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Age, physical activity and energy expenditure

By J. V. G. A. Durnin, *Institute of Physiology, University of Glasgow*

Let me begin by confessing that I am quite unable to correlate satisfactorily the three topics contained in the title of my talk. I hope I can give some factual description of levels of physical activity and energy expenditure in population groups covering a wide age-span. But neither I nor, I believe, anyone else can relate, in man, alterations in physical exercise to ageing, in a quantitative sense. We all have subjective impressions, based on a certain amount of evidence, that physical activity is less enjoyed and that it takes up less time with advancing age. However, the general truth of the statement does not tell us much about the several facets of this interesting question: How rapid is the decline? Does it apply only to leisure or to occupational exercise too? Is there ever very much physical activity in a population after the years of childhood? Is the decline in exercise with age physiological, or does it only reflect social conditions? These and many other questions are open only to speculation at present, because of the lack of good experimental information.

In this paper I propose to deal almost entirely with results from my own laboratory. This is partly because there is very little published material which gives a sufficiently detailed description of the physical activity of individuals throughout a period of some days. It also depends on the fact that I am interested in relationships between the time spent in physical exercise and various properties of body build or body composition, and with total quantities of daily energy expenditure. The source of information has thus been restricted but there are still data on some hundreds of individual people of a variety of age, sex, body build, social group and occupation.

Method of measurement

These data have been laboriously collected. The studies were always, with very few exceptions, done during 7 consecutive days on each individual. Energy output was obtained by a combination of a diary technique for recording physical activity and measurements, by indirect calorimetry, of the energy expended in the many varied activities of the day. The diary technique meant that the individual noted down on a special card the time at which he began all the different activities which occupied his entire day. A series of simple symbols was used and the method is one which can be accurately employed by people of even quite low intellect. At work, sometimes fairly lengthy periods were spent watching the subjects unobtrusively which allowed us an opportunity to cross-check their own time-recordings of what they were doing at work and also of forming a clearer idea of the physical stress involved in the work situation.

Populations studied

We feel therefore that we have accurate measurements of all the activity of our subjects, together with some varied anthropometric and social information. We have investigated (1) adolescents, 13–15 years of age, of both sexes and all social groups; (2) young adult, middle-aged and elderly men, (a) in sedentary occupations, (b) working in modern factories where nothing more than moderate physical effort was needed, and (c) doing hard physical work as coal miners, steel workers, forestry workers or farmers; (3) young, middle-aged and elderly women, most of whom were housewives though some worked in shops and in factories. There were about 600 subjects in these groups.

The divisions of the subjects were somewhat complex and are shown in Fig. 1*a* for the men and Fig. 1*b* for the women. Basically they are concerned with separating, first of all, sex and then subdividing for four types of body build (thin, 'normal', plump and obese), four varieties of social group, age (adolescents, adults from

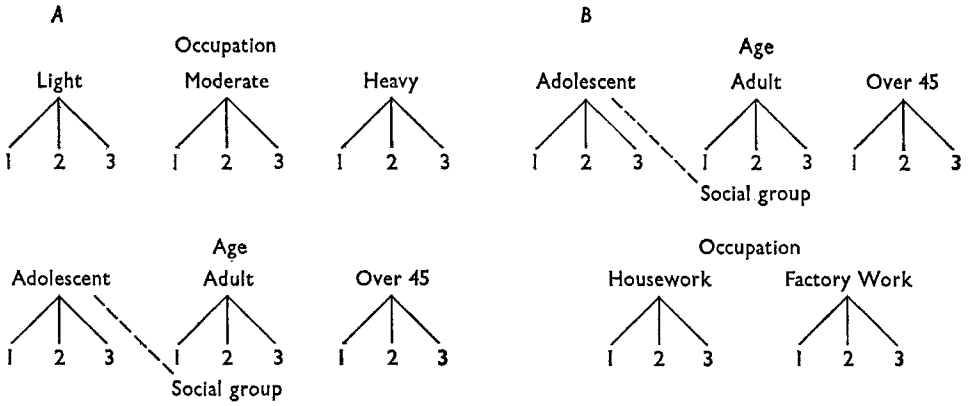

Fig. 1. Subdivisions of subjects, (*A*) men and (*B*) women, according to occuptional activity, age and body build (1, thin; 2, normal; 3, plump and obese).

https://doi.org/10.1079/PNS19660024 Published online by Cambridge University Press

17 to 45 years and 'over 45'), and occupation (sedentary, moderatively active and heavy).

