4	2	5	2	G	H	N-T
33	1	2	8	2	G	A	P
34	1	-	7	2	F	A	N-T
35	3	1	7	2	F	A	N-T
37	5	-	9	2	G	A	R
38	2	-	7	2	F-P	A	R
39	2	3	6	2	G-F	H	R
40	1	-	9	2	F	H	N-T
43	2	1	9	2	G-F	H	R

[a]F-Good; G-F-Good to Fair; F-Fair; F-P-Fair to Poor; P-Poor.

[b]H-High; A-Average; L-Low.

[c]N-T-Nervous, tense; R-Average, relaxed; P-Placid.

Table 7. (Continued)

Subject no.	Family members		House size		Health score	Efficiency level	Temperament
	Adults	Children	Rooms	Floors			
45	2	-	7	2	G-F	A	R
46	2	2	6	2	F-P	A	R
47	2	1	7	2	F-P	H	R
49	2	-	6	2	F	H	R
50	2	-	5	2	F	A	N-T
51	2	-	6	2	F-G	A	R
52	1	-	2	1	F-P	L	N-T
53	2	-	8	2	G	H	R
54	2	-	5	1	G	A	N-T
55	1	-	5	2	F	A	P
56	2	2	3 1/2	1	F	H	R
57	2	-	9	2	F	A	N-T
58	2	-	6	1	F	A	R
59	3	-	7	2	G	L	N-T
60	3	-	7	2	G	A	N-T
100	2	-	6	1	G	A	N-T

desirable weight.

Thirty-five of the subjects lived in houses with two floors. Of these, 11 were in houses with eight or more rooms. Eleven women lived in houses of one floor and with six rooms or less. The size of the house in which they lived was apparently not related to the body weight of the women.

The subjects were physically active and able to perform their usual homemaking activities. There was considerable variation, however, among the subjects with respect to the attributes associated with health. The inadequacy of the expression "poor health rating" is recognized; however, the term was used as a convenient means of describing those subjects whose medical histories and physical examinations indicated that they lacked some of the characteristics associated positively with health although they were not clinically ill. The health ratings of the subjects ranged from good to poor. The major disturbances that contributed to poor scores for the health schedules were: a history of digestive, circulatory, and hepatic disorders; major nervous disorders; major operations; broken bones; difficulty in childbearing. Among the minor disturbances which contributed to poor scores for the health schedules were: overweight or underweight; difficulty in menopause; anorexia; fatigue; frequent headaches; soreness of the mouth; pains in the joints; skin rash or pustules.

Eleven of the subjects had health ratings which would be considered indicative of a good state of health. There were 10 subjects with less than fair ratings.

Daily Energy Expenditure of Homemakers

The subjects are classified according to decade of age in Table 8 which presents the energy expenditures of the subjects for each of the two days of observation and the mean daily energy expenditure as estimated from the factors given in Table 3 as Calories per kilogram per hour. In Table 9 the subjects are classified as in Table 8 but the energy expendi-

Table 8. Mean energy expenditure of 46 homemakers on two days calculated energy expenditures[a]

Subject no.	Age yrs.	Body weight kg.	Body weight $kg.^{0.73}$	From factors: Calories per day 1[b]	2[c]	Av.	Cal./kg./hr. Mean Cal./kg./day
20	33	76.9	23.81	2221	2614	2418	31.4
21	33	45.0	16.10	1462	1663	1562	34.8
8	34	59.2	19.67	2501	2666	2584	43.6
7	35	46.5	16.49	1992	2013	2002	43.0
46	36	56.7	19.06	1532	1992	1762	31.0
18	39	57.6	19.28	2034	2483	2258	39.2
39	39	74.2	23.19	1776	2073	1924	25.9
Av.	35.6	59.44	19.66	1931	2215	2073	35.6
1	40	72.6	22.83	2444	2718	2581	35.6
22	40	95.0	27.78	2453	3206	2830	29.8
6	42	55.5	18.76	1847	1962	1904	34.4
33	42	66.2	21.34	1726	2026	1876	28.4
43	46	94.8	27.74	3664	3963	3814	40.2
47	46	61.5	20.22	2260	2355	2308	37.5
4	47	59.9	19.84	1876	2368	2122	35.4
35	47	58.1	19.40	1806	2056	1931	33.2
45	47	88.2	26.31	2718	3479	3098	35.1
15	49	59.4	19.72	1825	2013	1919	32.3
59	49	74.4	23.24	2177	2561	2369	31.8
9	49	71.7	22.62	2297	2473	2385	33.2
Av.	45.3	71.44	22.48	2258	2598	2428	33.9
11	52	72.9	22.90	2490	3375	2932	40.2
14	52	69.6	22.14	2435	2677	2556	36.7
32	52	70.3	22.30	2696	2748	2722	38.7
16	53	74.4	23.24	2405	3134	2770	37.2
26	54	64.4	20.91	1825	1837	1831	28.4
27	54	78.2	24.10	2637	2890	2763	35.3
37	54	54.4	18.49	1660	1832	1746	32.1
100	56	70.1	22.25	1860	1863	1862	26.6
31	57	66.2	21.34	2501	2756	2628	39.7
40	58	65.5	21.18	2290	2303	2296	35.1
38	59	91.2	26.96	2646	3249	2948	32.3
Av.	54.6	70.65	22.35	2313	2606	2459	34.8

[a]Factors for energy expenditure in Cal/kg./hr. are given in Table 3.

[b]Day 1 was considered by the subject to be a day of relatively light activity.

[c]Day 2 was considered by the subject to be a day of relatively strenuous activity.

Table 8. (Continued)

Subject no.	Age yrs.	Body weight kg.	Body weight $kg.^{0.73}$	From factors: Calories per day 1	From factors: Calories per day 2	From factors: Calories per day Av.	Cal./kg./hr. Mean Cal./kg./day
58	60	68.0	21.76	2113	2332	2222	32.7
23	62	53.2	18.19	1561	1739	1650	31.0
53	62	82.4	25.04	2111	2202	2156	26.2
57	63	91.4	27.01	3382	3539	3460	37.8
2	65	74.2	23.19	1992	2122	2057	27.7
51	65	69.6	22.14	2358	2609	2484	35.7
49	66	82.8	25.13	3379	3512	3446	41.6
50	67	79.6	24.41	2569	2772	2670	33.6
Av.	63.8	75.15	23.36	2433	2603	2518	33.3
56	70	76.7	25.96	2488	3059	2774	36.2
55	71	64.3	20.89	1546	1872	1709	26.6
60	71	62.6	20.49	1743	1792	1769	28.2
34	71	55.1	18.67	1702	1746	1724	31.3
28	72	65.8	21.25	1912	1926	1919	29.2
52	74	68.5	21.88	2157	2530	2344	34.2
10	76	70.3	22.30	2381	3002	2692	38.3
Av.	72.1	66.19	21.32	1990	2275	2133	32.0
54	85	38.6	14.40	1154	--	1154	29.9

tures were estimated from factors of Calories per kilogram to the 0.73 power per hour as given in Table 3. Although the two days on which records were kept were selected by the subjects as typical of a day of relatively light or easy activity and a day of relatively strenuous activity, the difference in energy expenditures between the two days varied widely for the subjects. Energy expenditures calculated from factors of Calories per kilogram to the 0.73 power per hour for the two days differed less than 50 Calories for seven subjects but more than 500 Calories for nine subjects. Thus there may

Table 9. Mean energy expenditure of 46 homemakers on two days calculated energy expenditures[a]

Subject no.	From factors: Cal./kg.$^{0.73}$/hr.			
	Calories per day			Mean
	1[b]	2[c]	Av.	Cal./kg.$^{0.73}$/day
20	2065	2649	2357	99.0
21	1516	1642	1579	98.2
8	2617	2774	2696	137.0
7	2039	2046	2042	123.9
46	1505	1998	1752	91.8
18	2018	2259	2138	110.9
39	1654	1939	1796	77.4
Av.	1916	2187	2051	105.5
1	2244	2535	2390	104.6
22	2164	2860	2512	90.4
6	1896	2014	1955	104.6
33	1638	1970	1804	84.6
43	3490	3700	3595	129.6
47	2337	2419	2378	117.6
4	1819	2390	2104	106.1
35	1770	2065	1918	98.8
45	2512	3289	2900	110.2
15	1772	1996	1884	95.5
59	2118	2495	2306	99.2
9	2174	2221	2198	97.2
Av.	2161	2496	2329	103.2
11	2430	2926	2678	117.0
14	2434	2650	2542	114.9
32	2486	2519	2502	112.2
16	2369	2858	2614	112.5
26	1784	1818	1801	86.2
27	2418	2752	2585	107.2
37	1658	1792	1725	93.2
100	175[illegible]	1768	1763	79.2
31	2482	2807	2644	124.0
40	2247	2325	2286	108.6
38	2292	3076	2684	99.6
Av.	2214	2481	2348	105.0

[a]Factors for energy expenditure in Cal./kg.$^{0.73}$/hr. are given in Table 3.

[b]Day 1 was considered by the subject to be a day of relatively light activity.

[c]Day 2 was considered by the subject to be a day of relatively strenuous activity.

Table 9. (Continued)

Subject no.	From factors: Cal./kg.$^{0.73}$/hr. Calories per day 1	2	Av.	Mean Cal./kg.$^{0.73}$/day
58	2018	2266	2142	98.4
23	1569	1953	1761	96.8
53	1947	2051	1999	79.8
57	3227	3351	3289	121.8
2	1993	2069	2031	87.6
51	2344	2437	2390	108.0
49	3111	3391	3251	129.4
50	2464	2690	2577	105.6
Av.	2334	2526	2430	103.4
56	2455	2802	2628	110.6
55	1487	2079	1783	85.4
60	1689	1783	1736	84.7
34	1720	1750	1735	92.9
28	1847	1887	1867	87.8
52	2048	2482	2265	103.5
10	2322	3108	2715	121.8
Av.	1938	2270	2104	98.1
54	1288	--	1288	89.4

have been less fluctuation in energy expenditure from day to day for some subjects than for others. Also, it is possible that the homemakers who reported activities for the two days on which the energy expenditures were essentially the same may have been unable to evaluate the daily activities in terms of the requirement for physical energy or to differentiate between fatigue from physical energy and fatigue caused by performing tasks less pleasant to them than other tasks. Knowles (18) has reported that psychological factors may affect metabolic rate; although this phase of the study was considered incomplete, Knowles found that energy expenditure increased 25% for a woman who performed a task which she disliked.

The mean energy expenditure on the day of "light" activity was 1989 Calories per day for the seven women for whom the difference between the two days was less than 50 Calories and 2157 Calories per day for the nine women for whom the difference between the two days was 500 Calories or more. The range of daily energy expenditures was 1720 to 2485 Calories per day and 1487 to 2512 Calories per day for the two groups, respectively. Thus one group did not appear to be more sedentary in nature than the other. Six of the nine women for whom the energy expenditures for the two days varied by 500 Calories or more were 20% or more over the desirable range in weight and one was of desirable weight; only one of the seven women for whom the energy expenditures of the two days differed by 50 Calories or less was 20% or more over the desirable range in weight and four were of desirable weight. Ages of the subjects in both groups ranged from the fourth to the eighth decade.

The mean energy expenditure on a day of "light" activity for the women in this study was similar to the values reported by Durnin et al. (15) and (11). Values of 2090 Calories per day were reported by these workers for middle-aged housewives, and 2133 Calories per day for elderly housewives.

Influence of age and body weight

According to Langford (19), the basal metabolism of adult women decreased with age but the increment of energy expenditure for the performance of standardized activities on the treadmill was not influenced by age. The increment in the energy expenditure for activity did vary directly with the extent of overweight. An increase in energy expended during the basal period and during work by obese subjects over subjects of desirable weight was reported also by McKee and Bolinger (28).

Table 10 presents the mean energy expenditure of the subjects grouped according to age and status of body weight. The number of subjects within each subgroup is limited; nevertheless, the data indicated that the energy expenditures of women may be influenced by age and by body weight.

Age When factors of Calories per kilogram to the 0.73 power per hour were used in calculation, the mean energy expenditures of the subjects for the two days were, in Calories per day, 2041, 2007, 1763, 1761 and 1735 for the women of desirable weight from the fourth through the eighth decade, respectively. Only one subject of desirable weight was studied in the seventh and in the eighth decades. Data for the fourth, fifth and sixth decades indicated a decrease with

Table 10. Mean energy expenditure of subjects grouped according to age and body weight

Subjects	No. of subjects	Mean daily energy expenditure					
		Factor: Cal./kg./hr. Calories per day			Factor: Cal./$kg.^{0.73}$/hr. Calories per day		
		day 1	day 2	av.	day 1	day 2	av.
30-39 yrs.							
Within range of desirable weight[a]	5	1904	2163	2034	1939	2144	2041
Moderate overweight[b]	2	1998	2344	2171	1860	2294	2076
Overweight[c]	-	-	-	-	-	-	-
40-49 yrs.							
Within range of desirable weight	6	1890	2130	2010	1872	2142	2007
Moderate overweight	-	-	-	-	-	-	-
Overweight	6	2626	3067	2846	2450	2850	2650
50-59 yrs.							
Within range of desirable weight	3	1782	1844	1813	1733	1793	1763
Moderate overweight	5	2482	2772	2627	2416	2645	2530
Overweight	3	2563	3091	2827	2360	2895	2628

[a]Desirable weight includes the entire range of weight for height, from small to large frame, as given in the 1959 Metropolitan Life Insurance tables of Standard Weight.

[b]Moderate overweight includes weights 19% over the range of desirable weight for height.

[c]Overweight includes weights 20% and over the range of desirable weight for height.

Table 10. (Continued)

Subjects	No. of subjects	Mean daily energy expenditure Factor: Cal./ kg./hr. Calories per day			Factor: Cal./ $kg.^{0.73}$/hr. Calories per day		
		day 1	day 2	av.	day 1	day 2	av.
<u>60-69 yrs.</u>							
Within range of desirable weight	1	1561	1739	1650	1569	1953	1761
Moderate overweight	3	2534	2682	2608	2359	2569	2464
Overweight	4	2575	2760	2667	2507	2637	2572
<u>70-79 yrs.</u>							
Within range of desirable weight	1	1702	1746	1724	1720	1750	1735
Moderate overweight	4	1840	2030	1935	1766	2058	1912
Overweight	2	2434	3031	2733	2388	2955	2672
<u>85 yrs.</u>							
Underweight, moderate	1			1154			1288

age in energy expended by the women. The tendency for a decrease in energy expenditure with increase in age was evident also when energy expenditures were calculated on the basis of factors of Calories per kilogram per hour. Values in Calories per day were 2034, 2010 and 1813 for women of desirable body weight of the fourth, fifth and sixth decades, respectively.

A 3% decrease in Calories per day for each decade from 25 to 55 years of life was reported by Durnin *et al*. (15) from a study of energy expenditure by housewives. Perhaps because of the small number of subjects in each group, the decrement in mean energy expenditure with age of the women was not uniform for successive decades. There was an average decrease of 1% from the fourth to the fifth decades and of 12% from the fifth to the sixth decades.

The values reported in Tables 8 and 9 indicate that the energy expenditures for days considered as strenuous by individual homemakers were as great for some of the women in the older age groups as for younger women. The activities which were listed in the diaries support this observation. The older women listed many outdoor activities such as gardening, raking, picking cherries, carrying coal, carrying feed to chickens and gathering eggs. They also reported strenuous indoor activities such as washing with non-automatic machines or by hand. One woman reported two hours of hand washing. Other strenuous indoor activities were ironing, scrubbing and canning. Of the younger women, only one reported any outside activity other than driving a car. This subject reported milking a cow and feeding animals. The others reported ironing as their most strenuous activity. Half of the younger women washed by automatic machines. Only one woman in the 70 to 79 year group washed with an automatic washer. For these subjects, the mode of living and customary patterns of activity of the women in the higher decades required higher energy expenditure than for the younger women. To some extent this factor may have counteracted the influence of age on energy expenditure. A graphic presentation of the average energy expenditure by age groups is given in Fig. 1.

Body weight The highest incidence of overweight women occurred in the fifth, sixth and seventh decades of life. Within each age group, the mean energy expenditures of women who were 20% or more above the range of desirable body weight for age and height were correspondingly higher than the mean energy expenditures of the women classed as moderately over-weight. Subjects who were moderately overweight had higher average energy expenditures than the subjects who were judged to be of desirable body weight with one exception. This exception was for one day when the average energy expenditure was calculated from the factors of Calories per kilogram to the 0.73 power for two women, 30 to 39 years of age who were classed as moderately overweight. One of the two subjects, no. 39, was relatively inactive; her energy expenditures were 1654 and 1939 Calories per day for the two days.

There was not a definite trend toward reduction of energy expenditure with age for the moderately overweight and the overweight women as there was for the women of desirable body weight. The mean energy expenditures for women who were moderately overweight were higher for subjects in the sixth and seventh decades than for subjects in the fourth and eighth

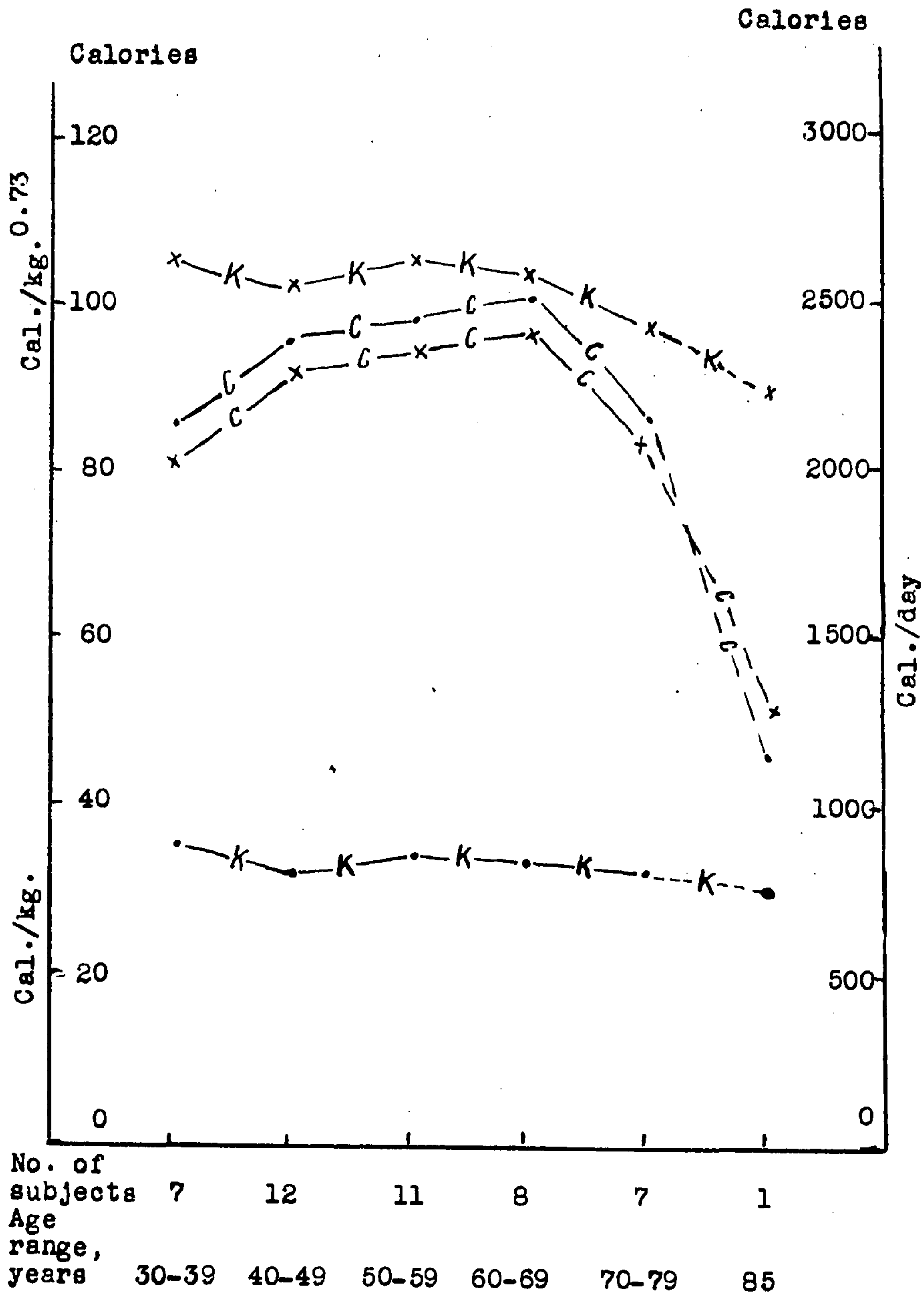
Fig. 1. Average daily energy expenditure by age groups of 46 homemakers by two methods of estimation

Total Calories per day estimated on basis of total body weight .——C——

Total Calories per day estimated on basis of effective metabolic body weight x—— C ——x

Calories per kilogram estimated on basis of total body weight .—— K——

Calories per kilogram to the 0.73 power estimated on basis of effective metabolic body weight x—— K——x


Calories
Calories
120
100
80
60
40
20
0
Cal./kg.0.73
Cal./kg.
3000
2500
2000
1500
1000
500
0
Cal./day
No. of subjects 7 12 11 8 7 1
Age range, years 30-39 40-49 50-59 60-69 70-79 85

decades. The average daily energy expenditure for the two women 70 to 79 years of age and 20% or more above the desirable body weight was greater than for women 60 to 69 years of age and in the same classification of body weight. The data in Table 10 would appear to indicate that body weight or the relative degree of overweight influenced daily energy expenditures to a greater extent than the age of the subjects. A graphic presentation of the average daily energy expenditure by per cent of weight deviation of the 46 homemakers is given in Fig. 2.

Health rating

The data were evaluated for a possible relationship of energy expenditure to the health rating of the subjects. The ratings which ranged from good to poor are presented in Table 11, and shown graphically in Fig. 3. The group which was rated good in health expended an average of 2009 Calories of energy daily. This was the lowest mean daily energy expenditure of all five health groups. The mean daily energy expenditure for the other groups from good-fair to poor was 2250, 2412, 2350 and 2451 Calories. The good health group expended an average of 97.8 Calories of energy per kilogram of metabolically effective body weight. This was approximately the same, 97.5 Calories, as the mean energy expenditure per kilogram of metabolically effective body weight by the group which

Fig. 2. Average daily energy expenditure by per cent of weight deviation of 46 homemakers by two methods of estimation

Total Calories per day estimated on basis of total body weight . —— C —— .

Total Calories per day estimated on basis of effective metabolic body weight x—— C —— x

Calories per kilogram estimated on basis of total body weight .—— k —— .

Calories per kilogram to the 0.73 power estimated on basis of effective metabolic body weight x —— k —— x.

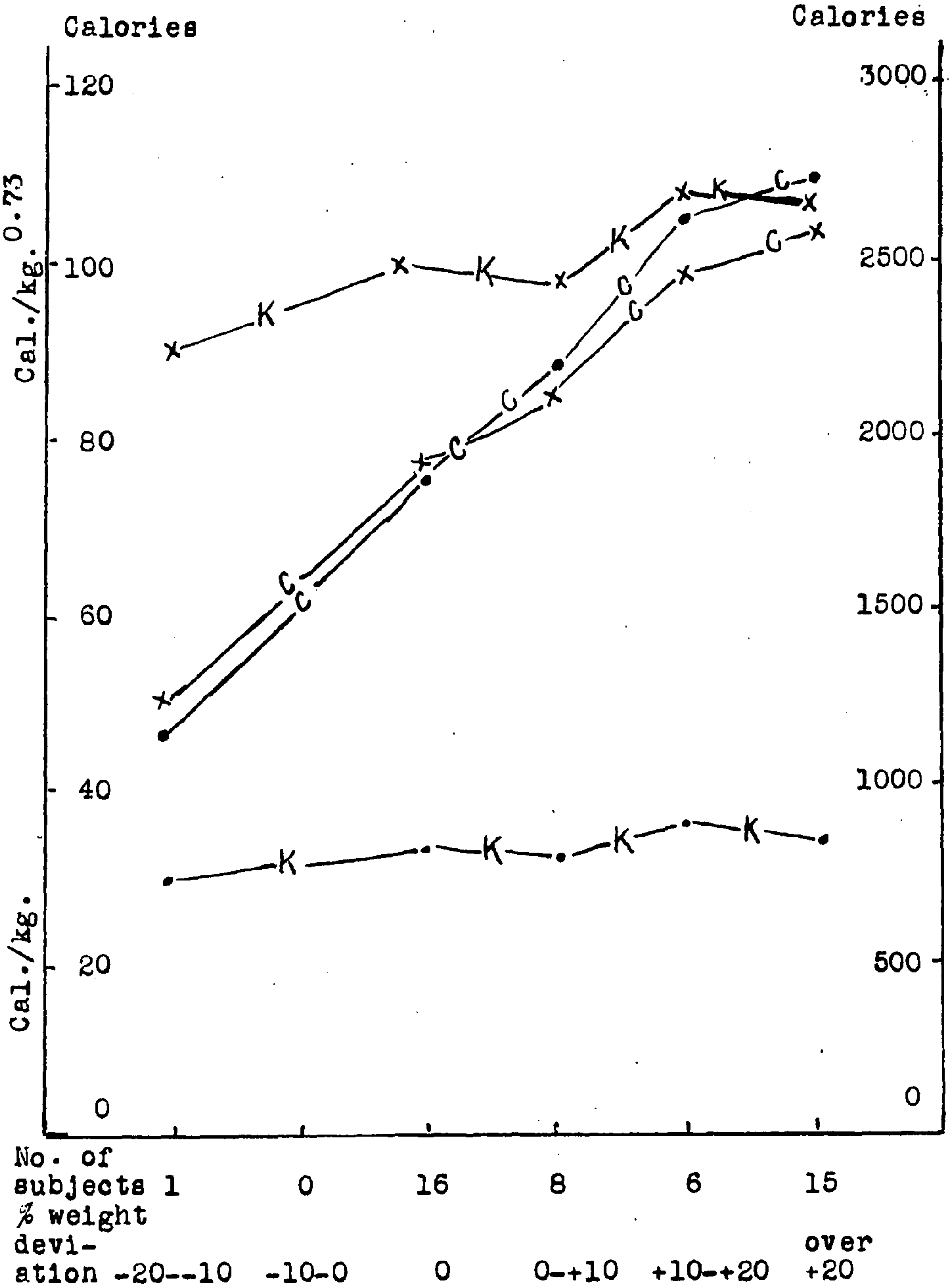

Calories
Calories
120
100
80
60
40
20
0
3000
2500
2000
1500
1000
500
0
Cal./kg. 0.73
Cal./kg.
Cal./day
K
C
No. of subjects 1 0 16 8 6 15
% weight deviation -20--10 -10-0 0 0-+10 +10-+20 over +20

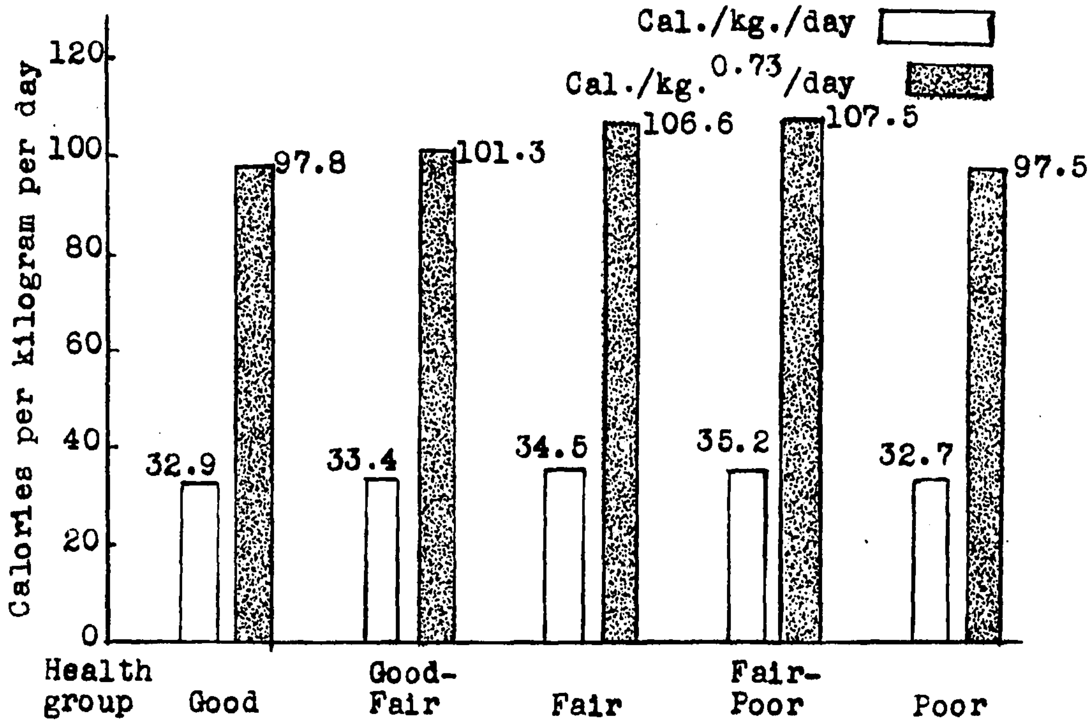
Table 11. Average daily energy expenditure by health rating of 46 homemakers

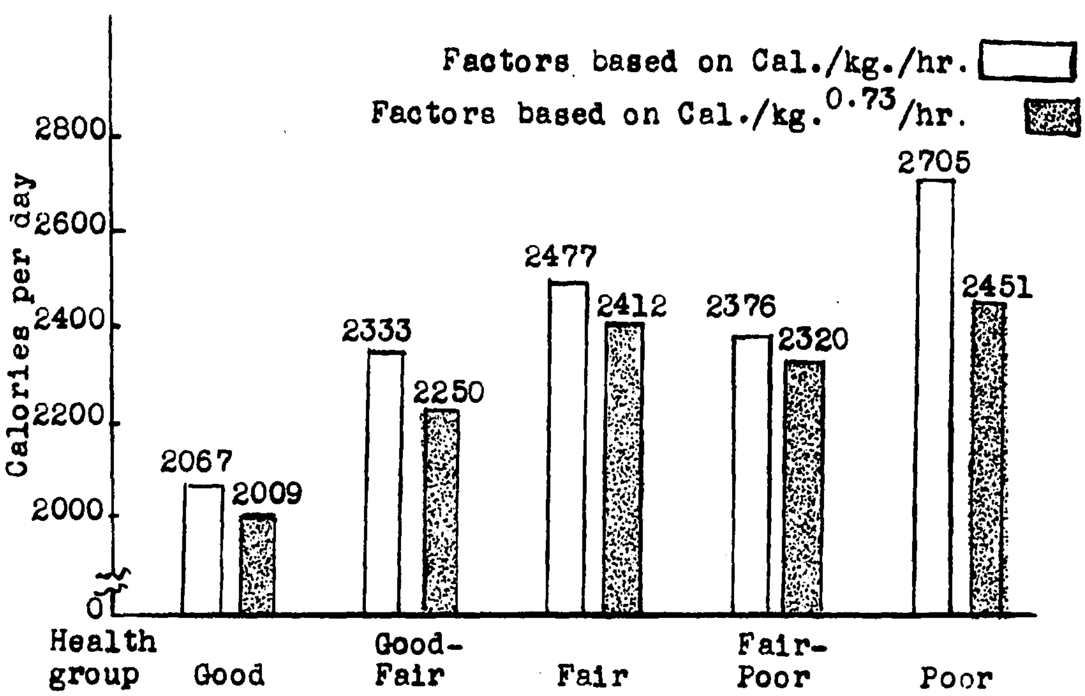
Rating	No. of subjects	Age years	Weight kg. deviation	BMR % of standard	Average Cal./kg.$^{0.73}$	Average Cal./day
		range	range	range		
Good	11	33-71	0 to +11.9	+7 to -23	97.8	2009
Good-Fair	11	39-85	-6.4 to +30.1	+5 to -26	101.3	2250
Fair	14	33-76	0 to +33.2	+5 to -17	106.6	2412
Fair-Poor	8	34-79	0 to +21.4	+3 to -21	107.5	2320
Poor	2	40	+15.4 to +32.3	-4 to -14	97.5	2451

Fig. 3. Average daily energy expenditure by health rating of 46 homemakers

Upper graph
- Calories per kilogram of total body weight per day
- Calories per kilogram to the 0.73 power of body weight per day

Lower graph
- Total calories per day based on factors of
  - Calories per kilogram per hour
  - Calories per kilogram to 0.73 power per hour


Cal./kg./day
Cal./kg.0.73/day
Calories per kilogram per day
120
100
80
60
40
20
0
97.8
101.3
106.6
107.5
97.5
32.9
33.4
34.5
35.2
32.7
Health group
Good
Good-Fair
Fair
Fair-Poor
Poor


Factors based on Cal./kg./hr.
Factors based on Cal./kg.0.73/hr.
Calories per day
2800
2600
2400
2200
2000
0
2067
2009
2333
2250
2477
2412
2376
2320
2705
2451
Health group
Good
Good-Fair
Fair
Fair-Poor
Poor

was rated poor in health. The energy expended in Calories per kilogram to the 0.73 power for the other health groups increased inversely with the quality of health, namely, 101.3, 106.3, 107.5.

Each health group included subjects of desirable weight and also subjects who were overweight. Weight had been one of the factors used in rating the subjects for health status. The maximum range of deviation above the desirable weight was +11.9 kg. for the group which was rated good in health. The other groups included individuals whose weight deviated +21.4 kg. or more over a desirable weight. The fair and poor health groups included subjects with weight deviations of +33.2 and +32.3 kg. respectively. These two groups also expended the highest average number of Calories of energy daily, 2412 and 2451. The group which was rated poor in health was small, only two subjects. They were +15.4 and +32.3 kg. overweight. Although the mean daily energy expenditure by this group was 442 Calories greater than the mean daily energy expenditure by the subjects rated good in health, the average Calories of energy expended per kilogram of metabolically effective body weight was approximately the same for both groups.

An evaluation of the mean daily energy expenditure by the subjects of similar weight in each health group was made. The subjects of desirable weight whose health rating was good, good-fair, fair, and fair-poor expended 1836, 1871, 1826, and 2195 Calories per day, respectively. The subjects whose weight was 13 kg. or less over desirable weight and whose health rating was good, good-fair, fair, fair-poor, and poor expended 2217, 2168, 2319, 2233, and 2390 Calories per day, respectively. Thus these results indicated that the mean daily energy expended by subjects of the health groups was related to the overweight condition rather than to the state of health.

The range of basal metabolic rate was similar for women in all of the health groups. There was no apparent relationship between the health rating and the level of the basal metabolic rate. These health groups may have had too few subjects for such a relationship to be indicated, or the negative basal metabolic rates may not have been enough below the standard range for the effects to be prominent. Booyens and McCance (29) found a much wider range in the basal energy expenditures of 36 healthy subjects and concluded that the limits usually accepted as standard may be too narrow.

The two subjects in the health group which was rated poor were 40 years of age. The other four health groups were composed of subjects from each decade of age through the eighth decade. This resulted in groups of such small numbers that the effect of age was not apparent as a factor related to the energy expenditure by the subjects of different health status.

Additional factors

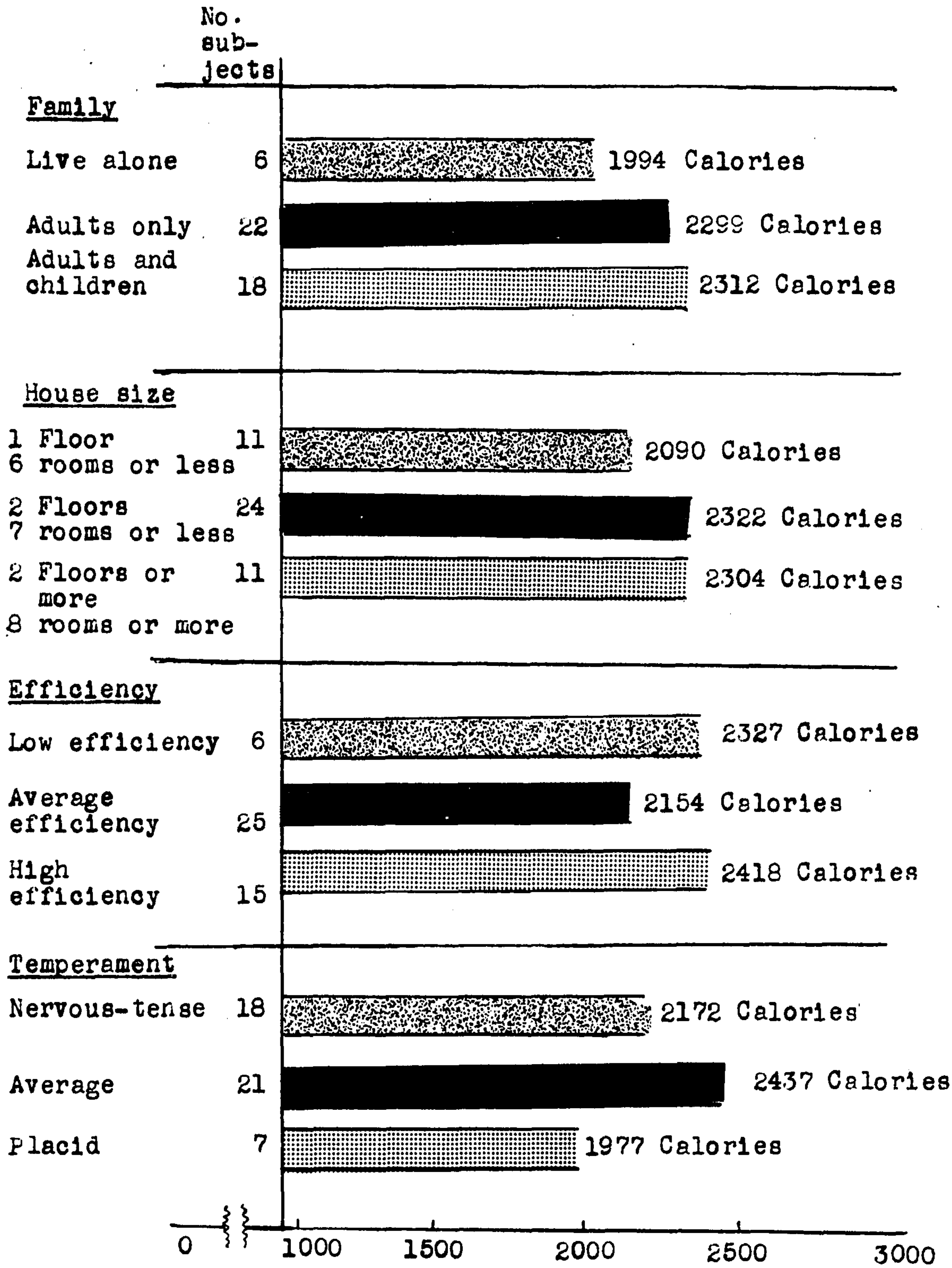
Fig. 4 presents the average daily energy expenditure of all of the subjects as they were studied according to the number of members of the family, the house size, and also as to their efficiency and temperament. The subjects were placed in groups for these last two characteristics by a subjective evaluation. This rating was made by the author and two other members of the research staff after the series of interviews and home visits made to collect data were completed.

Family members The six women who lived alone expended the least energy. These women were over 58 years of age. There was little difference in the Calories of energy expended by the homemakers when the other family members were adults or when they were adults and children.

House size Less energy was spent per day on the average by the women living in homes of six rooms or less on one floor. This group included women of all the decades of age. Women who lived in homes of two floors with seven rooms or less expended, on the average, as much energy per day as the women who lived in larger houses.

The amount of energy expended by a homemaker with a family showed no apparent relationship to the size of the family nor to the size of her house. This fact also was noted by Durnin et al. (11).

Fig. 4. Average daily energy expenditure by four characteristics of 46 homemakers


No. subjects
Family
Live alone 6
1994 Calories
Adults only 22
2299 Calories
Adults and children 18
2312 Calories
House size
1 Floor 6 rooms or less 11
2090 Calories
2 Floors 7 rooms or less 24
2322 Calories
2 Floors or more 8 rooms or more 11
2304 Calories
Efficiency
Low efficiency 6
2327 Calories
Average efficiency 25
2154 Calories
High efficiency 15
2418 Calories
Temperament
Nervous-tense 18
2172 Calories
Average 21
2437 Calories
Placid 7
1977 Calories
0
1000
1500
2000
2500
3000

Efficiency The homemakers who had been ranked as 'average' in efficiency expended less energy, 2154 Calories per day, than the homemakers who were ranked either 'low' or 'high' in efficiency. There was little difference, 91 Calories, in the energy expended daily between the latter groups. The 'high' efficiency group was composed of women from 39 to 63 years of age. The other levels of efficiency were composed of women from all the decades of age. The 'average' efficiency group included 12 of the 16 desirable weight women in the study. All of the women in the 'low' efficiency group were overweight. However, the 'high' and 'average' efficiency groups included the women with the greatest deviation in kilograms of weight.

Temperament Women of average temperament, as they were rated by subjective evaluation, expended more energy during the day than either the tense-nervous or the placid groups of women. Each temperament group included women from all the age groups studied. The one 85-year-old subject was in the tense-nervous group. Women from all weight deviation groups were in each of the three temperament classifications. However, the women in the tense-nervous temperament group had the greatest range in weight deviation, namely, -6.4 to +33.2 kg. of body weight. Nine of the 16 women of desirable body weight were ranked in the tense-nervous temperament group.

Comparison of factors for calculating energy expenditure

The mean energy expenditures given in Table 10 provide a basis for evaluating the information obtained by calculation of energy expenditures from activities on the basis of Calories per kilogram with that obtained by calculation on the basis of Calories per kilogram to the 0.73 power. In early studies of energy metabolism, body surface area was used as a basis for expression of energy expenditure on the assumption that surface area reflected more closely than body weight the relative amount of active protoplasmic tissue within the body. In a 1959 study Durnin (30) concluded that surface area and gross body weight were equally useful as a standard for reference in measurement of human energy expenditure. Likewise, Miller (25) concluded that the "surface area law" was no longer tenable. Brody (4, p. 383) had found an approximation of the metabolically effective body weight to be 0.73 power of body weight in kilograms. Thus it may be expected that the use of an exponential function of body weight as a unit for expression of energy expenditure would influence values for overweight individuals to a greater extent than values for individuals of desirable body weight. In overweight persons body fat represents a relatively higher percentage of the total body weight than in persons of desirable weight.

The difference between results obtained by these two methods of calculation of energy expenditure increased directly with an increase in deviation from desirable body weight as was shown in Fig. 2. For all 46 subjects, the average daily expenditure of energy was 79 Calories per day less when calculated by factors based on metabolically effective body weight than by factors based on total body weight. For the 16 subjects in the desirable weight range, the average difference was less than one Calorie; for the 14 subjects with a positive weight deviation of less than 20%, the difference was 86 Calories; for the subjects who were more than 20% overweight, the difference was 152 Calories. The one subject with a negative weight deviation of 10% expended 134 Calories more per day when calculated by factors based on metabolically effective body weight than by factors based on total body weight. The influence of overweight on the estimation of energy expenditure by calculation from the factors may be reduced by use of metabolically effective body weight as a basis rather than total body weight. Thus it may be expected that the energy expenditures calculated from factors of Calories per kilogram to the 0.73 power per hour have greater reliability than the energy expenditures calculated from factors of Calories per kilogram per hour. The agreement between values obtained by the two series of factors (Table 3) is sufficiently close, however, that the choice of factor probably contributes less to the error of estimation of energy expenditures than the problems associated with the determination of the time and nature of activities performed by subjects in their homes.

PART II. THE RELATIONSHIP OF PULSE RATE TO ENERGY EXPENDITURE OF WOMEN

REVIEW OF LITERATURE

A method for the precise measurement of the daily energy expenditure of an individual during the course of the usual activities and in the usual environment has been an important goal in the study of metabolism. Early investigators in the field of energy metabolism reported a positive relationship between the pulse rate and total heat production. In 1910, Benedict and Carpenter (5, pp. 135-136) emphasized the importance of this relationship. A change in the average pulse rate, for 12 subjects, from 62 in the resting post-absorptive state to 64 in the resting absorptive state was said to be a "considerable increase." The authors stated:

> It appears, therefore, that in metabolism experiments in the future, special attention should be paid to accurate continuous records of the pulse rate, as indicating in a general way the internal muscular work and muscular tonus. As these two factors apparently in large measure determine the total metabolism during rest, the pulse-rate can under these conditions be taken as a reasonable satisfactory index of the total metabolism. Experiments are much needed, using the same subject under widely varying conditions of pulse rate. That the observation of the pulse-rate should also be accompanied by a measurement of blood-pressure is obvious, and it is probably true that a simultaneous study of the pulse-rate, blood-pressure, respiration, and total metabolism will show some most interesting relationships which may prove of direct practical value to the practicing physician.

Three years later (1913), Benedict and Cathcart (6, p. 154) reported observations of energy expenditure and pulse rates as follows:

At 1.05 Cal./min., pulse rate rose from 60-64 to 125
At 1.50 Cal./min., pulse rate rose from 64 to 160
At 2.00 Cal./min., pulse rate rose from 60 to 163
At 2.25 Cal./min., pulse rate rose from 60 to 166

At about the same time, Henderson and Prince (31) reported a study of the "oxygen pulse" which was the amount of oxygen consumed from the blood of one systolic discharge of the heart. The formula was: Oxygen pulse = $\frac{O_2/\text{minute}}{\text{Beats/minute}}$. The quantity of oxygen consumed during body rest and with such slightly accelerated heart rates as are involved in merely walking around a room, tended to be proportional to the rate of the pulse. With heart rates such as were induced by distinct exertion and increasing amounts of work, that is rates of 80-100/minute up to 130-140/minute, a relationship prevailed between heart rate and oxygen use which differed from that reported by Benedict and Carpenter (5). The oxygen pulse at these heart rates increased rapidly with the acceleration of the heart and the maximum value was reached in most cases at 130-140/minute; with further cardioacceleration, it increased only slightly or tended to decrease.