Classification of 'activity'

For all these subjects, the amount of time spent in each day on physical activity of a moderate, heavy and very heavy nature has been extracted. Light activity has been deliberately excluded. I feel reasonably certain that exercise, if it has any physical benefits at all, only produces these when it causes moderate or severe stress on the body. Certain arbitrary decisions have therefore been made to place all activity (other than 'light') in the three categories of moderate, heavy, and very heavy. This subdivision is illustrated in Table 1, and depended on the measured level of energy expended on the activity. Allowance was made for the varying body-weights of the subjects.

Table 1. *Categories of 'activity' : energy expended (kcal/min)*

Activity	Men (65 kg)	Women (55 kg)
Moderate	5–7·4	3·5–5·4
Heavy	7·5–9·9	5·5–7·4
Very heavy	10+	7·5+

Results

Physical activity. The results are given in Tables 2–8, which show the mean time spent in physical activity, in min/day, as an average over the 7-day experimental period, for the various population groups.

Table 2. *Mean times, with standard deviations, (min/day) spent in moderate, heavy or very heavy 'physical activity' by men over 45 years*

	Total			At work		
Body build	Moderate	Heavy	Very heavy	Moderate	Heavy	Very heavy
1 (thin)	143±111	4±14	5±27	121±120	4±14	5±27
2 ('normal')	101±119	10±30	1± 5	75±109	8±23	0·3± 2
3 (plump)	87± 93	1± 5	0·4± 2	67± 83	1± 5	0·4± 2
All builds	110±113	7±21	2±13	84±107	5±17	1±13

Table 2 shows this subdivision for 160 men over the age of 45 years and arranged for body build. The totals were undoubtedly biased and were greater than would be expected for a random population; the groups included comparatively few men in sedentary occupations. However, it is interesting to see the decreasing time spent in moderate activity as the body build changed from thin through 'normal' to plump. The great majority of the time of physical activity was necessitated by work and, in all groups, only about 25 min activity/day occurred in leisure. Heavy and very heavy activity occupied only a few minutes of time on the average. The standard deviation of most of these values is high, showing the very considerable individual variability. For example, the maximum mean amount of time spent in moderate activity was 519 min by a Swiss peasant farmer, who on one particular day passed $11\frac{1}{2}$ h at this level of activity. A forestry worker spent 229 min in heavy activity as

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an average and the maximum on any one day was about $6\frac{1}{2}$ h. No men over 45 expended energy at levels equivalent to very heavy exercise, except on isolated occasions perhaps on one day in the week. One or two farmers, for example, spent about $1\frac{1}{2}$ h on one occasion in such strenuous activity.

Table 3 gives results similar to those in Table 2 but for men aged 17 to 45 years. No exact comparison can justifiably be made between these younger adult men and the men over 45 years, since the types of occupation were not similar for the two age ranges; a larger proportion of the younger men worked in sedentary or light jobs. The table gives values for only two types of body build—there were too few plump or very obese men for satisfactory analysis of the results.

Table 3. *Mean times, with standard deviations, (min/day) spent in moderate, heavy or very heavy 'physical activity' by men 17–45 years*

	Total			At work		
Body build	Moderate	Heavy	Very heavy	Moderate	Heavy	Very heavy
1 (thin)	79±83	12±14	2±5	33±35	9±22	0·1±0·3
2 ('normal')	97±87	21±25	3±8	58±59	17±26	0·3±1
All builds	91±86	17±20	2±7	49±48	14±24	0·3±1

No trends are clear between the two builds, but again there are large differences between individuals, and little time indeed was occupied by heavy or very heavy exercise. Work was not quite so determining a factor for activity in these younger men, and leisure accounted for about 40 min of moderate exercise.

The results for all the adult men were combined and the values subdivided for occupation (Table 4). In spite of the fact that the classification adopted for heavy physical activity was the one commonly accepted by physiologists, very little time at this severity of exercise was necessitated for the men working in a heavy occupation, i.e. farmers during the harvest, coal-face miners, forestry workers and steel workers. Indeed, the difference between heavy and moderate occupations was reflected in the varying times spent in moderate activity. There were also small, and perhaps expected, differences between the amount of leisure time in moderate activity between the occupations; men working in light and moderate occupations spent about 40 min of their leisure in an active fashion whereas for those in heavy jobs about 25 min was enough.