Murlin and Greer (32) in 1914 studied the ratio of total heart action to oxygen consumption of both men and women during various exercises and reported that the product of pulse pressure by pulse rate was a better index of metabolism than was pulse rate alone. Of all the organs in the body, the heart is in closest relationship to the requirements of the tissues for energy. Since very little available oxygen could be stored in the living substance, the response of the heart to the variation in requirement must be immediate and within very narrow limits of time proportional to this oxygen requirement. This was in agreement with Benedict's earlier report that the blood pressure played a role in the relationship of pulse rate and metabolism.

A linear relationship between pulse rate and oxygen consumption was depicted graphically by Boothby (33) in 1915. When data obtained in a study of the rate of circulation of the blood in a subject at rest and at work was plotted, the points representing the pulse rate fell within 3 per cent of a straight line relationship with oxygen consumption except in one instance in which the point was 9 per cent off the line. It was evident that in the main, pulse rate increased with oxygen consumption although in individual instances, nervous, or other influences modified the rate somewhat.

The linear relationship of pulse rate to oxygen consumption by subjects in a post-absorptive state was studied by Taylor (34) in 1942. A stethoscope was used to count the heart beat. The heart rate, total ventilation, oxygen consumption, and respiratory quotients of subjects increased with work load in approximately linear fashion. The slope of the regression line and the ultimate level attained varied with the individual subject. A linear increase in caloric expenditure with increase in number of heart beats also was observed, by Erickson et al. (35) in 1945, for men doing treadmill walking at different speeds and angles of incline.

Müller (36) in 1953 used the pulse rate in a study of the physiological basis of rest pauses in heavy work. It was observed that the index of the rise in pulse rate for certain rise of work per second gave the work capacity of the person examined. The amount of energy that is directly available for muscular work is limited by the capacity of the heart and lungs to get oxygen from the outside air to the muscles and by the anaerobic liberation of the energy reserved stored in the muscles. The apparatus used by Müller consisted of the Kofranyi and Michaelis respirometer to measure the oxygen consumption and an automatic portable pulse counter which was worn by the subject. The pulse counter was described by Müller (36, p. 210) as follows:

> . . . a photoelectric cell, which together with a small lamp can be clamped on the ear-lobe like an ear ring. The light of the lamp passes through the ear-lobe on to the photoelectric cell. Each pulse makes the ear-lobe a little less translucent and so lowers the voltage recorded by the cell. The fluctuations of voltage are amplified to move a relay and a counter which can be read at suitable intervals. Accumulators and batteries are fitted for counting during an 8- or 10-hour shift. In the laboratory we use amplifiers working on the main circuit, in connection with a counter which prints the number of pulses on paper from minute to minute. This apparatus has the advantage of being able to be used without inferfering with the work and without influencing the person during the test.

A high pulse rate, associated with a rapid increase in the initial stages of work, was reported by Asmussen and

Nielsen (37) in 1955. This pulse rate was considerably higher than the pulse rate that accompanies oxygen uptake for a steady rate of work. The pulse increase was approximately linear with increased oxygen consumption to rates of 170 to 180. These authors used the acetylene method and the direct Fick Method to measure the oxygen consumed from the blood which flowed through the working muscles.

The use of heart rate as an index of work output was investigated in 1957 by LeBlanc (38) in arctic field experiments with Canadian soldiers. The results of these experiments indicated a positive correlation between pulse rate and level of activity and it was concluded that the pulse rate by itself could be used for relative evaluation of certain levels of activity. The pulse rate was determined by radial palpation, and was taken within 30 seconds after exercise. LeBlanc suggested that if a correlation between pulse rate and oxygen consumption could be shown, the solution of problems involving calorimetric measurements, such as those encountered in nutrition or clothing studies would be greatly simplified. He also suggested that it would be advisable to determine pulse oxygen ratios on subjects in the laboratory prior to a series of field measurements.

The possibility of fitting appropriate curves to experimental data and testing for goodness of fit was demonstrated by Wyndham _et al_. (39) in a 1959 study of maximum oxygen intake and maximum heart rate during strenuous work. At a low rate of work there was a straight line relationship for both oxygen intake and heart rate when plotted against work rate, but at high work rates, the curve tended toward an asymptote. A positive relationship of oxygen intake and heart rate also was reported in 1961 by Åstrand and Saltin (40) who concluded that the aerobic capacity and maximal heart rate are the same in maximal running and cycling, or at least in well-trained subjects.

Evidence that a change in rhythm of movement such as from walking to running resulted in a change in the slope of the curve which graphically illustrated oxygen consumption plotted against work performed was found in 1934 by Ogasawara (41). The change in slope of the curve was attributed to the fact that more muscular movements were necessary in walking because the length of the stride was less. It was also found in this study that oxygen requirement was less when the subject wore light rubber shoes rather than leather shoes. Müller (36) described walking as a "natural activity" with a special pattern of movement to which the body has had many thousands of years to adapt itself. This was not the case with the many "odd movements and positions" required of the body during the performance of daily work. Recent experiments involving a change in rhythm of movement were reported in 1961 by Michael and Hutton (42). Prolonged exercises using a bicycle ergometer, or walking on a treadmill indicated that higher heart rates occurred during the bicycling than while walking when oxygen uptakes were equivalent. When pulse rate was plotted against oxygen uptake, a change in the slope of the curve occurred when a change was made in rhythm of movement.

A change in pulse rate with a change in the position of the subject's head while the body was maintained in its same position was noted by Steiner and Mueller (43) in a report of research related to the 'man in space' program. There was no change in the cardiac rate during the time the subject was in a neutral position (fully supine). The heart rate increased 20% with the head elevated, and decreased 16% with the head depressed. Changes in rate were produced by altering the position of the carotid baroreceptors in relation to those located in the trunk. It was suggested that these changes in rate might be caused by alterations produced by acceleration forces in the profusion pressures in the carotid arteries.

The validity of the prediction of energy expended in the daily round of activities from relationship of pulse rate (beats per minute) to metabolic rate expressed as Calories per square meter of surface area per hour was investigated by Booyens and Hervey (44) in 1960. Activities of ascending order of rates of work were performed by six subjects. After a steady pulse rate had been found in two successive counts, expired air was collected for a period of 10-minute intervals for each activity. During the collection of air, the pulse rate was counted three times at 3-minute intervals. Pulse rates were usually counted by palpation of the radial pulse for 1-minute periods, timed with a stop watch. When such counting was impossible as during walking and cycling outdoors, the first 10 beats immediately after cessation of the activity were timed. An electronic pulse rate meter also was used for some of the measurements. Although a good linear relationship could be established for pedalling the bicycle ergometer at three levels of work, the activities of lying, sitting, and standing did not give a relationship with as true a linearity. The slope of the line for the "quiet occupations" was steeper than the slope of the line for pedalling. Booyens and Hervey concluded that this method was not useful as a means of measuring the energy expenditure from a pulse rate record of "daily round" activities but might be valid for the higher level of activities if factors that influence pulse rate were controlled.

STATEMENT OF PROBLEM

A technique for the use of a continuous record of pulse rate to determine the energy expended by women was investigated. The assumption was made that pulse rate increments during activity might have a predictive value for the estimation of energy expenditure if the pulse rate varied linearly with oxygen consumption during activity. The experimental approach was used to: (a) study the relationship of increments in pulse rate to increments in energy expenditure; (b) study the extent to which variations among individuals might influence the linearity of the regression of pulse rate on energy expenditure; and (c) investigate the problems encountered in obtaining a 24-hour pulse record of a woman while she performed her customary activities in her own home.

METHOD OF PROCEDURE

A series of activities was selected which would require a range in energy metabolism from the resting state to the energy expenditure for active exercise. The subjects were six women who performed standardized activities in the laboratory. Measurements of oxygen consumption and of pulse rate were made during each of the activities. The energy expenditure for each activity was calculated from the oxygen consumption. Statistical analyses were made to investigate the linearity of the relationship between the pulse rate and the energy expenditure of the subjects.

A continuous record was obtained of the pulse rate of one subject, and her daily energy expenditure was predicted from the data using the predicting equation which had been determined for the regression of pulse rate on energy expenditure during the laboratory activities.

Measurement of Pulse Rate

Selection of equipment

The customary clinical procedure of radial palpation for the determination of pulse rate was rejected since a technique was desired which would not restrict the movements of the subject, which would detect small differences in pulse rates associated with intermittent activities of women of sedentary nature, and which might also be satisfactory for use in obtaining continuous records of the pulse rate over a period of time.

An investigation was made of the availability of equipment which could be used as a device for sensing characteristics of the heart beat and transmitting them to a recorder. Limiting factors in the selection of such an instrument included the interference of movement of the subject, the noise of the treadmill used in activities in the laboratory, disturbance from stray electrical fields, and the initial cost of the apparatus.

Although telemetering of the heart beat by radio offered the most promise for obtaining continuous records of the pulse rate without undue restriction of the movements of the subject, no commercially available unit was found which would be satisfactory for use. The development of an instrument for radio telemetry of the heart beat was in progress on this campus in another department but it was not considered* that the instrument was ready for experimental use.

Since a digital cardiotachometer** had been used successfully for transmitting the pulse rate of subjects

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*Victor W. Bolie, Ames, Iowa. Information on an instrument for radio telemetry of the heart beat. Private communication. 1961.

**Digital Cardiotachometer, Model 120, Gilford Instrument Laboratories Inc., Elyria, Ohio.

performing on a treadmill, this instrument was selected for use despite the fact that a lead wire from the subject to the apparatus was required. Pick-up units for the electrocardiogram and for the change in opacity of the skin which accompanies the pulsation of blood were available for use with the cardiotachometer. The change in opacity of the skin of the pinna of the ear caused by the flow of blood at each pulse of the heart was selected as the characteristic for measurement. A small clip which contained a photoelectric cell was used as the sensing element. The clip was attached to the pinna of the ear, and the response of the photoelectric cell to the change in the opacity was transmitted to the cardiotachometer. A rectilinear recorder* with adjustable speeds recorded graphically the frequency of response in impulses per minute.

Subjects

Six subjects participated in the study. Four of the subjects were women who had participated in Part I. The fifth subject, who was from a small town, volunteered to complete the laboratory tests and also to be the subject for the recording of the 24-hour pulse rate records. These five

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*'recti/riter' Recorder, Model PRR 1M-A16, Rectilinear Recording Milliammeter, Texas Instruments Inc., Houston, Texas.

subjects were in the sixth, seventh, and ninth decades of age. Three of the subjects lived in the urban area, the fourth lived on an acreage just outside the urban district and the fifth lived on a farm, the house of which was now in the city limits. The sixth subject was a woman 21 years of age.

Procedure for Activity Tests

A series of activities were chosen for the laboratory tests which were of the type and degree of strenuousness that the women performed each day. The activities were performed in series from the least strenuous to the most strenuous. The tests were as follows: basal test, lying quietly after eating, sitting with arm movements, standing with some arm and body movement, and walking on the treadmill at increments of speed and grade. The degrees of work performed on the treadmill were selected according to the physical capacity of each subject.

In preparation for the tests, women in the sixth to ninth decades of age were given a cardiac checkup by the physician in charge of the Iowa State University Hospital to verify that they were all physically able to undergo the tests on the treadmill. To avoid nervous stimulation of the heart, no test was undertaken that the subject seemed dubious about doing comfortably.

The subjects were brought to the laboratory singly and by appointment for the tests. No test was scheduled if a subject had symptoms of a cold or other illness. The laboratory tests were carried on during the months of January to May. The women were requested to wear comfortable clothes and low-heeled walking shoes when they came for the tests. For the basal metabolism test, they were instructed to eat their usual meal on the night before the test and consume no food or beverage except water after the meal. They were also instructed to obtain at least 8 hours of sleep or rest in bed and to engage in no physical activity on rising other than the minimum amount that was required for dressing. They were asked to drink no coffee and not to smoke any cigarettes before the test in the morning. The subject was brought to the laboratory by automobile as soon as possible after rising. She rested on a bed in a quiet comfortable atmosphere for 30-45 minutes before the test.

The temperature of each subject was recorded upon her arrival at the laboratory for the basal metabolism test. Immediately following the basal metabolism test, the subject was weighed. No correction was made for the weight of the clothing. The height of the subject was measured when she was standing with her back against a rigid vertical upright to which standard meter sticks were attached. The subject was required to stand with the head held comfortably erect, the shoulders, buttocks, and heels touching the upright, and the feet parallel. The hardwood triangle in contact with the upright was brought down to touch the subject's head, and the reading was taken at that point, parallel to the contact. The subject was then served a breakfast of orange juice, egg, toast, butter, jam, milk, and coffee. The tests were continued after a brief interval of time given the subject for a rest period. At this time, the subject was asked to recall the menus of the meals she had eaten on the previous day, and a record was made of the foods and quantities as they were recalled.

For afternoon tests, the subject ate lunch at home and was brought to the laboratory by automobile. Before the first test, she rested quietly on a bed for 30 minutes. All subsequent tests were preceded by a minimum rest period of 5 minutes while the subject relaxed in a chair. Wherever possible, each test was performed in duplicate by the subject. A maximum of six different activities was performed during one testing period. In some cases the failure of the equipment or the fatigue of the subject made it impossible to complete all the tests.

During each test a continuous record of pulse rate was obtained simultaneously with the collection of expired air. The total volume of expired air was determined by the difference of the reading of the meter before and after testing. The recorder was adjusted to give a recording of the pulse rate of 6 inches per minute on the chart paper. At this speed an interpretation of the pulse rate was made every 7 1/2 seconds during the period the expired air was collected. The duplicate test was performed under conditions as nearly identical as possible to those of the original test. The instruments were calibrated at the beginning of each test period and also at intervals between individual tests. The procedure used in calibrating the instruments was as follows: The cardiotachometer was turned on one hour before the calibration period. After equilibration, the calibration dial was set for the zero reading and the ink record was made. The dial was then turned, in succession, to the readings of 60, 120, and 240 and a recording was made of the position of the pen on the chart for each reading. Since this was a linear progression, the reading of any position between zero and 240 could be determined from a scale fitted to the progression. To obtain the zero reading for the calibration between individual tests, the ear clip was removed from the subject before calibration.

Interpretation of the recording

A scale was prepared from the section of the graph paper where the graduations from zero to 240 had been calibrated by the digital cardiotachometer. Finer divisions of the scale were calculated and marked to fit the linear progression. The scale was taped to the bottom of an open-end frame that could be moved along the chart over the ink record of the pulse rate. A magnifying or reading glass with an electric light attachment was put on top of the frame to enlarge and brighten the area of the record and the scale to be read. Division lines on the chart paper divided it longitudinally into spaces 3/4 inch in length. An interpretation was recorded for each of these division lines. Since the speed of the recorder was set at 6 inches per minute for the laboratory tests, eight interpretations were made of the pulse each minute or one every 7 1/2 seconds. The interpretations were totaled per test and the average per minute was taken as the average pulse rate for the test. The speed of the recorder was adjusted for 3 inches per minute for the 24-hour continuous record of pulse rate made in the home. This record was interpreted four times a minute or once every 15 seconds for the entire 24-hour period.

The 24-Hour Pulse Records

The 24-hour records of the pulse rate were taken in the home of one subject on two days that were separated by an interval of six weeks. This lapse of time was for the repair of the equipment that had failed to function properly. The laboratory tests to establish the slope of regression of the pulse rate to Calories per minute for this subject were conducted on three different days during this six-week period.

The digital cardiotachometer and the recorder were taken to the home of the subject for the purpose of making the 24-hour pulse record. Electric extension cords were used to permit the equipment to be moved as the subject moved from room to room. Her home was a one-floor house that had a room arrangement suitable for the use of the equipment.

The first record was started in the morning and completed at the same hour the next morning. The second record was started in the evening and continued until the same hour the next evening. The ear clip was attached to the ear of the subject and held in place for the entire 24-hour period. For the first record, it was held in place by a head band especially designed for that purpose. This was uncomfortable for the subject before the 24 hours were completed. Therefore, for the second record, a hair net was used which was more comfortable for the subject than the head band.

The author watched the two instruments continuously during the 24-hour recording period and made frequent notations in pencil on the chart of simultaneous readings of the cardiotachometer dial. The time at half-hour intervals was written also on the chart paper. These notations were made to assist in an accurate interpretation of the completed record at a later time.

The chart paper moved at the rate of 3 inches per minute. The installation of a new roll of chart paper required

1 minute and 40 seconds. A calibration of the instrument was made before the recording of the pulse record was continued. Other calibrations were made each time the equipment had been moved to follow the subject in her work.

The author kept a timed diary of the activities which the subject performed during each 24-hour period. The Calories of energy expended for each period were calculated by factors based on total body weight, Calories per kilogram per hour, and by factors based on the effective metabolic body weight, Calories per kilogram to the 0.73 power per hour.

Measurement of Oxygen Consumption at Rest and During Activity

The oxygen consumption was determined by the gas analysis of the air expired during each test of an activity. The expired air was measured by a Kofranyi-Michaelis respirometer which provided also for a continuous sampling and collection of the expired air. The Weir formula was used for calculation of the Calories of energy expended per minute. The walking tests were performed on a treadmill.

Treadmill

The treadmill* was adjusted for the speed and the per cent of grade desired for each test. The Kofranyi-Michaelis

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*A. R. Young, Power Transmission Engineers, Indianapolis, Indiana.

respirometer was hung on the frame of the treadmill. The subject did not wear the respirometer at any time during the laboratory tests. The subject took her position on the treadmill and grasped the frame with one hand to maintain her feeling of security. She used the other hand to steady the tubing which connected the mouth piece and the respirometer. The mouth piece and nose clamp were adjusted to fit comfortably and checked for leaks before the treadmill was started.

Respirometer

The respirometer developed by Kofranyi and Michaelis* was used in this study. The instrument consisted of a small gas meter that measured the total volume of air exhaled and at the same time collected 0.6 per cent of the expired air in a rubber collection bag for analysis. The respirometer could be used to collect exhaled air for extended periods of time because of this method of sampling. The meter counter could be read accurately to 0.1 liter. The respirometer and the accessory straps weighed approximately 8 pounds so it could be worn by the subject. However, in this study, the respirometer was placed on the table or hung from a support beside the subject.

In preparation for the study, the respirometer was fitted

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*Des Max Planck-Instituts fur Arbeitsphysiologie, Dortmund, Germany.

with new rubber diaphragms between the piston pump and the collecting tubes, with new rubber collection bags, and was then calibrated to establish correction factors for these new fittings. The procedure used in the respirometer calibration was as follows: The Tissot spirometer was filled with room air. The air was metered through the respirometer at different volumes per unit of time selected to correspond to the range of values observed in the tests. Initial and final readings were recorded of volumes and temperatures of air in the Tissot, volumes and temperatures of air metered through the respirometer, and of the ambient barometric pressure. The correction factors were calculated from these data for various rates of gas flow through the respirometer. These correction factors are listed in Table 12.

Table 12. Calibration factors for the Kofranyi-Michaelis respirometers

Respirometer No. 0.986		Respirometer No. 1.000	
Liters/minute	Correction factor	Liters/minute	Correction factor
7.0 - 11.9	1.048	7.0 - 11.9	1.031
12.0 - 16.9	1.034	12.0 - 16.9	1.045
17.0 - 21.9	1.051	17.0 - 21.9	1.076
22.0 - over	1.013	22.0 - over	1.030

The rubber collection bags were calibrated for the change in concentration of oxygen and carbon dioxide by the standard method used at the Iowa State University Nutrition Laboratory as reported by Langford (19, p. 42).

> A Douglas bag of 150 liters capacity was filled with expired air. The contents were mixed by gently kneading the closed bag. The composition of this air was determined by sampling for analysis directly into Bailey gas sampling bottles at the beginning and end of the metering periods. Air from the Douglas bag was metered through the Kofranyi-Michaelis respirometer at different volumes per unit of time according to the range of values observed in the tests. Palpitation of the bag by hand was done to simulate the rhythmic pattern of successive expirations. Samples of air were taken from the rubber collection bags and analyzed for oxygen and carbon dioxide.

The changes in the concentrations of oxygen for the rubber collection bag No. 5 is given in Table 13.

The respirometer was made ready before each test as follows: The parts of the connection valve were assembled and fitted snugly in one end of the rubber tube which was attached to the respirometer. Exhaled air was passed through the apparatus for several minutes and adjustments were made until the check showed that the action of the meter counter was satisfactory. The rubber collection bags, which were kept with some expired air in them at all times, were rinsed three times with portions of the operator's expired air. These portions of air were expelled as completely as possible by rolling the bags tightly into a roll. The collapsed bag was connected to a two-way glass stopcock attached to the

Table 13. Calibration factors for concentration of oxygen of expired air in respirometer bags

Rate of flow liters/minute	Bag No. 5 Oxygen	Bag No. 6[a] Oxygen
For 8 minute collection periods	% of original	% of original
3	102.2	101.0
4	101.5	101.0
5	101.0	101.0
6	101.0	101.0
7	101.0	100.8
8	101.0	100.3
9	101.0	100.0
For 5 minute collection periods	% of original	
11.5	101.0	
12	100.9	
13	100.8	
14	100.6	
15	100.4	
16	100.0	

[a]Bag 6 was not used in the study.

respirometer. The rubber mouth pieces were soaked in distilled water to increase their softness and pliability. Just before measuring the expired air of a subject, the rubber mouth piece was adjusted on the connection valve and the subject then inserted the mouth piece inside her mouth but outside of her teeth. If a subject with dentures preferred to remove them, she was permitted to do so, as in the case of subject No. 34. The subject assisted in the check to eliminate leaks and in the adjustment of the mouth piece for maximum comfort. A clamp was placed on the subject's nose and adjusted to insure that no leakage was present. The subject then exhaled through the respirometer and a sample of 8 liters of the expired air was collected in each rubber bag. The meter counter was turned off, the glass stopcock was closed, and the rubber bag was removed. The bag was massaged with the subject's exhaled air, rolled tightly to completely expel the air, and then in the collapsed state was reattached to the respirometer. The equipment was then ready for the actual test.

Chemical Analysis

Gas analyses

The samples of expired air were analyzed for oxygen. Immediately after collecting the sample in the rubber bag, aliquots were transferred to Bailey* gas-sampling bottles for storage over mercury until analyzed. The analysis** was completed within 24 hours of the collection period. The samples were analyzed in duplicate using the electronic

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*A. H. Thomas Co., Philadelphia, Pennsylvania.

**Appreciation is expressed to Duane Hougham for the oxygen analyses made with the Beckman Oxygen Analyzer.

analyzer manufactured by Beckman.* This instrument determined the oxygen partial pressure of an air sample by measuring the magnetic susceptibility with a magnetic torsion balance. Since oxygen is relatively paramagnetic, oxygen concentration can be measured in practically all gases. This analyzer was calibrated on test days with oxygen free nitrogen gas and also with a sample of water-saturated outside air. The barometric reading of the laboratory was recorded on the days of the experiments. Aliquots of the samples also were analyzed for oxygen concentration using the Haldane-Henderson method, Peters and Van Slyke (45, pp. 86-91), to check the accuracy of the results from the Beckman Analyzer. The analyses were accepted when two check samples showed an agreement within 0.06 per cent of the duplicate sample determinations using the Beckman Analyzer.

Calculation of Data

The caloric equivalent of the oxygen consumption was determined from the data on oxygen uptake collected with the Kofranyi-Michaelis respirometer. All gas volumes were reduced to standard conditions: temperature of zero degrees Celsius and pressure of 760 millimeters of mercury, dry. The formula of Weir (46) was used for the calculation of the Calories of

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*Beckman Oxygen Analyzer, Model B, Beckman Instruments, Inc., Fullerton, California.

energy. Fig. 5 is a copy of the data calculation sheet used in the study.

The slope of regression of energy expenditure on pulse rate was determined by the regression formula of Wert et al. (47, p. 227). The F-value was determined to test for significance of regression, Wert et al. (47, p. 233). The data that presented two different slopes of linear regression were subjected to the F two-tail test, Snedecor (48, p. 96), and also the t-test, Steel and Torrie (49, p. 173) were used to test the significance of the difference between the two slopes.

The chart of the 24-hour pulse rate records was interpreted for each 15 seconds of time during the 24 hours. The recorded rates were summarized in four different ways, namely, for the average pulse rate of each 10-minute interval, for the average pulse rate of each 15-minute interval, for the average pulse rate of each interval of 1 hour, and for the average pulse rate for the entire 24-hour period. The caloric equivalent for each time interval was calculated from the pulse rate according to the regression equation predicted for this subject from the data obtained under controlled laboratory conditions. The energy expenditure was calculated for each 24-hour period from the four pulse rate summaries and comparisons were made. The energy expenditure also was calculated for each 24-hour period from records of activities

CALCULATION OF ENERGY EXPENDITURE

WEIR METHOD

Subject____________________Date__________Test No._______

Weight, kg._____; $kg.^{.73}$_____Height________Age______________

Activity____

____

Time of Day__________________Length of Test_________________

Meter No._____Meter Factor_____Bag No._____Bag Factor_______

Temp.________________Barometer_____________STP Factor_______

(calculations)

Air Expired, liters_________Air Expired, corrected__________

% Oxygen determined_________% Oxygen corrected______________

WEIR Formula:

1.046 - 0.05 (% O_2 corrected) = ______Cal./liter Air exp.

(Cal./liter Air) x (Air exp. corr.) = ___________Calories expended

$$\frac{\text{Cal. expended}}{\text{length of test}} = \_\_\_\_\_\_\_\_\_ \text{Calories per minute}$$

Fig. 5. Data calculation sheet

using Calorie factors based on Cal./kg./hr./activity and Cal./kg.$^{0.73}$/hr./activity. The energy expenditure for the two 24-hour periods as determined from the pulse rate records and from the activity records were compared.

RESULTS AND DISCUSSION

Relationship of Pulse Rate to Energy Expenditure

The relationship of pulse rate to Calories of energy expended per minute during the performance of controlled activities was studied for six subjects in the laboratory.

Subjects

The physical description of the subjects is given in Table 14. Five of the subjects were women who ranged in age

Table 14. Physical description of the subjects

	Subject No.					
	100	99	35	34	18	14
Age in years	56	21	58	83	52	63
Weight, kg.	70.1	60.9	61.6	51.7	59.5	69.8
Weight, $kg.^{0.73}$	22.2	20.1	20.2	17.8	19.7	22.2
Height, cm.	173.0	167.0	167.5	160.2	165.5	166.0

from 52 to 83 years. The sixth subject was a woman, 21 years of age, who assisted in the nutrition laboratory. All of the subjects were of desirable weight for their height and age and all appeared to be in good health. The women of the sixth to ninth decades were given a cardiac examination by a physician at the University Hospital prior to their participation in this study. Four of the subjects had participated in energy studies that had been conducted in the laboratory previously and were somewhat familiar with the laboratory and the apparatus used in energy expenditure studies.

Evaluation of food recall records

Each subject was asked to recall the food eaten on the day previous to her tests in the laboratory. These records of the food were evaluated for the grams of protein and the number of Calories. The tables of composition of food in the Yearbook of Agriculture, 1959 (50, pp. 245-266), were used for the calculations. The analysis is presented in Table 15. The mean energy value of the diets ranged from 1805 to 2350

Table 15. Analysis of food recall records

	Subject No.					
	100	99	35	34	18	14
Gms. protein in day's menu	55.6	73.7	66.3	43.0	49.0	54.8
Calories in the protein	222	295	265	172	196	219
Calories of daily intake	2056	2350	1954	1618	1805	1848
% of total Calories in protein	10.8	12.6	13.6	10.6	10.9	11.9

Calories per day for five of the subjects. These values exceeded the mean of 1735 Calories per day reported by Swanson et al. (51) from a survey of the food intakes of 1072 women in Iowa. The subject whose diet supplied a mean of 1614 Calories per day was 83 years of age. The grams of protein in the menus ranged from 43.0 to 73.7. When this was evaluated for the per cent of the Calories in the diet which was furnished by protein, the range in per cent was 10.8 to 13.6. Thus the protein supplied from 10 to 15 per cent of the Calories, the accepted standard for use of the Weir Formula for the calculation of Calories of energy expended from the per cent of oxygen in the expired air sample.

Weir (46) reported a formula, $K = 1.046 - 0.5\ O_e$, that he had worked out to simplify the calculation of the caloric value from samples of expired air which included the effect of protein metabolism. This formula will correct for the protein in the diet when it comprises 12.5% of the Calories consumed in the daily diet. The use of this formula eliminates the need for the collection of the urine sample and the analysis for nitrogen. It also eliminates the need of analysis for carbon dioxide.

The Weir formula was used by Durnin and co-workers (15) and (11), by Richardson and McCracken (23), by Keiser and Weaver (52), and by McCracken and Richardson (22) in energy expenditure studies. A comparison was made of values calculated by the Weir method and values calculated on the basis of the heat equivalent of the non-protein respiratory quotient by Duane F. Hougham.* The data were from studies of nine women who performed seven types of activities. He found good agreement between values obtained by the two methods of calculation.

The activity tests

The results of the activity tests for all the subjects are given in Table 16. Each value is the average of duplicate tests performed on the same day except for instances when a duplicate test could not be obtained because of a failure in the equipment or some indisposition of the subject.

Six subjects completed duplicate tests on two different days for the activities of lying quietly after eating, sitting and standing. The pulse rates of the subjects in these positions were not related to their ages. Subject 99, who was 21 years of age, and Subject 14, who was 63 years of age, had pulse rates of 60.0 and 60.5 respectively for lying quietly after eating; these were the lowest pulse rates for this activity. The 56 and 58 year old subjects had the highest pulse rates of the group when lying awake after a meal. These

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*Duane F. Hougham, Ames, Iowa. A comparison of methods for determining energy costs. Personal communication. 1962.

Table 16. Pulse rate per minute to Calories per minute, average of duplicate tests, AM

Activity	Test day no.	Subject #100 Pulse rate/min.	Subject #100 Cal./ min.	Subject #99 Pulse rate/min.	Subject #99 Cal./ min.	Subject #35 Pulse rate/min.	Subject #35 Cal./ min.
Basal	1	78.5	0.88			75.5	0.80
Basal	2	75.5	0.84				
Basal	3	71.0	0.80				
<u>Tests after a meal</u>							
Lying quietly	1	90.0	1.13	60.0[a]	0.97[a]	85.0	0.98
Lying quietly	2	88.5	1.08	60.5[a]	0.83[a]	78.5	0.80
Sitting quietly	1			63.5[a]	0.96[a]		
Sitting quietly	2			56.0[a,b]	0.74[a,b]		
Sitting quietly	3						
Sitting, sifting	1	94.5	1.31			84.5	1.18
Sitting, sifting	2	95.5	1.27	73.0[a,b]	1.13[a,b]	80.5	1.09
Sitting, sifting	3	88.0	1.23				
Sitting, typing	3	99.0	1.35				
Sitting, writing				62.5[a]	0.98[a]		
Standing, relaxed	1			69.5[a]	0.95[a]		
Standing, relaxed	2			79.0[a]	0.95[a]		
Standing, sifting				86.0[a,b]	1.12[a,b]		

[a]Afternoon.

[b]Single test.

Table 16. (Continued)

Activity	Test day no.	Subject #100 Pulse rate/min.	Subject #100 Cal./min.	Subject #99 Pulse rate/min.	Subject #99 Cal./min.	Subject #35 Pulse rate/min.	Subject #35 Cal./min.
Standing, dusting	2					87.0	1.23
Standing, dusting	3						
Standing, sweeping	1	114.0[b]	1.42[b]				
Standing, sweeping	2	118.0	1.50				
Standing, vacuuming	2					95.0	1.59
Standing, vacuuming	3	107.5	1.54				
Walk, 1 mi./hr., no grade	2					96.0	2.10
Walk, 1 mi./hr., no grade	3	98.0	2.02				
Walk, 1 mi./hr., 4% grade	3	101.5	2.38				
Walk, 1 1/2 mi./hr., no grade	3						
Walk, 1 1/2 mi./hr., 4% grade	1			86.5[a]	2.70[a]		
Walk, 1 1/2 mi./hr., 4% grade	2			81.0[a,b]	2.39[a,b]		
Walk, 2 mi./hr., 4% grade	1	111.5	3.35				
Walk, 2 mi./hr., 4% grade	2	113.0	3.00			102.5	2.45
Walk, 2 1/2 mi./hr., 4% grade	1			100.0[a]	3.37[a]		
Walk, 2 1/2 mi./hr., 4% grade	2			95.0[a,b]	2.80[a,b]		
Walk, 3 mi./hr., 4% grade	1	120.5	4.42				
Walk, 3 mi./hr., 4% grade	2	120.5	4.04				

Table 16. (Continued)

Activity	Test day no.	Subject #100 Pulse rate/min.	Subject #100 Cal./min.	Subject #99 Pulse rate/min.	Subject #99 Cal./min.	Subject #35 Pulse rate/min.	Subject #35 Cal./min.
Basal	1	66.0	0.60	63.0	0.82	55.5	0.72
Basal	2	64.5	0.48				
Basal	3						
<u>Tests after a meal</u>							
Lying quietly	1	78.0[b]	0.77[b]	72.0[a]	1.21[a]	60.5[a]	0.76[a]
Lying quietly	2	73.0	0.60	76.0	1.18	68.0	0.84
Sitting quietly	1						
Sitting quietly	2						
Sitting quietly	3	78.0[a,c]	0.72[a,c]				
Sitting, sifting	1	83.0[b]	1.12[b]	81.0[a]	1.46[a]	69.0[a]	0.80[a]
Sitting, sifting	2	82.0	0.91	80.0	1.43	77.0	1.06
Sitting, sifting	3						
Sitting, typing	3						
Sitting, writing							
Standing, relaxed	1						
Standing, relaxed	2						
Standing, sifting							

[c]Pulse pick-up from little finger.

Table 16. (Continued)

Activity	Test day no.	Subject #100 Pulse rate/min.	Subject #100 Cal. min.	Subject #99 Pulse rate/min.	Subject #99 Cal./ min.	Subject #35 Pulse rate/min.	Subject #35 Cal./ min.
Standing, dusting	2						
Standing, dusting	3	88.0	1.09				
Standing, sweeping	1	88.0[b]	1.27[b]	85.0[a]	1.54[a]	71.5[a]	0.98[a]
Standing, sweeping	2			88.0	1.46	80.5	1.29
Standing, vacuuming	2						
Standing, vacuuming	3	93.0[b]	1.32[b]				
Walk, 1 mi./hr., no grade	2						
Walk, 1 mi./hr., no grade	3	100.0[b]	1.59[b]				
Walk, 1 mi./hr., 4% grade	3						
Walk, 1 1/2 mi./hr., no grade	3	101.0[b]	1.64[b]				
Walk, 1 1/2 mi./hr., 4% grade	1	102.0[b]	1.96[b]	98.0[a]	2.92[a]	84.0[a]	1.77[a]
Walk, 1 1/2 mi./hr., 4% grade	2			92.0	2.52		
Walk, 2 mi./hr., 4% grade	1			100.0[a,b]	3.25[a,b]	93.0	2.84
Walk, 2 mi./hr., 4% grade	2						
Walk, 2 1/2 mi./hr., 4% grade	1			104.0[a,b]	3.49[a,b]	92.0[a]	2.44[a]
Walk, 2 1/2 mi./hr., 4% grade	2			94.0	2.91		
Walk, 3 mi./hr., 4% grade	1						
Walk, 3 mi./hr., 4% grade	2					104.0	3.92

two subjects (Subjects 100 and 35) had basal pulse rates of 71.0 and 75.5; there was a difference between their pulse rates of 20 beats per minute during the standing activities. Subjects 18 and 34, who were 52 and 83 years of age, had basal pulse rates of 63 and 64.5 respectively, but the pulse rates for the two subjects increased with approximately equal increments to a pulse rate of 88.0 beats per minute for both subjects during the standing activities.

Variations from day to day   The results of the tests for three activities performed on separate days were compared for the subjects as listed in Table 17. There were 14 tests

Table 17. A comparison of results of three activities for first day and last day of the tests

Activity	Subject No.	Age	Difference Pulse/min.	Difference Cal./min.
Lying	99	21	+0.5	-0.14
	18	52	+4.0	-0.03
	100	56	-1.5	-0.05
	35	58	-6.4	-0.17
	14	63	+7.5	+0.07
	34	83	-5.0	-0.17
Sitting, sifting	18	52	-1.0	-0.03
	100	56	-6.5	-0.08
	35	58	-4.0	-0.09
	14	63	+8.0	+0.26
	34	83	-1.0	-0.21
Standing, sweeping	18	52	+3.0	-0.01
	100	56	+4.0	+0.07
	14	63	+9.0	+0.31

which were carried out by three or more subjects on different days. Some were performed on the first and second test days. Others, as indicated in Table 16, were carried out on three different days and some on the second and third test days. In 11 of the tests, a positive or negative change in Calories per minute of energy expended occurred with a change of similar nature in pulse rate. There were 10 values for the second day of tests that were below the values of the first day.

Variations in duplicate tests per day The differences between the duplicate tests for all of the activities performed by Subject No. 100, who was the subject for the two 24-hour continuous pulse records, are given in Table 18. The amount of work performed or nature of the activity did not appear to influence the reproducibility of values for measurement of either the pulse rate or of energy expenditure. The largest difference between duplicate tests for the measurement of energy expenditure was on the first day of walking on the treadmill at 3 miles per hour and a 4% grade. The difference was 0.45 Calories per minute. However on the second day, the values for duplicate tests differed only by 0.01 Calories per minute. Duplicate determinations of basal metabolism agreed within $\pm$ 0.10 Calories per minute. The largest difference between duplicate tests for the interpretation of pulse rate was 6 beats per minute while sitting typing. The differences of pulse rate and of Calories per minute varied

Table 18. Differences between duplicate tests for Subject No. 100

Activity	Pulse rate/minute Test day	Pulse rate/minute Difference	Calories/minute Difference
Basal	1	-1.0	+0.01
	2	+1.0	+0.10
	3	-2.0	-0.09
Lying (after eating)	1	-2.0	-0.08
	2	-3.0	+0.03
Sitting, sifting (rice from sugar)	1	-3.0	-0.04
	2	+3.0	-0.10
	3	+2.0	+0.06
Sitting, typing	3	-6.0	-0.14
Standing, sweeping (hand electric with extension)	2	-2.0	+0.07
Standing, vacuuming (upright beater type)	3	-3.0	+0.11
Treadmill			
Walk, 1 mi./hr., no grade	3	0.0	-0.12
Walk, 1 mi./hr., 4% grade	3	+3.0	-0.16
Walk, 2 mi./hr., 4% grade	1	-1.0	+0.10
	2	+2.0	+0.02
Walk, 3 mi./hr., 4% grade	1	+5.0	+0.45
	2	+3.0	+0.01

directly in nine and inversely in seven of the duplicate tests on the same day of testing.

As was shown in Table 16, the mean values for pulse rate and energy expenditure for duplicate activities were correspondingly higher or lower from day to day except in the case of two of the activities performed on the treadmill. Mean values for both pulse rate and energy expenditure for Subjects No. 34 and No. 18 during the treadmill walking at 2 miles per hour and 4% grade were lower on the second day than the first day of testing. In general the variations in duplicate tests and the variations in tests from day to day were similar in nature for values for pulse rate during activity and for energy cost of activity.

<u>Relationship of energy expenditure to pulse rate</u> In studying the pattern of relationship of energy expenditure to pulse rate for the individual subjects, the first approach was to test the linearity of the regression of the data for the total range of observations for each subject. The linearity of regression was significant at $P \leq 0.01$ for each subject, thus indicating an increment in pulse rate for a corresponding increment in Calories per minute (Table 19). The next approach was to examine the individual graphs to determine if the single straight line relationship was the best fit for the data. Booyens and Hervey (44) had found two lines of slope where activity changed from quiet occupations to ergometer work. All of the activities of the tests were self-directed except for the treadmill walking. The coefficients of regression for each of these two kinds of activities for

Table 19. Tests of significance

Tests of significance	Subject No. 34	35	100	14	18	99
Total activities						
F-value	141.73	70.29	21.19	58.62	71.50	28.77
$P \leq 0.01$	9.65	12.25	8.53	12.25	10.04	9.65
Low level activities						
F-value			81.00	24.98	40.89	7.57
$P \leq 0.01$			10.04	16.26	16.26	12.68
Treadmill walking						
F-value			47.57	104.21	28.24	12.68
$P \leq 0.01$			21.20	98.49	34.12	18.51
Two-tail distribution						
F-value			2.36	0.86	3.22	1.04
$P \leq 0.05$			8.84	39.29	14.92	39.35
t-value			2.40	1.56	1.18	1.12
$P \leq 0.05$			2.14	2.36	2.31	2.26

each subject were tested for significance.

Data for Subjects No. 35 and No. 34 indicated no change in slope and were significant at $P \leq 0.01$ as a single linear regression for each subject (Fig. 6 and Fig. 7). Data for Subjects No. 18 and No. 99, shown graphically in Fig. 8 and in Fig. 9, indicated a posibility of two slopes of linear regression for each of the two subjects. For Subject No. 18 the slopes of regression for self-directed activities and for treadmill walking were each significant at $P \leq 0.01$. However, the difference between the two slopes was not