Table 4. *Mean times, with standard deviations, (min/day) spent in moderate, heavy or very heavy 'physical activity' by men in occupations involving light, moderate or heavy activity*

	Total			At work		
Occupational group	Moderate	Heavy	Very heavy	Moderate	Heavy	Very heavy
Light	45± 51	2± 7	2± 7	8± 12	0·04	0·05
Moderate	67± 78	0	0	23± 42	0	0
Heavy	173±114	21±42	3±18	147±110	20±41	3±18
All groups	103±114	11±32	6±24	79±107	11±31	3±14

https://doi.org/10.1079/PNS19660024 Published online by Cambridge University Press

Table 5. *Mean times, with standard deviations, (min/day) spent in moderate, heavy or very heavy 'physical activity' by boys 13–15 years*

	Total			At school		
Body build	Moderate	Heavy	Very heavy	Moderate	Heavy	Very heavy
1 (thin)	68±57	25±25	9±12	13±13	6±6	1±2
2 ('normal')	74±57	33±41	13±26	14±15	5±8	2±4
All builds	71±56	29±36	12±22	13±14	5±7	2±3
Highest social grouping	57±41	23±34	14±20	11± 9	3±6	2±3
Lowest social grouping	84±65	35±36	10±24	16±18	6±7	2±3

Table 6. *Mean times, with standard deviations, (min/day) spent in moderate, heavy or very heavy 'physical activity' by girls 13–15 years*

	Total			At school		
Body build	Moderate	Heavy	Very heavy	Moderate	Heavy	Very heavy
1 (thin)	91±67	12±17	5±9	16± 9	2±3	1±2
2 ('normal')	93±56	9±13	2±4	21±15	2±4	0·5±1
3 (plump)	63±48	10±13	3±7	16±13	2±3	0·1±0·2
All builds	87±58	10±14	3±6	19±14	2±3	0·5±2
Highest social grouping	78±37	9±13	5±7	17± 9	2±3	0·8±2
Lowest social grouping	101±76	10±15	0·03±0·2	22±18	2±3	0·03±0·2

Tables 5 and 6 deal with the results of the adolescent boys and girls and in some respects are similar. However, although there were over 100 boys (and about the same number of girls), there were too few classed as 'plump' for analysis, so there is immediately a difference between the sexes. In both sexes there was no difference in activity between thin and 'normal' builds. On the other hand, the plump girls spent less time in activity than the rest of the group. Social class seems to exert an effect also, both boys and girls in the upper social groups taking less active exercise than those of the poorer groups. The girls were apparently slightly more active than the boys though the differences were small.

Table 7. *Mean times, with standard deviations, (min/day) spent in moderate, heavy or very heavy 'physical activity' by women over 45 years and by women between 17 and 45 years*

	Total			At work		
Body build	Moderate	Heavy	Very heavy	Moderate	Heavy	Very heavy
			Over 45 years			
1 (thin)	99±112	0·1± 0·2	—	77±108	0·1±0·2	—
2 ('normal')	57± 92	3±13	0·02	44± 66	1±3	0·02
3 (plump)	36± 80	0·3± 1	0·03	30± 76	0·3±1	0·03
All builds	59± 97	1± 7	0·04	46± 86	0·3±2	0·04
			17–45 years			
All builds	59± 71	2± 5	0·6±3	30± 50	0·04	0·04

The inhibiting effect of increasing fatness on physical activity is shown again for women over 45 years (Table 7). There were only about thirty young women in the

https://doi.org/10.1079/PNS19660024 Published online by Cambridge University Press

study so that they have not been subdivided for build, and only the combined results are shown in Table 7. However, when values for them are added to those for the women over 45, the pattern remains the same (Table 8), and the total time spent in activity by 'all builds' in these two age ranges was identical.

Table 8. *Mean times, with standard deviations, (min/day) spent in moderate, heavy or very heavy 'physical activity' by all the adult women studied*

	Total			At work		
Body build	Moderate	Heavy	Very heavy	Moderate	Heavy	Very heavy
1 (thin)	80±103	0·1± 0·3	0·04	62±97	0·04	0·04
2 ('normal')	67± 87	2±11	0·4±2	42±63	0·3±2	0·05
3 (plump)	33± 77	0·7± 3	0·02	28±74	0·2±1	0·02

There may be a variation between men and women in that the women over 45 seemed to be even less active voluntarily in their leisure time than the men, but perhaps this is because they may have had less time for leisure!

I am unable to stress with sufficient emphasis that these results have been discussed mainly as averages of groups and not pertaining to individuals. There are always exceptions to the average, one or two of which I have instanced for men over 45 years. Equally exceptional values for activity can be given for the women over 45. For example, one who worked as a cleaner in a biscuit factory averaged $7\frac{1}{2}$ h/day in moderate activity and 70 min in heavy activity, her greatest expenditure on one day being 9 h in moderate and over 2 h in heavy exercise. There was even one very obese woman (body build 4—of whom there were too few to allow analyses to be made) who spent 5 h/day and almost 9 h during one particular day in moderate physical activity.

Among the older men and women, no woman studied in this country over the age of 60 spent more than a few minutes in moderate activity, with only two exceptions—one averaging $2\frac{1}{2}$ h/day. On the other hand, a Swiss peasant woman of 77 years was active for 3 h/day. Several of the elderly men were very active; for example, an elderly retired man walked fast enough to be moderately active for about 2 h/day, a forestry worker of 70 averaged almost $6\frac{1}{2}$ h at this level as also did a Swiss peasant farmer aged 77, and a Scots farmer of 80 spent a mean time of $2\frac{1}{2}$ h/day in moderate activity. Heavy activity in the old men was limited to the above-mentioned Swiss farmer, who averaged 50 min/day.

Energy expenditure. I intend to deal only briefly with this part of my subject matter. It is necessary, first of all, to say that there is not usually a very high correlation between time spent in physical activity and total daily energy expenditure when these are analysed in a population group. In an individual a very large amount of time spent in physical exercise will undoubtedly markedly affect energy output. But, with the amounts of time spent in exercise shown in the tables, the correlation coefficient for activity and energy is quite low for most groups. We have also, incidentally, found very low correlations for height and gross body-weight with energy expenditure, though height is frequently much more related to energy output than is weight.

I have to repeat again, and apologize for, my inability to give much indication of the effect of ageing on total daily energy expenditure. We have, however, seldom found much obvious difference between the mean values for comparable populations; the mean energy output of sedentary men aged about 60 we have measured as about 2600 kcal/day, which is similar to values found for young men. Our elderly forestry workers expended over 3500 kcal/day, and the farmers over 3500 kcal/day. Several individuals reached levels of up to 4500 kcal/day although none of our Scottish subjects approached the 5000 kcal/day of one of the elderly Swiss peasants we studied.

From our measurements on women, a small effect of age on energy output seems obvious. The mean values are usually low for all age groupings, means of 2200 kcal/day for young women comparing with 2100 kcal/day in middle-aged women and about 2000 kcal/day in the elderly. The upper limit of the range is very much lower for elderly women than for men, 3000 kcal/day being the maximum we have seen in Scotland; I hesitate to say that we obtained a value of 3900 kcal/day for a Swiss peasant woman.

I have only scratched the surface of this problem of age and physical activity. It is an interesting problem and likely to have much medical and sociological significance. It would be pleasant to think that the accumulation of new experimental information might induce the Society to repeat this Symposium in a few years time.

Some of the earlier studies reported in this paper were supported by a grant from the Medical Research Council. Most of the work, however, was supported by US Public Health Service Grant AM 05104–05.

Food intakes and weight changes in climatic extremes

By O. G. Edholm and R. Goldsmith, *Division of Human Physiology, National Institute for Medical Research, London, NW 3*

For a number of years field studies of food intake, weight changes and energy expenditure have been made by members of the Division of Human Physiology in regions of climatic extremes. Long-term studies have been made in Antarctica on members of the British Antarctic Survey (BAS) while shorter-term studies have been made on soldiers in the hot, humid climate of Aden.

Cold-climate studies

Climate, exposure and activity. The climates of the stations of the BAS where observations have been made are very severe: yearly mean temperatures range from −20° at Halley Bay (75°26′S) to −4·6° at the Argentine Islands (65°13′S). The cooling effects of the low temperatures are multiplied by the fairly constant wind. On the other hand, the climatic stress is mitigated by the high thermal radiation from the sun, both direct and reflected (Chrenko & Pugh, 1961–2). Furthermore, it has been shown (Norman, 1965) that much of the time is spent in the shelter of the hut