Fig. 6. Relationship of pulse rate to Calories per minute for Subject No. 34

a   Regression formula of total activities

x   Average of duplicate tests per day per activity

o   Single tests per day per activity

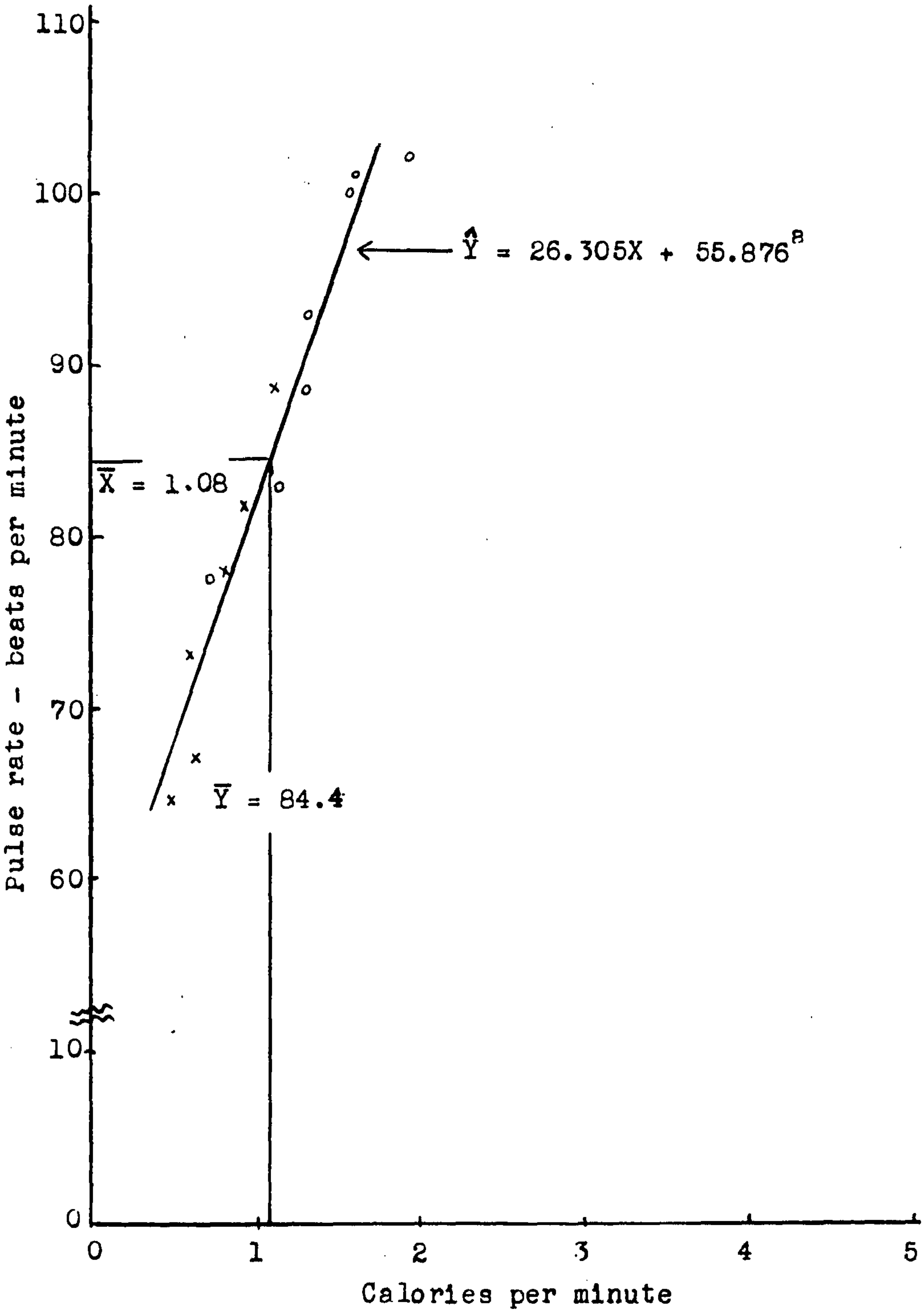
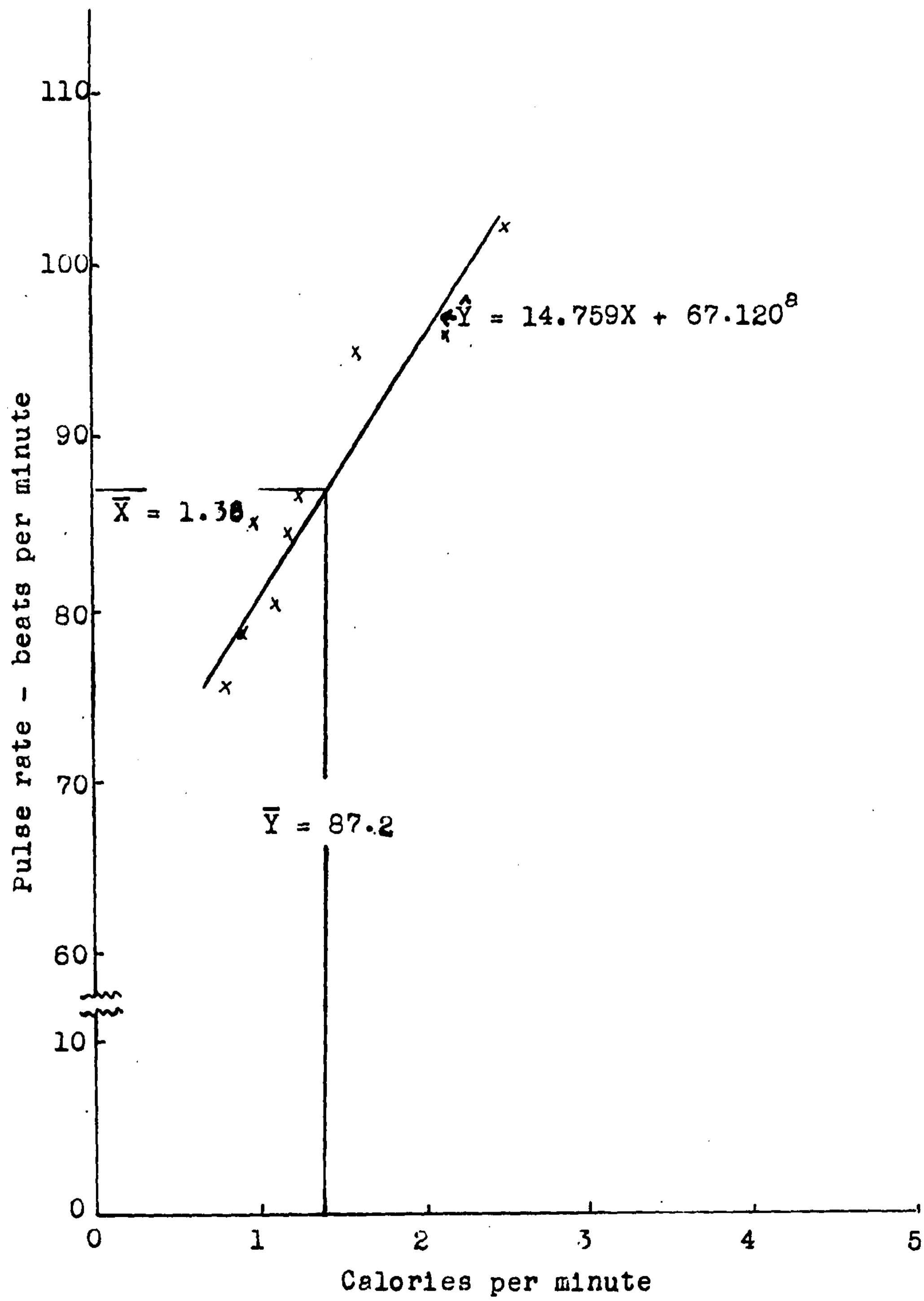

110
100
90
80
70
60
10
0
0
1
2
3
4
5
Ŷ = 26.305X + 55.876[8]
X̄ = 1.08
Ȳ = 84.4
Pulse rate - beats per minute
Calories per minute

Fig. 7. Relationship of pulse rate to Calories per minute for Subject No. 35

a Regression formula of total activities

x Average of duplicate tests per day per activity

o Single tests per day per activity



Pulse rate - beats per minute
110
100
90
80
70
60
10
0
Calories per minute
0
1
2
3
4
5
Ŷ = 14.759X + 67.120[8]
X̄ = 1.38
Ȳ = 87.2

Fig. 8. Relationship of pulse rate to Calories per minute for Subject No. 18

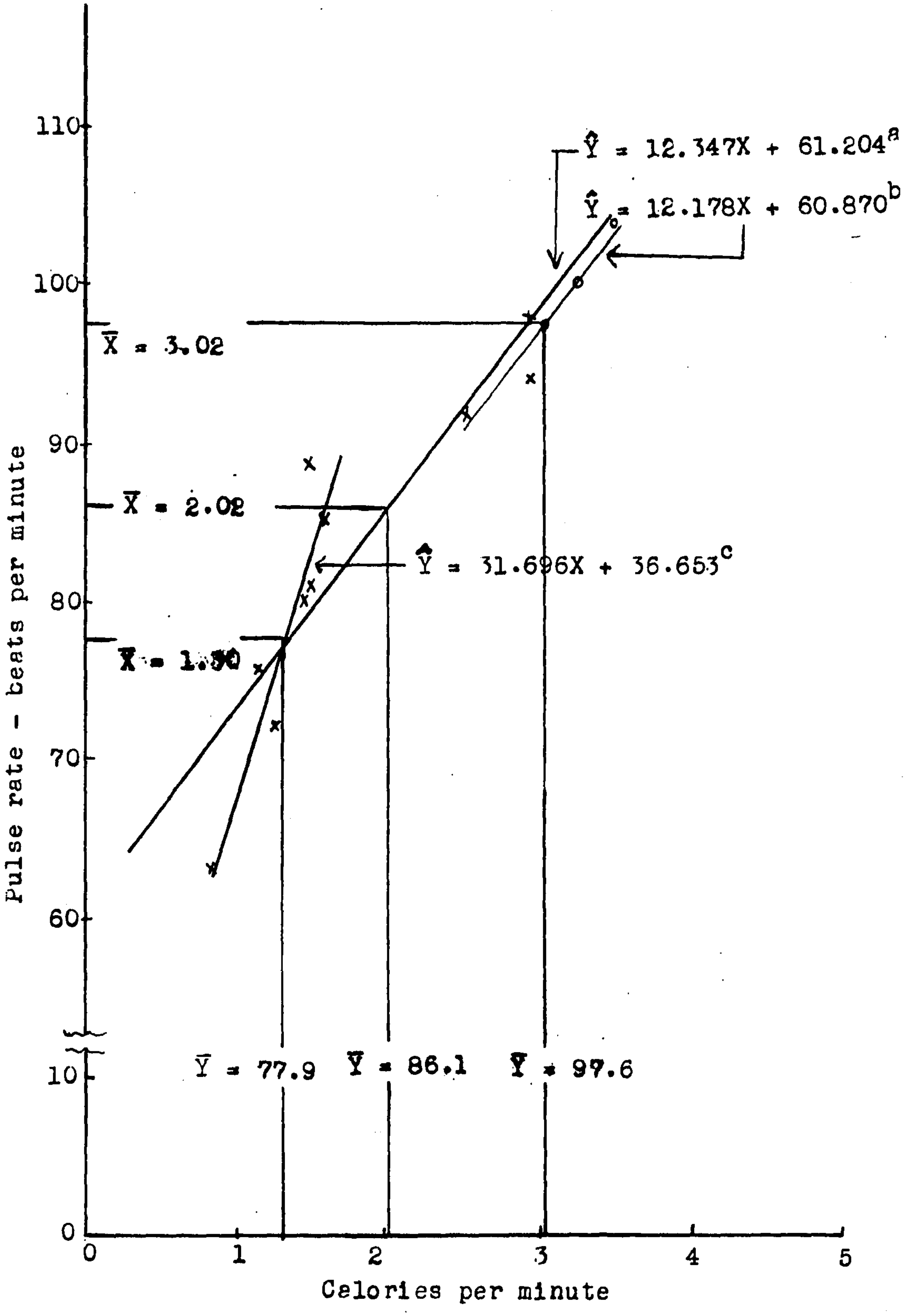
a Regression formula for total activities

b Regression formula for treadmill tests

c Regression formula for self directed activities

x Average of duplicate tests per day per activity

o Single tests per day per activity



$\hat{Y}$ = 12.347X + 61.204[a]
$\hat{Y}$ = 12.178X + 60.870[b]
$\hat{Y}$ = 31.696X + 36.653[c]
$\bar{X}$ = 3.02
$\bar{X}$ = 2.02
$\bar{X}$ = 1.30
$\bar{Y}$ = 77.9
$\bar{Y}$ = 86.1
$\bar{Y}$ = 97.6
Pulse rate - beats per minute
Calories per minute
110
100
90
80
70
60
10
0
1
2
3
4
5

Fig. 9. Relationship of pulse rate to Calories per minute for Subject No. 99

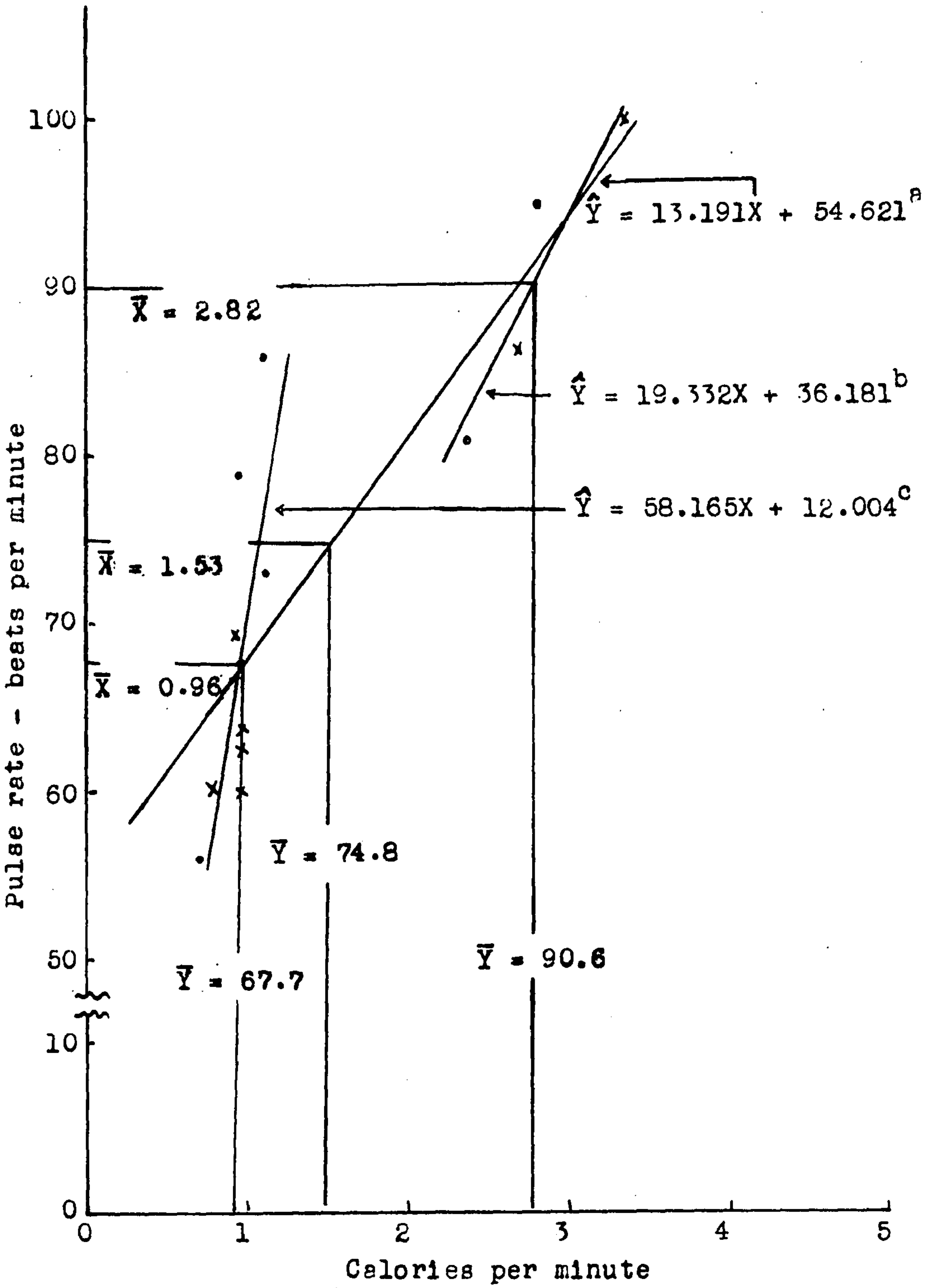
a Regression formula for total activities

b Regression formula for treadmill tests

c Regression formula for self directed activities

x Average of duplicate tests per day per activity

o Single tests per day per activity



Ŷ = 13.191X + 54.621a
Ŷ = 19.332X + 36.181b
Ŷ = 58.165X + 12.004c
X̄ = 2.82
X̄ = 1.53
X̄ = 0.96
Ȳ = 74.8
Ȳ = 67.7
Ȳ = 90.6
Pulse rate - beats per minute
Calories per minute
100
90
80
70
60
50
10
0
1
2
3
4
5

significant. For Subject No. 99 the slope of regression for total activities was the only slope of regression that was significant at $P \leq 0.01$. The difference between the slopes of regression of treadmill walking and of other activities was not significant although the plot of the points on the graph indicated a possibility of two independent slopes rather than a single slope. Additional tests of activities of faster speeds of treadmill walking and also of activities of a minimum of energy use providing a greater number of degrees of freedom are needed to determine whether the pulse rate-energy expenditure relationship for the self-directed activities is similar to or different from that of the treadmill walking.

The slopes of regression of total activities, of treadmill walking, and of the self-directed activities were each significant at $P \leq 0.01$ for both Subject No. 100 and for Subject No. 14. Fig. 10 and Fig. 11, respectively, present graphically the data for these two subjects. The difference between the slopes of regression of treadmill walking and of self-directed activities was significant at $P \leq 0.05$ for Subject No. 100 but was not significant for Subject No. 14. However, as was suggested above for Subjects No. 18 and No. 99, results from additional testing of both levels of activity for Subject No. 14 might indicate significantly different slopes for the two areas on the graph.

Fig. 10. Relationship of pulse rate to Calories per minute for Subject No. 100

b Regression formula for treadmill tests

c Regression formula for self directed activities

x Average of duplicate tests per day per activity

o Single tests per day per activity

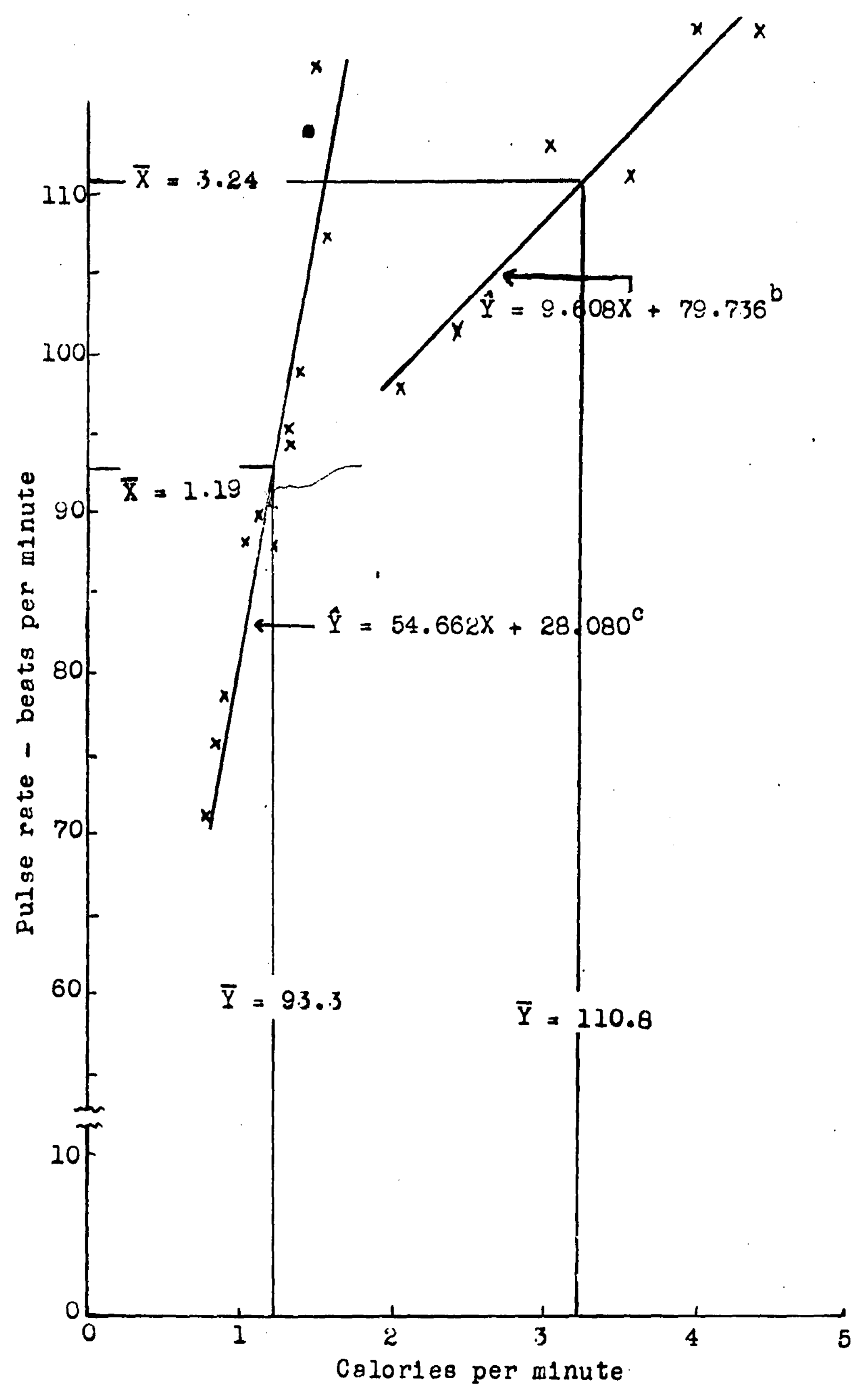
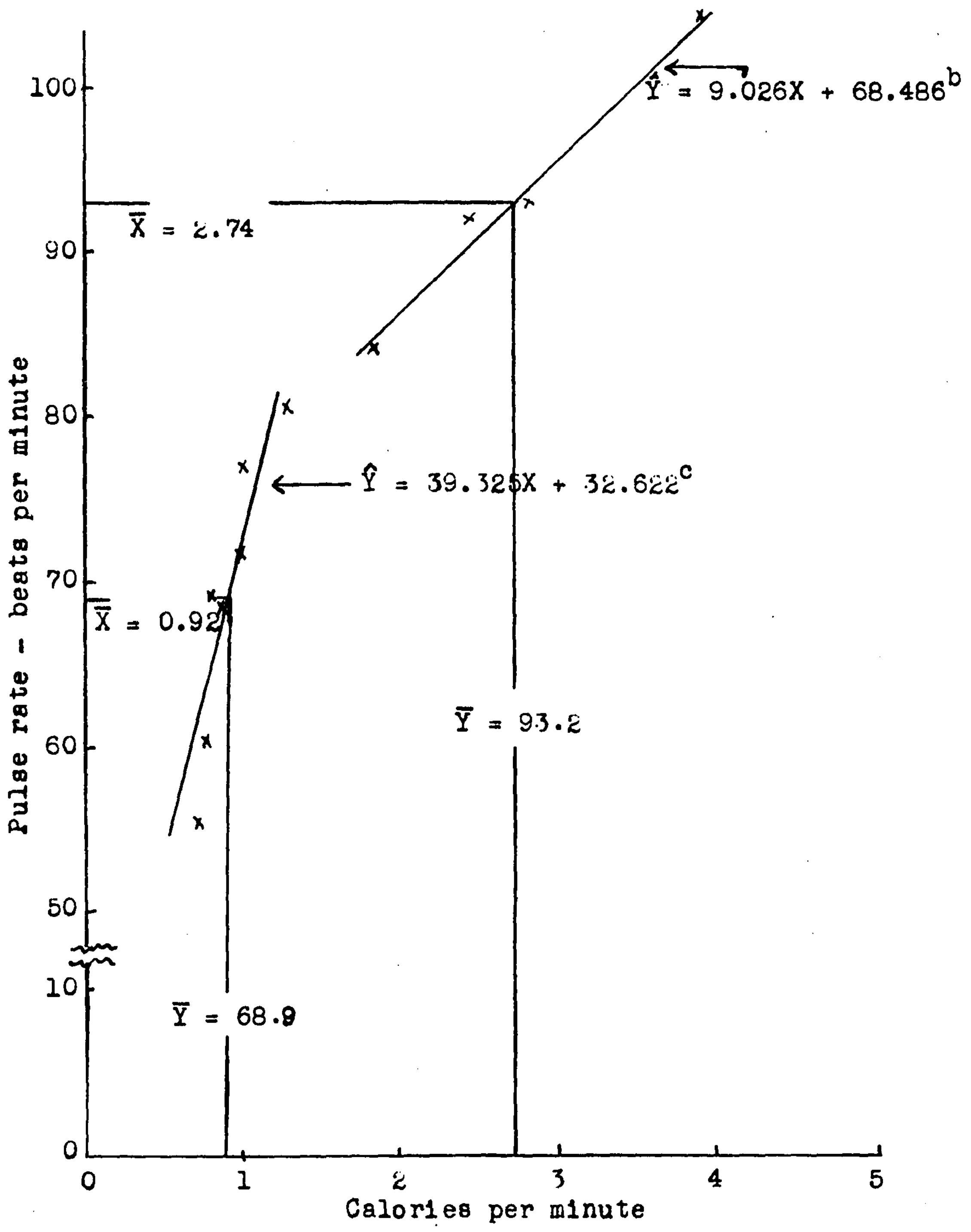

X̄ = 3.24
X̄ = 1.19
Ŷ = 9.608X + 79.736b
Ŷ = 54.662X + 28.080c
Ȳ = 93.3
Ȳ = 110.8
Pulse rate - beats per minute
0
10
60
70
80
90
100
110
Calories per minute
0
1
2
3
4
5

Fig. 11. Relationship of pulse rate to Calories per minute for Subject No. 14

b Regression formula for treadmill tests

c Regression formula for self directed activities

x Average of duplicate tests per day per activity


Ŷ = 9.026X + 68.486b
X̄ = 2.74
Ŷ = 39.325X + 32.622c
X̄ = 0.92
Ȳ = 93.2
Ȳ = 68.9
Pulse rate - beats per minute
Calories per minute
100
90
80
70
60
50
10
0
1
2
3
4
5

The coefficient of regression of pulse rate on energy expenditure for the total activities was 26.305 for Subject No. 34, who was 83 years of age. This was the largest coefficient of any of the subjects. The coefficient of regression for all activities for Subject No. 100 was 10.271. The coefficients of regression for the other subjects ranged from 12.178 to 14.759 for the total range of activities.

The coefficients of regression of pulse rate on energy expenditure for the treadmill activities ranged from 9.026 to 19.332 for Subjects No. 14, 18, 99, and 100. Of these subjects, the largest coefficient of regression for both the work on the treadmill and self-directed activities was for Subject No. 99, who was 21 years of age. The range of coefficients of regression for the four subjects was from 31.696 to 58.165 for self-directed activities. Although the differences between slopes for the self-directed activities and for treadmill walking were not statistically different for Subjects No. 100, 99, 18, and 14, data on the graph for individual subjects suggest that the data were not continuous for the entire series of activities. The area of uncertainty appeared to be with activities in which the pulse rate was high in relation to the energy cost of the activity. Subject No. 100 had pulse rates of 114 and 118 for energy expended of 1.42 and 1.49 Calories per minute for self-directed activity of standing sweeping. During treadmill walking this same subject had pulse rates of 113 and 120 for energy expended of 3.35 and 3.00

Calories per minute. Similar results were obtained for Subject No. 99. During standing exercises this subject had pulse rates of 79 and 86 with Calories per minute of 0.95 and 1.12 respectively but during treadmill walking pulse rates of 81 and 86.5 were recorded with energy expenditures of 2.39 and 2.70 Calories per minute, respectively.

Subjects No. 18 and 14 did not have as high a pulse rate for the self-directed exercise of standing sweeping as was observed for Subject No. 100. The pulse rates for these two subjects were 88 and 80.5 and the Calories per minute were 1.46 and 1.29, respectively. At the same speed of treadmill walking for which Subject No. 100 had pulse rates of 111 and 113, Subjedts No. 18 and 14 had pulse rates of 100 and 93 with corresponding Calories per minute of 3.25 and 2.84. Although a similar number of Calories per minute of energy were expended for the same activity by these three subjects, the accompanying pulse rates were different.

The change in activity from standing, where the muscles must maintain the upright position, to the controlled, rhythmical walking on a treadmill, where the upright position was supported by hand on the treadmill framework may account for some of the change in slope of the energy expenditure to pulse rate relationship. Michael <u>et al</u>. (42) reported higher heart rates with a bicycle ergometer than with walking on a treadmill with equivalent oxygen uptake.

The change in body position may be another factor in the change in relationship of energy expenditure to pulse rate.

Schneider and Truesdell (53) reported an average increase of 17.9 in pulse rate of men during a change of activity from lying to standing. In a later study (54) these same workers noted an average increase of seven in pulse rate from reclining to standing. These workers also reported that no diurnal change occurred in this pulse rate increase. Knox (55) likewise found an average increase of seven in standing pulse rate over that of sitting. Knox attributed this increase to the dynamic movement of standing up and also to the steady gravitational factor when erect. Subject No. 100 exhibited a greater rise of pulse rate on standing than did either Subject No. 18 or Subject No. 14. (These three subjects showed the greatest change in the slope of the relationship of energy expenditure to pulse rate relationship for the six subjects in this study.) The increase in pulse rate from sitting exercises to standing exercises for Subject No. 100 (Table 16) may result from the pooling of the blood in the lower areas of the body with a change to upright position as suggested by Asmussen and Nielsen (37).

The activity of eating resulted in a rise in pulse rate for Subject No. 100. This elevation of pulse rate occurred as she began to eat each meal and continued for nearly an hour after the meal was finished. The pulse rate elevation continued during either a sitting or lying position maintained by the subject following a meal. Work activities had an additive effect on the elevation of the pulse rate. Passmore and

Ritchie (56) found an increase of energy expenditure for a period immediately following eating which, they reported, lasted for approximately 45 minutes to one hour. Buskirk *et al.* (57) also reported increased oxygen consumption after ingestion of food. Schneider and Truesdell (54) found an increase in pulse rate after ingestion of food which showed no diurnal effects.

Prediction of Daily Energy Expenditure from a Continuous Record of the Pulse Rate

If the relationship of pulse rate to energy expenditure is constant for an individual within a given period of time, changes in the pulse rate during daily activity would provide a basis for estimation of the daily energy expenditure of the individual. The applicability of this approach to the estimation of energy expenditure was studied for one of the subjects, No. 100, in her home environment. Continuous records of the pulse rate of Subject No. 100 were obtained from two 24-hour periods within six weeks. Since it was necessary to have the pulse rate pick-up connected by wire to the cardiotachometer and recorder, the movements of the subject were restricted by the length of the cord. However the subject pursued her customary activities of food preparation, light housework, dishwashing, and work performed in a sitting position.

Analysis of the pulse rate record

The 24-hour continuous record of the pulse rate was analyzed to determine the mean pulse rate per minute for successive intervals of time. The time units were 10 minutes, 15 minutes, 1 hour, and 24 hours. The data for Day 1 are given in Table 23 of the Appendix and the summaries of the time units of 15 minutes, 1 hour, and 24 hours are shown graphically in Fig. 13. Data for Day 2 are given in Table 24 of the Appendix and the summaries of the time units of 10 minutes, 1 hour, and 24 hours are shown graphically in Fig. 14.

The records on Day 1 were begun at 8:00 A.M. and observations were made for a 24-hour period. The mean pulse rate for hourly intervals varied from 62.6 to 69.6 during the night hours. The lowest pulse rate was at 5:00 A.M. The highest mean pulse rate for a one-hour period was 104.2 beats per minute. During this time the rate varied for 10-minute periods from 85.0 to 114.9. The average pulse rate per minute for the 24-hour period was 80.2.

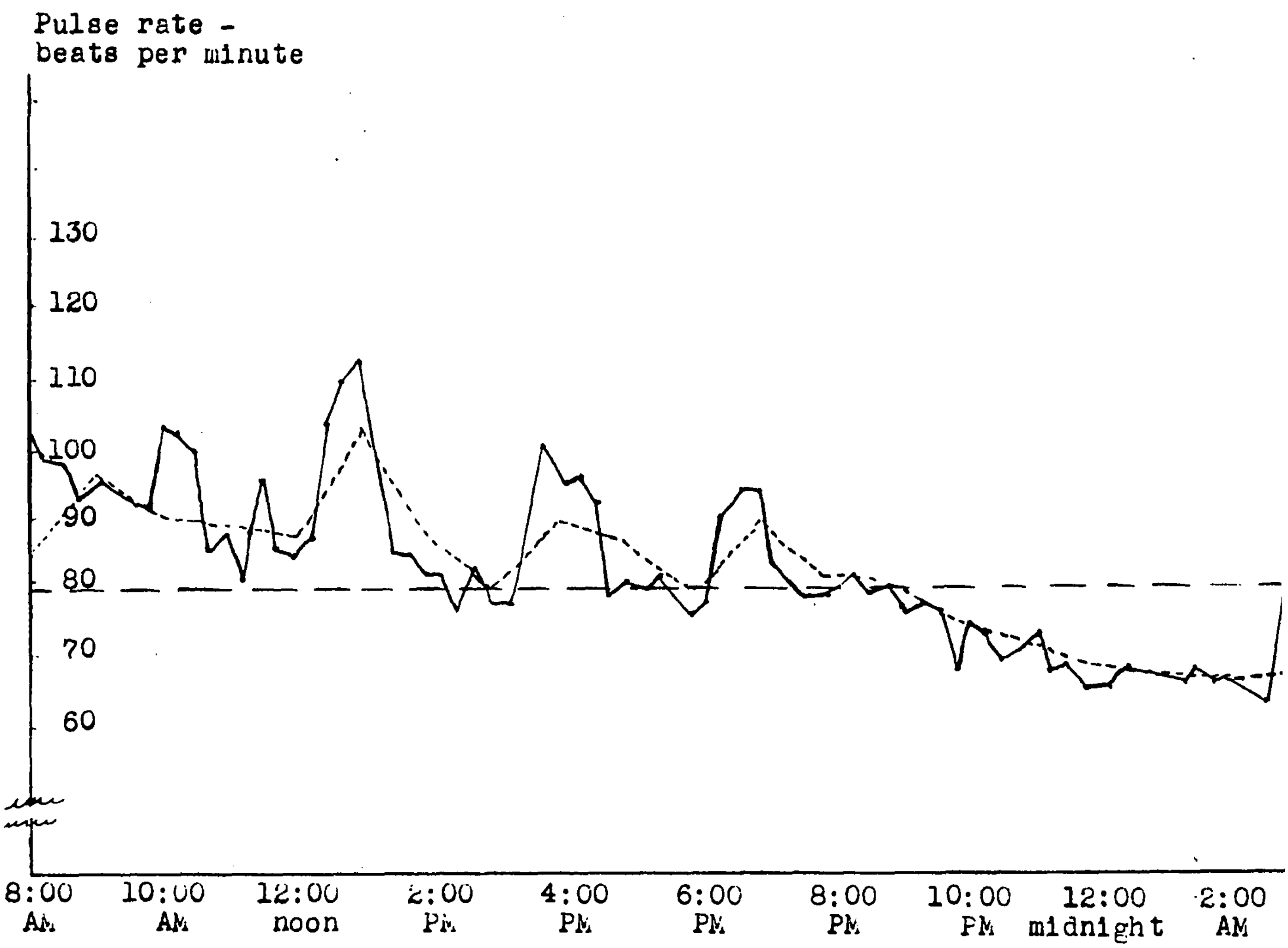
Records for the second day were begun at 9:20 P.M. and continued for a 24-hour period. The pulse rate at night varied from 68.1 to 73.9 counts per minute when averages were calculated for successive hours. The highest mean pulse rate for a one-hour period was 107.0 counts per minute. During this time the pulse rate for successive 10-minute periods varied from 103.8 to 111.4 counts per minute. The average

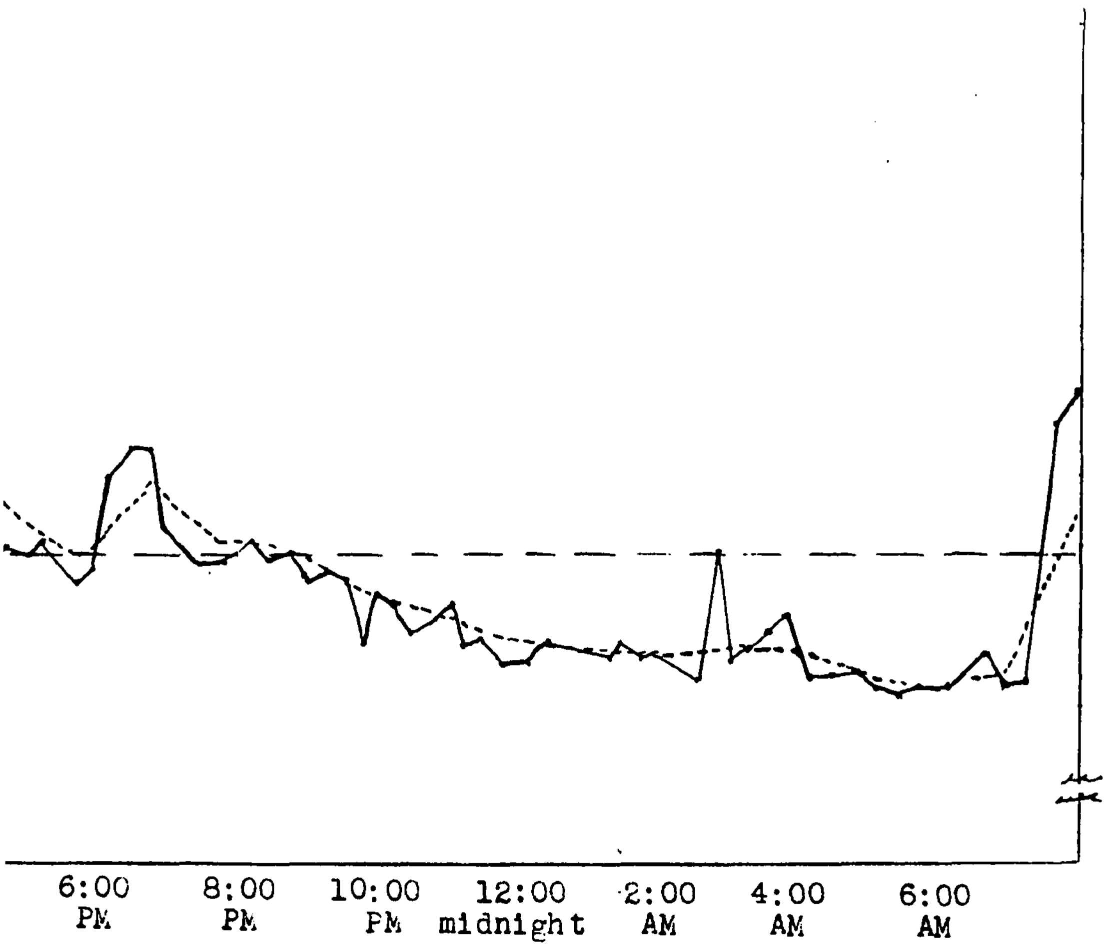
Fig. 12. Pulse rate record for Day 1

Summarized by averages of 15-minute intervals ————

Summarized by averages of 1-hour intervals - - - - - -

Summarized by average of 24 hours —— —— ——


Pulse rate -
beats per minute
130
120
110
100
90
80
70
60
8:00 AM
10:00 AM
12:00 noon
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 midnight
2:00 AM



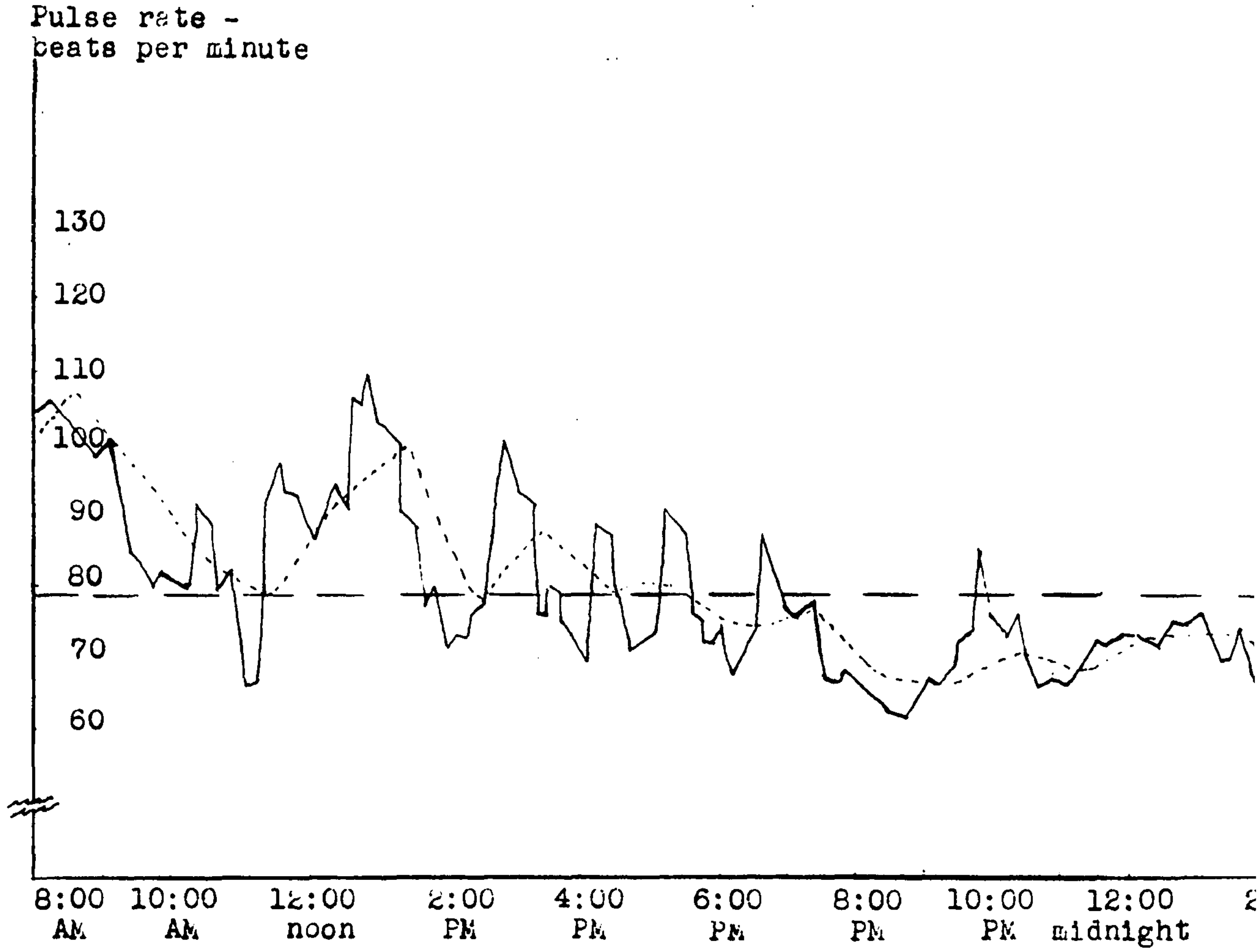
6:00 PM
8:00 PM
10:00 PM
12:00 midnight
2:00 AM
4:00 AM
6:00 AM

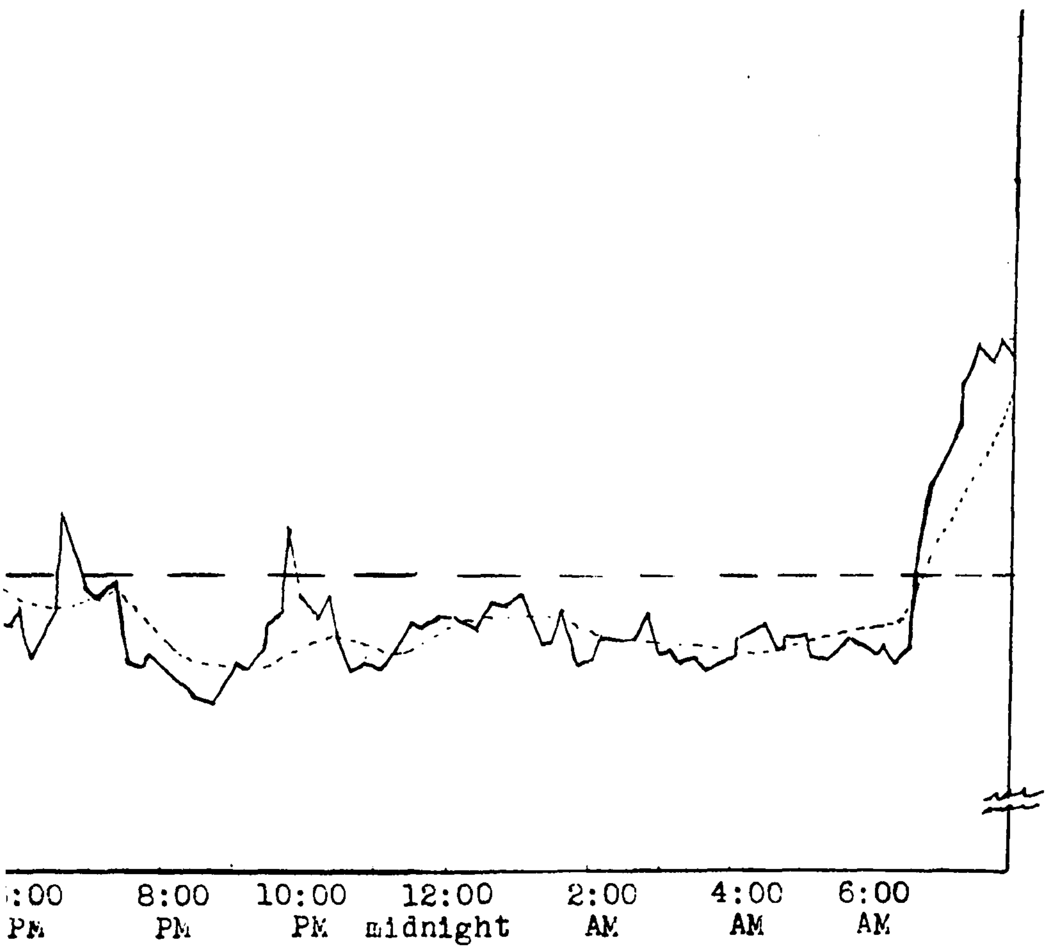
Fig. 13. Pulse rate record for Day 2

Summarized by averages of 10-minute intervals ———

Summarized by averages of 1-hour intervals — — — —

Summarized by average of 24 hours —— ——


Pulse rate -
beats per minute
130
120
110
100
90
80
70
60
8:00 AM
10:00 AM
12:00 noon
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 midnight



:00 PM
8:00 PM
10:00 PM
12:00 midnight
2:00 AM
4:00 AM
6:00 AM

pulse rate per minute for the 24-hour period was 79.2.

During the laboratory studies of pulse rate and energy expenditures for various activities, the pulse rate of Subject No. 100 ranged from 71.0 to 120.5. The pulse rate of the subject in the basal state averaged 78.5, 75.5 and 71.0 on three different test days. Thus the pulse rate observed under controlled conditions was higher than the pulse rate during sleep for both test days. The range of pulse rate for the self-directed activities under laboratory conditions was from 71.0 to 118.0. Since this range exceeded the upper limits of pulse rate of the subject on the two test days, the predicting equation for the self-directed activities was used first to interpret the pulse rate data obtained during the two 24-hour periods in the home. The equation was

$$\text{Cal. per min.} = \frac{\text{pulse rate} - 28.08}{54.662} \qquad \text{Equation 1}$$

On this basis, the total energy expenditure was calculated as 1368 and 1354 Calories per day for Day 1 and Day 2, respectively.

Since the predicting equation for the linear regression of pulse rate on energy expenditure during the self-directed activities was influenced by postural effects and did not include the metabolic cost of activity when work was performed by movement of the body, the daily energy expenditure estimated on this basis undoubtedly represents an under-estimation of daily energy expenditures.

The linearity of the regression of pulse rate on energy expenditure was statistically significant when the data included all of the activities studied in the laboratory. However this relationship apparently was weighted heavily by the relationship of pulse rate to energy expenditure during the work on the treadmill since the equations were:

(1) For all data: $Y = 10.271\ X + 79.911$ Equation 2

(2) For work on the treadmill: $Y = 9.608\ X + 79.736$ Equation 3

X = energy expenditure in Calories per minute

Y = pulse rate in counts per minute

An artifact would be introduced by use of the predicting equation calculated for the data from all of the activities since the proportion of time spent by the subject during the 24-hour period in lying, sitting and standing positions was considerably greater than the time spent in movement corresponding to the work on the treadmill.

The application of Equations 1 and 3 to periods of activity corresponding in nature to the laboratory activities for which the data were obtained appeared to be the most reliable basis for interpretation of the records of pulse rate for the two 24-hour periods. The diaries of activity of the subject on the two test days were analyzed for periods of activity corresponding in nature to the activities from which Equations 1 and 3 were derived. The pulse rates of the subjects corresponding to the various time periods of the two types of activity were tabulated. A summary of the data is given in Table 20.

The daily energy expenditures were calculated using Equations 1 and 3 for activities of low energy expenditure and for the treadmill work, respectively. Since the pulse rate

Table 20. Mean pulse rate and time period for two types of activity

	Low energy expenditure		Treadmill work	
	Average pulse rate	Total time	Average pulse rate	Total time
		min.		min.
Day 1	77.06	1141	98.73	299
Day 2	77.88	1156	97.61	284

during sleep was below the pulse rate for the basal, the Calories per minute expended during the basal state was assumed for calculating the energy of all pulse rates that were below the basal pulse rate. On this basis, the energy expenditures for Day 1 and Day 2 were 1613 and 1583 Calories per day, respectively.

The energy expenditures of Subject No. 100 were calculated also from the diaries of activity for the two test days by the use of the factors summarized in Table 3 of Part I. The energy expended for the two days as calculated on the basis of Calories per kilogram per hour was 1860 Calories and 1863 Calories. The energy expended for the two days as calculated on the basis of Calories per kilogram to the 0.73 power per hour was 1768 Calories and 1758 Calories.

The estimated energy expenditures of Subject No. 100 on Day 1 and Day 2 are summarized in Table 21.

Table 21. Estimation of daily energy expenditure by two methods

Method	Day 1	Day 2
	Cal.	Cal.
Interpretation of pulse rate		
Equation 1	1368	1354
Equations 1 and 3	1613	1583
Calculation by factors		
Cal./kg./hr.	1860	1863
Cal./kg.$^{0.73}$/hr.	1768	1758

The daily energy expenditure calculated on the basis of metabolically active body weight exceeded the daily energy expenditure predicted by Equations 1 and 3 by 9 per cent for Day 1 and 11 per cent for Day 2.

The lack of any method for determining directly the energy expenditure of a person in his customary work and home environment without restriction on movement makes it difficult to assess the reliability of indirect methods of estimation of energy expenditure. Although the estimation of energy expenditure for the two test days by interpretation of the pulse rate using Equations 1 and 3 is in relatively good agreement with the estimation of energy expenditure by calculation using factors based on $Kg.^{0.73}$ of body weight, both methods may be biased by the same factor, i.e., the subjective interpretation of a record of activities. The bias is lessened by the fact that the two methods necessitate different kinds of analysis of the activity records. Nevertheless both are dependent upon the reliability of the record of activities. If in the pulse rate record elevated pulse rates accompany certain activities which require relatively low energy expenditure or reflect nervous stimulation, the use of a predicting equation for areas of the pulse rate record would be limited in application by the record of activity performed. If extended studies furnished better understanding of the area of the graph where the slope of regression of pulse rate on Calories per minute for self-directed activities approached the slope of regression of pulse rate on Calories per minute for treadmill walking, the values of the plotted curve might provide a basis for estimation of the energy expended. If the relationship of the pulse rate to energy expenditure was established for a subject during selected activities in the home rather than from controlled tests performed in the laboratory, it is possible that the data then would have greater reliability for prediction of daily energy expenditure from continuous pulse rate records.

Energy expenditure values estimated from factors based on Calories per kilogram to the 0.73 power are influenced by the reliability of this calculated measure of effective metabolic tissue for an individual subject.

A comparison of the methods of estimation of energy expenditure can be made only when applied to the same subject because of the variations among individuals that affect the total energy expenditure.

Technical Difficulties in the Determination of Oxygen Consumption

Certain problems are inherent in the determination of oxygen consumption by a subject. One of the problems encountered most frequently was that of a mouthpiece or face mask which could be worn comfortably by the subject during exercise for a desired period of time. Partial or complete dentures interfered with a mouth piece and the pull of the hose and mouth piece was uncomfortable for some subjects. Face masks which were available commercially either caused uncomfortable pressure or did not fit snugly enough to prevent leakage of expired air.

In preparation of equipment for this research problem, the author participated in the designing, modeling, and testing of a new rubber face mask for use in energy studies.

The mask was designed with a cup-shape to fit down under the chin and also to extend up to cover the nose and mouth area.* A pneumatic ridge under the outer edge of the mask caused it to cling to the cheeks and nose. The area over the nose was rigid in shape. The mask was comfortable to wear and facilitated swallowing which is difficult for some subjects when they wear a mouth piece and nose clip. Initial tests for calibration of the mask with the regular mouth piece gave excellent results. The mask was not completed in time to be used in this study, but will be ready for later research.

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*Pilar Garcia, Associate Professor of Foods and Nutrition, Duane F. Hougham, Associate in Foods and Nutrition, and Andrew J. Wunderlich, Instrument Maker, Instrument Shop, participated in development of the mask.

GENERAL DISCUSSION

The lack of a direct method for the determination of daily energy expenditure means that there is no absolute reference for establishing the validity of indirect methods of estimation of energy expenditure. Comparison of findings of various indirect methods may give confidence to the experimental findings if the results are in close agreement.

The present study was concerned with the development and modification of methodology for two procedures of indirect estimation of energy expenditure. The first procedure was concerned with analysis of diaries of activities by tables of Calorie values. The second procedure dealt with analysis of pulse rate/oxygen consumption records. Data for one subject observed for two 24-hour periods gave a basis for determination of the various sources of errors in the two procedures and disclosed areas for future study.

A linearity of pulse rate increment to increment in energy expenditure was shown to exist for each of six subjects. For four of the six, a possibility existed that the slope of the regression of pulse rate on Calories per minute differed between self-directed activities and treadmill walking or, for two of the subjects, that the relationship might be curvilinear. Reliability of the prediction of energy expenditure from pulse rate records is dependent upon the linearity of relationship between the pulse rate increment and increment of Calories per minute for the total range of activities. The nature of the relationship should be investigated further to determine the effect of self-directed activity at high rates of energy expenditure in the usual environment versus the effect of controlled activity such as treadmill walking in the laboratory. The influence of variable factors such as deviation from desirable weight or degree of physical fitness should be investigated. Further study is needed also to interpret variations in pulse rate with activities which require relatively low energy expenditures. Differences among the subjects of this study indicate that the relationship of energy expenditure to pulse rates should be determined for the individual in order to have predictive value for activities over a 24-hour period.

Reliability of field study results will be increased when the pulse rate record can be made without hindrance of equipment to the subject during usual activities but with freedom of movement both indoors or outdoors, in vehicles of transportation, or in peculiar positions of work.

Problems involved in the prediction of energy expenditure from the diaries of activities are related to the exactness of the record and the appropriateness of the values of Calories per kilogram per activity per hour used in the estimation of the record. The exact timing of the duration of each activity may involve error even with the use of a stop watch. Another possibility of error lies in the estimation of the level of work performance of the individual. Training for the work, purposeful movement during the work, and nervous tension created during the work can affect the muscle involvement by different individuals performing the same task.

Close agreement in estimates obtained by use of the refined methods of the two procedures of this study when compared for many subjects, may serve as a reliable reference of energy expenditure.

SUMMARY

Part I of this study was designed to estimate energy expenditure from 24-hour records of activities using Calorie factors based on two measures of body weight, namely, total body weight and metabolically effective body weight.

The subjects were 46 women who ranged in age from 33 to 85 years. Twenty-seven of the women were over 50 years of age. The subjects had a weight deviation range of -6.4 to +33.2 kilograms from the desirable weight range. Sixteen of the women were of desirable weight. The greatest weight deviation occurred in the 40 to 60 age group.

Each subject kept two 24-hour records of her activities that were typical of a light-work day and a strenuous-work day. These records were analyzed for the energy expended by tables compiled from available literature of energy costs of activities based on Calories per kilogram per hour per activity and Calories per kilogram to the 0.73 power per hour per activity.

The difference between results obtained by these two methods of calculation of energy expenditure increased directly with an increase in deviation from desirable body weight.

The mean daily energy expenditures estimated on the basis of metabolically effective body weight when compared to the mean daily energy expenditures estimated on the basis of total body weight resulted in the following differences; namely,

152 Calories less for subjects 20% or more overweight, 86 Calories less for subjects not exceeding 20% overweight, only one Calorie less for subjects of desirable weight, and 134 Calories more for the one subject who was 10% underweight.

The average daily energy expenditure was studied with relation to the following variables: age, body weight, health status, family members, house size, temperament, efficiency, and strenuous activity in homemaking. The relationships were evaluated in terms of energy costs based on the metabolically effective body tissue since this basis appeared to give a more valid estimate of average energy expenditure.

A decrease in mean energy expenditure occurred, but not uniformly, with an increase in age of the women. The average expenditure of energy for the two days of activities by women of desirable weight from the fourth to the eighth decade was 2041, 2007, 1763, 1761, and 1735 Calories, respectively. Some women in the 60 to 79 year groups listed activities of a strenuous nature that made their day's energy expenditure as great as that of women in the 30 year group. These strenuous activities included canning, gardening, carrying coal, feeding chickens, and washing on the board. Only one of the younger women reported outdoor activity.

An increase in mean energy expenditure occurred with an increase in the weight of the subjects. Within each age group, the mean energy expenditures of women who were 20% or more above the range of desirable weight for age and height were correspondingly higher than the mean energy expenditures of women classed as moderately overweight. Overweight was one of the factors used in rating the subjects for health status. There was apparently little relationship between the health status and the mean energy expenditure other than that which might be related to the condition of overweight.

Women who lived alone in houses of one floor in size expended, on an average, 1994 Calories of energy. Women with families who lived in two-story houses expended an average of 2300 Calories. It made very little difference in the daily expenditure of energy if the family members were adults only, or if they were adults and children.

The women who were rated "average" in temperament had higher daily energy expenditures than women rated "tense-nervous" or "placid". The women who were rated "average" in efficiency expended less energy daily than subjects who were in the "high" efficiency group. However the effects of temperaments or efficiency could not be isolated from the influence of other factors on total energy expenditure.

The women recorded a "light" day and a "strenuous" day of homemaking. The difference in energy expenditures between the two days varied widely for the subjects. Seven women reported days that differed less than 50 Calories and nine women reported days that differed more than 500 Calories. The range of daily energy expenditures was 1720 to 2485 Calories per day and 1487 to 2512 Calories per day for the two groups, respectively.

In Part II, a study was made of the estimation of energy expenditure of women as related to the pulse rate. The pulse was taken by a photoelectric cell ear-pickup connected by a 12-ft. extension cord to a digital cardiotachometer. The record was made by an ink recorder.

Six women served as laboratory subjects for a series of controlled activities. The relationship of the increment in pulse rate to the increment in Calories of energy expended per minute in the performance of the series of activities was established by linear regression. One of the six women served as the subject for the two 24-hour continuous pulse rate records.

Three patterns of linear regression were evident. The pattern of regression for Subjects No. 34 and 35 indicated a linear regression that was significant at $P \leq 0.01$. The pattern for Subjects No. 18 and 99 indicated a different coefficient of linear regression for the two levels of activity, namely, self-directed activities and treadmill walking. However, the difference between the two slopes of regression was not significant. The pattern for Subjects No. 14 and 100 indicated a similar difference in slopes of linear regression for the two levels of activity. The difference between the two slopes of regression was significant at $P \leq 0.05$ for Subject No. 100 but not significant for Subject No. 14.

Two 24-hour continuous pulse rate records were taken of Subject No. 100 as she performed usual activities in her home. A record of her activities was made simultaneously with the pulse record. The time was written on the pulse rate record at one-half hour intervals throughout the day of recording. The interpretation was made later at every 15-second time interval of each 24-hour record.

The pulse rate of the subject fell below the basal rate for 8 hours of sleep on Day 1 and for 7 hours of sleep on Day 2. This decrease amounted to as much as 0.16 Calories per minute. A rise in pulse rate occurred as the subject began to eat each meal and the pulse remained elevated for nearly one hour after the meal was finished. Work activities following the meal increased the level of the pulse rate still more.

Four summaries of the pulse rate records were made, namely, 10-minute, 15-minute, 1-hour, and 24-hour unit intervals. The energy expended for each of the two 24-hour periods was estimated by two different analyses of the pulse record. The first estimation used the average pulse rate for each of these units of time and Equation 1, the relationship of pulse rate to Calories per minute for the self-directed activities. The second estimation evaluated the pulse rate record as it related to the activity record by use of Equations 1 and 3, the relationships of pulse rate to Calories per minute and the minutes of time and pulse rate levels attributed to each equation.

Subject No. 100 was the only subject whose daily energy expenditure could be calculated by all methods, namely, total body weight, metabolically effective body weight, pulse rate by the first estimation, and pulse rate by the second estimation. Her average daily energy expenditure as estimated by these methods was as follows:

Total body weight	1862 Calories
Metabolically effective body weight	1763 Calories
Pulse rate, Equation 1	1361 Calories
Pulse rate, Equations 1 and 3	1589 Calories

The daily calorific requirement for Subject No. 100 estimated according to metabolically effective body weight and the pulse rate second estimation were within 9-11% agreement. The pulse rate estimations were 300 to 500 Calories below the estimations of daily energy expenditure made by the factors based on total body weight.

RECOMMENDATIONS

The author suggests that the pulse rate method of determining energy expenditure be investigated further in regard to the following:

The relationship of increment of pulse rate to increment of Calories per minute in regard to high rate energy expenditure in self-directed activity in contrast to controlled treadmill walking.

The effect of the status of physical fitness or deviation from desirable weight and influence of cardiac output on the regression of the increment of pulse rate to increment of Calories per minute during activities.

The use of pulse counters or telemetered pulse rate records to obtain daily energy expenditure for a greater number of subjects.

LITERATURE CITED

1. Bourne, Geoffrey H. Structural changes in aging. American Association for the Advancement of Science, Publication No. 65: 123-136. 1960.

2. Calorie requirements. United Nations. Food and Agriculture Organization. Second Committee on Calorie Requirements. FAO Nutritional Studies No. 15. 1957.

3. Van Gehuchten, Pierre. World fiber co-existence. American Fabrics No. 57: 62-63. Summer, 1962.

4. Brody, Samuel. Bioenergetics and growth. 1st ed. New York, New York. Reinhold Publishing Corporation. 1945.

5. Benedict, Francis G. and Thorne M. Carpenter. The metabolism and energy transformations of healthy man during rest. Carnegie Institution of Washington, Publication No. 126. 1910.

6. Benedict, Francis G. and Edward P. Cathcart. Muscular work: a metabolic study with special reference to the efficiency of the human body as a machine. Carnegie Institution of Washington, Publication No. 187. 1913.

7. Rowley, Donald A., Seymour Glagov, and Peter Stoner. Measurement of human heart rate during usual activity. Science 130: 976-977. 1959.

8. Harten, G. A. and Koroncai, A. K. Radio transmitter for remote heart beat measurements. Electronics 33, No. 52: 54-55. 1960.

9. Holter, Norman J. New method for heart studies. Science 134: 1214-1220. 1961.

10. Webb, J. C., L. E. Campbell, and J. G. Hartsock. Electrocardiograph telemetering (Radio). Institute of Radio Engineers, National Convention Record 9: 43-49. 1958.

11. Durnin, L. V. G. A., Elaine C. Blake, Margaret K. Allan, Elizabeth J. Shaw, and Susan Blair. Food intake and energy expenditure of elderly women with varying-sized families. Journal of Nutrition 75: 73-76. 1961.

12. Langworthy, C. F. Report of work on energy expenditure for sewing and some other household tasks. Journal of Home Economics 14: 621-625. 1922.

13. Swartz, VeNona W. The human energy cost of certain household tasks. Washington Agricultural Experiment Station Bulletin No. 282. 1933.

14. Droese, Werner, Ernst Kofranyi, Heinrich Kraut, und Liesel Waldemann. Energetische Untersuchung der Hausfrauenarbeit. Arbeitsphysiologie 14: 63-81. 1949.

15. Durnin, J. V. G. A., Elaine C. Blake, and J. M. Brockway. The energy expenditure and food intake of middle-aged Glasgow housewives and their adult daughters. British Journal of Nutrition 11: 85-94. 1957.

16. Passmore, R. and J. V. G. A. Durnin. Human energy expenditure. Physiological Reviews 35: 801-840. 1955.

17. Gairns, S. and M. K. O'Brien. A discussion of the method of A. D. Waller for computing energy output, and results of experiments determining energy expenditure during some household tasks. Journal of Industrial Hygiene 4: 283-291. 1922.

18. Knowles, Eleanor Elaine. Posture and other physiological responses of the worker in relation to height of working surface used in household tasks. Unpublished Ph. D. thesis. Ithaca, New York, Library, Cornell University. 1944.

19. Langford, Florence. Influence of body weight on energy expenditure of women during controlled physical activity. Unpublished Ph. D. thesis. Ames, Iowa, Library, Iowa State University of Science and Technology. 1960.

20. Langworthy, C. F. and H. G. Barott. Energy expenditure in household tasks. American Journal of Physiology 52: 400-408. 1920.

21. Langworthy, C. F. and H. G. Barott. Energy expenditure in sewing. American Journal of Physiology 59: 376-380. 1922.

22. McCracken, Earl C. and Martha Richardson. Human energy expenditure as criteria for the design of household storage facilities. Journal of Home Economics 51: 198-206. 1959.

23. Richardson, Martha and Earl C. McCracken. Energy expenditure of women performing selected activities. United States Department of Agriculture, Agricultural Research Service. Home Economics Research Report No. 11. 1960.

24. Kleiber, Max. Body size and metabolic rate. Physiological Reviews 27: 511-541. 1947.

25. Miller, A. T. Energy metabolism and metabolic reference standards. Methods in Medical Research 6: 74-83. 1954.

26. Metropolitan Life Insurance Company. New weight standards for men and women. Metropolitan Life Insurance Company. Statistical Bulletin V40. 1959.

27. Guyton, Arthur C. Textbook of medical physiology. 2nd ed. Philadelphia, Pennsylvania. W. B. Saunders Co. 1961.

28. McKee, Wallace P. and Robert E. Bolinger. Caloric expenditure of normal and obese subjects during standard work tests. Journal of Applied Physiology 15: 197-200. 1960.

29. Booyens, J. and R. A. McCance. Individual variations in energy expenditure. Lancet 1957, Vol. 1: 225-229. 1957.

30. Durnin, J. V. G. A. The use of surface area and of body weight as standards of reference in studies of human energy expenditure. British Journal of Nutrition 13: 68-71. 1959.

31. Henderson, Yandell and Alexander L. Prince. The oxygen pulse and the systolic discharge. American Journal of Physiology 35: 106-115. 1914.

32. Murlin, J. R. and J. R. Greer. The relation of the heart action to the respiratory metabolism. American Journal of Physiology 33: 253-282. 1914.

33. Boothby, Walter M. The determination of the circulation rate in man at rest and at work. American Journal of Physiology 37: 383-417. 1915.

34. Taylor, Craig. Studies in exercise physiology. American Journal of Physiology 135: 27-42. 1942.

35. Erickson, Lester, Ernst Simonson, Henry Longstreet Taylor, Howard Alexander, and Ancel Keys. The energy cost of grade walking on the motor-driven treadmill. American Journal of Physiology 145: 391-401. 1945.

36. Müller, E. A. The physiological basis of rest pauses in heavy work. Quarterly Journal of Experimental Physiology 38: 205-215. 1953.

37. Asmussen, Erling and Marius Nielsen. Cardiac output during muscular work and its regulation. Physiological Reviews 35: 778-800. 1955.

38. LeBlanc, J. A. Use of heart rate as an index of work output. Journal of Applied Physiology 10: 275-280. 1957.

39. Wyndham, C. H., N. B. Strydom, J. S. Martis, J. F. Morrison, J. Peter, and Z. U. Potgieter. Maximum oxygen intake and maximum heart rate during strenuous work. Journal of Applied Physiology 14: 927-936. 1959.

40. Åstrand, Per-Olof and Bengt Saltin. Maximal oxygen uptake and heart in various types of muscular activity. Journal of Applied Physiology 16: 977-981. 1961.

41. Ogasawara, M. The energy expenditure in walking and running. Journal of Physiology 81: 255-264. 1934.

42. Michael, Ernest D., Jr., Kenneth E. Hutton, and Steven M. Horvath. Cardio-respiratory responses during prolonged exercise. Journal of Applied Physiology 16: 997-1000. 1961.

43. Steiner, Sheldon H. and Gustave C. E. Mueller. Heart rate and forward acceleration. Journal of Applied Physiology 16: 1078-1080. 1961.

44. Booyens, J. and G. R. Hervey. The pulse rate as a means of measuring metabolic rate in man. Canadian Journal of Biochemistry and Physiology 38: 1301-1309. 1960.

45. Peters, John P. and Donald D. Van Slyke. Quantitative clinical chemistry: Vol. 2: Methods. Baltimore, Md. The Williams and Wilkins Co. 1932.

46. Weir, T. B. de V. New methods for calculating metabolic rate with special reference to protein metabolism. Journal of Physiology 109: 1-9. 1949.

47. Wert, James E., Charles O. Neidt, and J. Stanley Ahmann. Statistical methods in educational and psychological research. New York, New York. Appleton-Century-Crofts, Inc. 1954.

48. Snedecor, George W. Statistical methods applied to experiments in agriculture and biology. 5th ed. Ames, Iowa. The Iowa State College Press. 1959.

49. Steel, Robert G. D. and James H. Torrie. Principles and procedures of statistics. New York, New York. McGraw-Hill Book Company. 1960.

50. United States Department of Agriculture. Yearbook of agriculture, 1959.

51. Swanson, Pearl, Elisabeth Willis, and Emil Jebe. Food intakes of 2,189 women in five north central states. Iowa Agricultural and Home Economics Experiment Station Research Bulletin 468. 1959.

52. Keiser, Marjorie Branin and Elaine Knowles Weaver. Body movements related to energy used. Journal of Home Economics 54: 479-482. 1962.

53. Schneider, Edward C. and Dorothy Truesdell. A statistical study of the pulse rate and the arterial blood pressures in recumbency, standing and after a standard exercise. American Journal of Physiology 61: 429-474. 1922.

54. Schneider, Edward C. and Dorothy Truesdell. Daily variations in cardio-vascular conditions and a physical efficiency rating. American Journal of Physiology 67: 193-202. 1923.

55. Knox, J. A. C. The effect of posture and exercise components on the heart rate during a brief step test. Journal of Physiology 108: 340-344. 1949.

56. Passmore, R. and Fiona J. Ritchie. The specific dynamic action of food and the satiety mechanism. British Journal of Nutrition 11: 78-84. 1957.

57. Buskirk, E. R., P. F. Iampietro, and B. E. Welch. Variations of resting metabolism with changes in food, exercise and climate. Metabolism, Clinical and Experimental 6: 144-152. 1957.

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APPENDIX

Table 22. Conversion table, kg. to $kg.^{0.73}$

Kg.	$Kg.^{0.73}$	Kg.	$Kg.^{0.73}$	Kg.	$Kg.^{0.73}$
38.6	14.40				
40.0	14.77	44.0	15.84	48.0	16.88
40.1	14.80	44.1	15.87	48.1	16.90
40.2	14.83	44.2	15.89	48.2	16.93
40.3	14.86	44.3	15.92	48.3	16.95
40.4	14.88	44.4	15.94	48.4	16.98
40.5	14.91	44.5	15.97	48.5	17.01
40.6	14.94	44.6	16.00	48.6	17.03
40.7	14.96	44.7	16.02	48.7	17.06
40.8	14.99	44.8	16.05	48.8	17.08
40.9	15.02	44.9	16.07	48.9	17.11
41.0	15.04	45.0	16.10	49.0	17.13
41.1	15.07	45.1	16.13	49.1	17.16
41.2	15.10	45.2	16.15	49.2	17.18
41.3	15.12	45.3	16.18	49.3	17.21
41.4	15.15	45.4	16.21	49.4	17.24
41.5	15.18	45.5	16.23	49.5	17.26
41.6	15.20	45.6	16.26	49.6	17.29
41.7	15.23	45.7	16.28	49.7	17.31
41.8	15.26	45.8	16.31	49.8	17.34
41.9	15.28	45.9	16.33	49.9	17.37
42.0	15.31	46.0	16.36	50.0	17.39
42.1	15.34	46.1	16.39	50.1	17.41
42.2	15.36	46.2	16.41	50.2	17.44
42.3	15.39	46.3	16.44	50.3	17.46
42.4	15.42	46.4	16.46	50.4	17.49
42.5	15.44	46.5	16.49	50.5	17.51
42.6	15.47	46.6	16.52	50.6	17.54
42.7	15.50	46.7	16.54	50.7	17.57
42.8	15.52	46.8	16.57	50.8	17.59
42.9	15.55	46.9	16.59	50.9	17.62
43.0	15.57	47.0	16.62	51.0	17.64
43.1	15.60	47.1	16.64	51.1	17.66
43.2	15.63	47.2	16.67	51.2	17.69
43.3	15.65	47.3	16.70	51.3	17.72
43.4	15.68	47.4	16.72	51.4	17.74
43.5	15.71	47.5	16.75	51.5	17.77
43.6	15.73	47.6	16.78	51.6	17.79
43.7	15.76	47.7	16.80	51.7	17.82
43.8	15.79	47.8	16.83	51.8	17.84
43.9	15.81	47.9	16.85	51.9	17.87

Table 22. (Continued)

Kg.	Kg.$^{0.73}$	Kg.	Kg.$^{0.73}$	Kg.	Kg.$^{0.73}$
52.0	17.89	56.0	18.89	60.0	19.86
52.1	17.92	56.1	18.91	60.1	19.89
52.2	17.94	56.2	18.94	60.2	19.91
52.3	17.97	56.3	18.96	60.3	19.94
52.4	17.99	56.4	18.98	60.4	19.96
52.5	18.02	56.5	19.01	60.5	19.98
52.6	18.04	56.6	19.04	60.6	20.01
52.7	18.07	56.7	19.06	60.7	20.03
52.8	18.09	56.8	19.08	60.8	20.06
52.9	18.12	56.9	19.11	60.9	20.08
53.0	18.14	57.0	19.13	61.0	20.10
53.1	18.17	57.1	19.16	61.1	20.13
53.2	18.19	57.2	19.18	61.2	20.15
53.3	18.22	57.3	19.21	61.3	20.18
53.4	18.24	57.4	19.23	61.4	20.20
53.5	18.27	57.5	19.26	61.5	20.22
53.6	18.29	57.6	19.28	61.6	20.25
53.7	18.32	57.7	19.31	61.7	20.27
53.8	18.34	57.8	19.33	61.8	20.30
53.9	18.37	57.9	19.35	61.9	20.32
54.0	18.39	58.0	19.38	62.0	20.34
54.1	18.42	58.1	19.40	62.1	20.37
54.2	18.44	58.2	19.43	62.2	20.39
54.3	18.47	58.3	19.45	62.3	20.42
54.4	18.49	58.4	19.47	62.4	20.44
54.5	18.52	58.5	19.50	62.5	20.46
54.6	18.54	58.6	19.52	62.6	20.49
54.7	18.57	58.7	19.55	62.7	20.51
54.8	18.59	58.8	19.57	62.8	20.54
54.9	18.62	58.9	19.60	62.9	20.56
55.0	18.64	59.0	19.62	63.0	20.58
55.1	18.67	59.1	19.65	63.1	20.61
55.2	18.69	59.2	19.67	63.2	20.63
55.3	18.71	59.3	19.69	63.3	20.65
55.4	18.74	59.4	19.72	63.4	20.68
55.5	18.76	59.5	19.74	63.5	20.70
55.6	18.79	59.6	19.77	63.6	20.73
55.7	18.81	59.7	19.79	63.7	20.75
55.8	18.84	59.8	19.81	63.8	20.77
55.9	18.86	59.9	19.84	63.9	20.80

Table 22. (Continued)

Kg.	$Kg.^{0.73}$	Kg.	$Kg.^{0.73}$	Kg.	$Kg.^{0.73}$
64.0	20.82	68.0	21.76	72.0	22.69
64.1	20.85	68.1	21.79	72.1	22.71
64.2	20.87	68.2	21.81	72.2	22.74
64.3	20.89	68.3	21.83	72.3	22.76
64.4	20.91	68.4	21.86	72.4	22.78
64.5	20.94	68.5	21.88	72.5	22.81
64.6	20.96	68.6	21.90	72.6	22.83
64.7	20.99	68.7	21.93	72.7	22.85
64.8	21.01	68.8	21.95	72.8	22.87
64.9	21.03	68.9	21.97	72.9	22.90
65.0	21.06	69.0	22.00	73.0	22.92
65.1	21.08	69.1	22.02	73.1	22.94
65.2	21.11	69.2	22.04	73.2	22.97
65.3	21.13	69.3	22.07	73.3	22.99
65.4	21.15	69.4	22.09	73.4	23.01
65.5	21.18	69.5	22.12	73.5	23.04
65.6	21.20	69.6	22.14	73.6	23.06
65.7	21.22	69.7	22.16	73.7	23.08
65.8	21.25	69.8	22.18	73.8	23.10
65.9	21.27	69.9	22.21	73.9	23.13
66.0	21.29	70.0	22.23	74.0	23.15
66.1	21.32	70.1	22.25	74.1	23.17
66.2	21.34	70.2	22.27	74.2	23.19
66.3	21.36	70.3	22.30	74.3	23.22
66.4	21.38	70.4	22.32	74.4	23.24
66.5	21.41	70.5	22.34	74.5	23.26
66.6	21.44	70.6	22.37	74.6	23.29
66.7	21.46	70.7	22.39	74.7	23.31
66.8	21.48	70.8	22.41	74.8	23.33
66.9	21.51	70.9	22.44	74.9	23.35
67.0	21.53	71.0	22.46	75.0	23.38
67.1	21.55	71.1	22.48	75.1	23.40
67.2	21.58	71.2	22.51	75.2	23.42
67.3	21.60	71.3	22.53	75.3	23.45
67.4	21.62	71.4	22.55	75.4	23.47
67.5	21.65	71.5	22.58	75.5	23.49
67.6	21.67	71.6	22.60	75.6	23.51
67.7	21.69	71.7	22.62	75.7	23.54
67.8	21.72	71.8	22.64	75.8	23.56
67.9	21.74	71.9	22.67	75.9	23.58

Table 22. (Continued)

Kg.	$Kg.^{0.73}$	Kg.	$Kg.^{0.73}$	Kg.	$Kg.^{0.73}$
76.0	23.60	80.0	24.50	84.0	25.39
76.1	23.63	80.1	24.53	84.1	25.42
76.2	23.65	80.2	24.55	84.2	25.44
76.3	23.67	80.3	24.57	84.3	25.46
76.4	23.69	80.4	24.59	84.4	25.48
76.5	23.72	80.5	24.62	84.5	25.50
76.6	23.74	80.6	24.64	84.6	25.53
76.7	23.76	80.7	24.66	84.7	25.55
76.8	23.79	80.8	24.68	84.8	25.57
76.9	23.81	80.9	24.71	84.9	25.59
77.0	23.83	81.0	24.73	85.0	25.61
77.1	23.85	81.1	24.75	85.1	25.64
77.2	23.88	81.2	24.77	85.2	25.66
77.3	23.90	81.3	24.79	85.3	25.68
77.4	23.92	81.4	24.82	85.4	25.70
77.5	23.94	81.5	24.84	85.5	25.72
77.6	23.97	81.6	24.86	85.6	25.75
77.7	23.99	81.7	24.88	85.7	25.77
77.8	24.01	81.8	24.91	85.8	25.79
77.9	24.03	81.9	24.93	85.9	25.81
78.0	24.06	82.0	24.95	86.0	25.83
78.1	24.08	82.1	24.97	86.1	25.85
78.2	24.10	82.2	24.99	86.2	25.88
78.3	24.12	82.3	25.02	86.3	25.90
78.4	24.15	82.4	25.04	86.4	25.92
78.5	24.17	82.5	25.06	86.5	25.94
78.6	24.19	82.6	25.08	86.6	25.97
78.7	24.21	82.7	25.11	86.7	25.99
78.8	24.24	82.8	25.13	86.8	26.01
78.9	24.26	82.9	25.15	86.9	26.03
79.0	24.28	83.0	25.17	87.0	26.05
79.1	24.30	83.1	25.20	87.1	26.07
79.2	24.33	83.2	25.22	87.2	26.10
78.3	24.35	83.3	25.24	87.3	26.12
79.4	24.37	83.4	25.26	87.4	26.14
79.5	24.39	83.5	25.28	87.5	26.16
79.6	24.41	83.6	25.31	87.6	26.18
79.7	24.44	83.7	25.33	87.7	26.20
79.8	24.46	83.8	25.35	87.8	26.23
79.9	24.48	83.9	25.37	87.9	26.25

Table 22. (Continued)

Kg.	$Kg.^{0.73}$	Kg.	$Kg.^{0.73}$	Kg.	$Kg.^{0.73}$
88.0	26.27	92.0	27.14	96.0	27.99
88.1	26.29	92.1	27.16	96.1	28.01
88.2	26.31	92.2	27.18	96.2	28.04
88.3	26.34	92.3	27.20	96.3	28.06
88.4	26.36	92.4	27.22	96.4	28.08
88.5	26.38	92.5	27.24	96.5	28.10
88.6	26.40	92.6	27.27	96.6	28.12
88.7	26.42	92.7	27.29	96.7	28.14
88.8	26.44	92.8	27.31	96.8	28.16
88.9	26.47	92.9	27.33	96.9	28.18
89.0	26.49	93.0	27.35	97.0	28.21
89.1	26.51	93.1	27.37	97.1	28.23
89.2	26.53	93.2	27.39	97.2	28.25
89.3	26.55	93.3	27.42	97.3	28.27
89.4	26.57	93.4	27.44	97.4	28.29
89.5	26.59	93.5	27.46	97.5	28.31
89.6	26.61	93.6	27.48	97.6	28.33
89.7	26.64	93.7	27.50	97.7	28.35
89.8	26.66	93.8	27.52	97.8	28.38
89.9	26.68	93.9	27.55	97.9	28.40
90.0	26.71	94.0	27.57	98.0	28.42
90.1	26.73	94.1	27.59	98.1	28.44
90.2	26.75	94.2	27.61	98.2	28.46
90.3	26.77	94.3	27.63	98.3	28.48
90.4	26.79	94.4	27.65	98.4	28.50
90.5	26.81	94.5	27.67	98.5	28.52
90.6	26.84	94.6	27.70	98.6	28.54
90.7	26.86	94.7	27.72	98.7	28.57
90.8	26.88	94.8	27.74	98.8	28.59
90.9	26.90	94.9	27.76	98.9	28.61
91.0	26.92	95.0	27.78	99.0	28.63
91.1	26.94	95.1	27.80	99.1	28.65
91.2	26.96	95.2	27.82	99.2	28.67
91.3	26.99	95.3	27.84	99.3	28.69
91.4	27.01	95.4	27.87	99.4	28.71
91.5	27.03	95.5	27.89	99.5	28.74
91.6	27.05	95.6	27.91	99.6	28.76
91.7	27.07	95.7	27.93	99.7	28.78
91.8	27.09	95.8	27.95	99.8	28.80
91.9	27.12	95.9	27.97	99.9	28.82
				100.0	28.84

Table 23. Summaries of 24-hour continuous pulse record for Day 1 of Subject No. 100

Summary by 10-minute intervals								Summary by 15-minute intervals						Av. per hour
Intervals 10 min.		10	20	30	40	50	60	Intervals 15 min.		15	30	45	60	
AM	8:00	99.9	98.6	98.0	94.2	94.7	96.6	AM	8:00	99.0	98.6	94.7	95.6	97.0
	9:00	95.8	93.0	93.6	90.6	98.2	104.2		9:00	95.2	93.1	91.8	103.9	96.0
	10:00	102.8	103.4	99.8	90.3	80.3	92.3		10:00	103.6	100.4	86.4	88.7	94.8
	11:00	83.8	89.6	95.5	83.0	90.4	84.0		11:00	82.7	96.4	86.6	85.0	87.7
	12:00	85.0	100.2	104.1	109.8	114.9	111.4		12:00	88.9	104.0	110.8	113.5	104.3
PM	1:00	107.9	89.2	84.9	86.3	82.6	81.9	PM	1:00	102.3	85.6	85.0	82.2	88.8
	2:00	83.4	78.0	77.3	82.5	84.5	77.3		2:00	81.9	77.0	83.7	78.1	80.2
	3:00	79.4	78.8	87.5	101.2	101.0	93.9		3:00	78.1	85.6	101.4	95.4	90.1
	4:00	93.6	101.8	88.2	80.3	79.1	83.2		4:00	96.1	93.0	79.4	81.8	87.6
	5:00	81.2	81.3	82.0	79.7	77.6	76.2		5:00	80.8	81.8	79.2	76.6	79.6
	6:00	77.2	89.9	88.0	94.0	95.8	94.0		6:00	79.4	90.9	94.9	94.1	89.8
	7:00	85.3	82.0	81.2	81.2	80.2	78.0		7:00	84.4	81.2	79.4	79.2	81.0
	8:00	80.0	80.7	82.5	81.2	78.1	81.4		8:00	80.3	81.9	79.8	80.7	80.7
	9:00	76.6	77.1	78.6	78.4	71.6	68.6		9:00	76.3	78.4	77.1	68.8	75.2
	10:00	70.7	79.6	71.9	70.5	71.0	70.7		10:00	75.2	73.2	70.2	71.3	72.5
	11:00	73.4	71.2	69.1	69.5	69.2	65.5		11:00	73.2	68.8	69.5	66.6	69.5
	12:00	65.8	68.0	69.2	69.3	69.4	67.0		12:00	66.1	69.0	68.6	68.0	67.9
AM	1:00	68.3	66.3	67.4	67.5	67.5	66.9	AM	1:00	67.6	67.1	68.3	67.1	67.5
	2:00	67.4	65.8	65.4	63.5	64.4	83.5		2:00	66.9	65.1	63.8	81.5	69.3
	3:00	66.1	69.8	66.8	70.7	69.0	66.4		3:00	66.7	68.3	70.1	67.5	68.1
	4:00	64.1	65.7	63.7	65.0	65.0	64.8		4:00	64.5	64.4	64.7	65.0	64.6
	5:00	63.2	61.0	62.7	62.6	63.3	62.6		5:00	63.0	62.1	62.7	63.1	62.7
	6:00	63.1	64.1	65.2	68.5	64.7	64.0		6:00	62.7	64.4	67.6	63.8	64.6
	7:00	64.1	64.1	83.0	102.8	95.6	103.4		7:00	63.9	76.9	98.6	102.5	85.5

Summary for 24-hour interval average, 80.2

Table 24. Summaries of 24-hour continuous pulse record for Day 2 of Subject No. 100

Summary by 10-minute intervals							Summary by 15-minute intervals					Av. per hour
Intervals 10 min.	10	20	30	40	50	60	Intervals 15 min.	15	30	45	60	
PM 9:20	71.9	74.5	86.7	75.8	72.8	77.2	PM 9:20	72.7	82.6	75.5	76.4	76.8
10:20	69.5	66.1	67.5	67.0	68.0	70.3	10:20	68.8	66.6	66.8	70.1	68.1
11:20	73.2	72.0	73.7	74.7	73.6	72.9	11:20	72.6	73.1	74.6	72.9	73.3
AM 12:20	73.6	75.8	75.1	76.1	73.0	69.8	AM 12:20	73.8	75.9	76.2	69.8	73.9
1:20	70.9	73.9	67.6	67.9	71.1	70.2	1:20	71.0	71.1	68.9	70.5	70.4
2:20	70.9	70.5	73.7	68.6	68.3	67.8	2:20	70.8	72.6	68.6	68.0	70.0
3:20	67.6	66.8	66.9	68.2	70.2	71.6	3:20	67.6	67.1	68.7	71.2	68.6
4:20	77.5	68.2	70.5	70.9	68.6	68.1	4:20	74.6	69.1	70.2	67.9	70.4
5:20	69.5	70.6	69.1	69.5	69.8	67.9	5:20	69.7	69.7	69.8	68.5	69.4
6:20	69.1	79.7	95.9	95.2	99.0	106.2	6:20	68.3	89.7	93.3	106.7	89.5
7:20	109.5	107.4	111.4	104.2	106.0	103.8	7:20	109.3	109.6	105.3	104.0	107.0
8:20	101.4	99.4	97.9	100.3	96.7	84.7	8:20	100.6	98.6	98.3	88.4	96.5
9:20	82.4	80.5	82.1	81.1	80.0	92.0	9:20	82.4	81.0	80.2	88.5	83.0
10:20	89.4	79.9	83.0	66.3	66.2	91.2	10:20	87.2	81.0	65.6	83.5	79.3
11:20	97.7	93.5	92.2	87.0	91.8	94.6	11:20	96.6	92.2	88.7	93.6	92.8
PM 12:20	90.8	105.3	109.1	103.9	99.8	90.6	PM 12:20	95.2	108.4	104.5	91.8	100.0
1:20	88.4	77.6	79.1	71.8	73.0	76.4	1:20	84.4	77.7	74.3	74.9	77.8
2:20	78.2	85.5	100.9	93.2	91.2	75.6	2:20	79.8	96.7	91.0	83.3	87.7
3:20	80.7	77.9	72.6	69.7	89.0	87.9	3:20	80.1	74.0	74.0	90.4	79.6
4:20	81.6	70.6	72.2	73.4	91.7	89.8	4:20	77.7	71.9	79.1	90.8	79.9
5:20	88.2	76.5	73.0	74.4	68.9	70.8	5:20	84.6	73.8	74.1	71.1	75.9
6:20	74.0	89.1	82.6	77.2	76.2	74.8	6:20	75.3	88.6	77.1	74.9	79.0
7:20	70.1	66.6	69.5	67.1	65.6	64.8	7:20	68.6	68.9	66.4	65.3	67.3
8:20	63.9	63.4	63.0	67.7	66.4	68.5	8:20	63.9	62.9	67.4	67.9	65.5

Summary for 24-hour interval average, 79.2

Table 25. Diary of activities for Day 1, Subject No. 100

Time	Activity	Minutes
AM 7:55	Stand and walk in house	5
8:00	Washing dishes	45
8:45	Clean refrigerator and work in kitchen	75
10:00	Standing cooking	35
10:35	Sit, read, and talk	10
10:45	Eat popcorn, sitting	15
11:00	Sitting visiting	15
11:15	Standing cooking	15
11:30	Sit and read	13
11:43	Stand and cook	3
11:46	Sit and read	22
PM 12:08	Walking	2
12:10	Eating dinner	20
12:30	Walking and standing	5
12:35	Washing dishes	30
1:05	Standing and walking	5
1:10	Lying down reading	95
2:45	Sitting visiting	45
3:30	Walking in house, standing around, 4 times up and down stairs	45
4:15	Vacuuming rug with Hoover	5
4:20	Sitting resting	35
4:55	Sitting talking	80
6:15	Walking around house	15
6:30	Eating	15
6:45	Sit and talk	5
6:50	Stand and walk in house	5
6:55	Sitting reading and watching TV	195
10:10	Undressing, ready for bed	5
10:15	In bed, lying awake	60
11:15	Asleep	224
AM 2.59	Go to bathroom	3
3:02	In bed	241
7:03	Awake, lying in bed	25
7:28	Got up and dressed	5
7:33	Ate breakfast	16
7:49	Stand and walk in house	6
7:55	End of 24-hour period	

Table 26. Diary of activities for Day 2, Subject No. 100

Time		Activity	Minutes
PM	9:20	Sit and read	25
	9:45	Walk in house and prepare for bed	5
	9:50	Sit and watch TV	22
	10:12	Go to bed	3
	10:15	In bed	505
AM	6:40	Got up and went to bathroom	5
	6:45	Started eating breakfast, sitting eating	15
	7:00	Finished breakfast, sitting	2
	7:02	Stand up to dress and wash up	8
	7:05	Walked to bedroom	
	7:10	Moving machine to kitchen, washed dishes	45
	7:55	Clean refrigerator and move about kitchen	45
	8:40	Clean and peel vegetables	20
	9:00	Clean in kitchen	10
	9:10	Typing, and sitting at intervals	65
	10:15	Making coffee, preparing meal, and moving around slowly in kitchen	10
	10:25	Sit and talk and drink coffee	17
	10:42	Moving about and standing	8
	10:50	Sit and read	20
	11:10	Clean - dust and Hoover vacuum	30
	11:40	Prepare lunch, standing working	15
	11:45	Sitting talking	5
	12:00	Cooking, standing	5
PM	12:05	Eating dinner	25
	12:30	Washing dishes	30
	1:00	Stand and walk in house	6
	1:06	Sit and visit	17
	1:23	Go to bath room	2
	1:25	Rest lying down	65
	2:30	Dressing etc.	7
	2.37	Made bed	6
	2:43	Stand and visit	17
	3:00	Sit and visit	5
	3:05	Up and down 3 steps stairs	2
	3:07	Sit and read	53
	4:00	Vacuum dining room	6
	4:06	Standing about	19
	4:25	Sit and read	30
	4:55	Prepare meal	20
	5:15	Eat supper	10
	5:25	Read and watch TV	68
	6:33	Go to bathroom	2
	6:35	Read, watch TV, sit and visit	165
	9:20	End of 24-hour period	