ENERGY COST AND MECHANICAL EFFICIENCY OF CLIMBING STAIRS WITH LOADS

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ALL of us climb stairs and carry loads some time or other. And carrying loads manually happens to be a common job by which innumerable 'coolies' earn their livelihood in India. At construction sites, warehouses, goods transport centres, factories, markets, residences, and other such places, a large number of workers are routinely employed for such work. In India, the worker generally carries the load on the head. Very often load carriage involves going up a staircase, be it a properly designed one as in a public building or an improvised one as found in building sites. Ergonomical studies on this type of muscular work have been undertaken by this laboratory for defining the optimum conditions of work. The present preliminary report on the experimental observations of the energy cost and efficiency of human volunteers using stairs to lift a load, forms a part of a comprehensive investigation in progress.

Experimental Results and Discussion

Seven healthy volunteers of average age 32 years and weight 53·04 kg. in light summer clothing, normally engaged in sedentary work, ascended stairs from the ground to the fourth floor of a building at the rate of one step per second, halting briefly for 8 to 10 seconds on each floor. The total period of work was 145 seconds (± 3 secs.) on the average, and during this period the gas expired by the subject was collected in a Douglas Bag for determining the energy expenditure according to standard procedures (Consolazio *et al.*, 1963). These volunteers performed three experiments each; first without any external load, when the weight carried is the subject's body weight, and then with loads of 15 and 30 kg. of stone chips in a basket on the head. The staircase had 96 steps arranged in a spiral fashion along three sides of a stairwell with a total vertical height of 18·54 metres. The mean air temperature and relative humidity during these experiments were 28·8° C. and 74·4% respectively. Everyday the experiment was preformed 2 hr. after morning meal in order to minimise the specific dynamic action of food.

Table I presents the values of the energy expenditure in Kilocalories per minute for the seven subjects for three loadings. The mean energy cost for stairclimbing was 3·91, 5·22 and 6·13 Kcal./min. for external loads of 0, 15 and 30 kg. respectively, with a standard deviation of ± 0·6. The energy cost for climbing with no external load obtained here is consistent with similar values for Indians (Banerjee, 1962; Ramanathan *et al.*, 1967), but comparable data for load carrying are not available. However, the energy costs of 4·8, 6·4 and 7·5 Kcal./min./65 kg. man for the three loadings are meaningful in comparison with data for grade walking outdoors and on treadmills (Durnin and Passmore, 1967).

The ratio of the energy cost to the gross weight carried (body weight *plus* external load) was found to be fairly constant within a range of 0·068 to 0·080. By a statistical test it was found that the ratio E/W was not different among subjects or with the load, and has a mean value of 0·074 Kcal./min./kg. gross weight. Therefore, the energy expenditure for

Table I

Energy cost of seven human volunteers climbing stairs with and without a load on the head

(E = Energy expenditure in Kcal /min., W = Gross weight in kg.. M.E. = Mechanical efficiency in %)

Subject	Load kg.	0			15			30		
	Weight kg.	E	E/W	M.E.	E	E/W	M.E.	E	E/W	M.E.
RKH ..	48·5	3·79	0·078	22·6	4·71	0·074	23·4	6·05	0·077	23·4
HM ..	51·8	4·03	0·078	22·5	5·14	0·074	21·7	6·56	0·085	28·6
KR ..	41·0	2·85	0·069	26·7	4·47	0·080	20·0	4·99	0·070	25·2
BM ..	65·6	4·82	0·073	25·4	6·15	0·076	25·3	6·92	0·072	24·2
LNM ..	59·6	4·07	0·068	23·9	5·72	0·076	24·1	6·06	0·068	26·7
AC ..	49·8	3·56	0·071	26·3	5·13	0·079	22·7	6·13	0·077	23·4
SRD ..	55·0	4·27	0·078	22·4	5·20	0·074	24·3	6·20	0·073	23·9
Mean ..	53·04	3·91	0·074	24·3	5·22	0·076	23·1	6·13	0·073	25·1

similar work by a similar subject could be predicted to the first degree of approximation from

$$E\left(\frac{\text{Kcal}}{\text{min.}}\right) = 0{\cdot}074\ W\ kg.$$

Mahadeva *et al.* (1953) obtained a relation between gross weight and energy cost for walking on a horizontal plane ($E = 0{\cdot}047\ W + 1{\cdot}02$) and for step test ($E = 0{\cdot}066\ W$), with which the present equation bears comparison. The constant of multiplication in the present case is higher since stairclimbing is far more strenuous than walking.

The gross mechanical efficiency of physical work defined as,

$$100 \times \frac{\text{External work in kilogram meters} \times \text{Factor for conversion to Kcal.}}{\text{Internal energy expenditure in Kilocalories}}$$

$$= \frac{\text{Weight carried (kg)} \times \text{Vertical height (m.)} \times 0{\cdot}234}{\text{E (Kcal./min.)} \times \text{Time of work (min.)}}$$

was computed in each case. The mechanical efficiency was found to have a mean value of 24·17% (range 20·0 to 28·6%). This gross mechanical efficiency of ascending stairs with loads upto 30 kg. may be taken as fairly constant. The efficiency values in the present study are quite compatible with such values reported for Occidentals for different muscular exercises (20–28%) (Bobbert, 1960) and for Indians climbing hills with a load 22·94% (Das and Saha, 1966).

Experimental studies on the same lines for establishing the relation between gross weight and energy cost and the constancy of mechanical efficiency under different conditions of work stress, rate and mode of carrying are in progress.

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HARMONIA ARCUATA FABRICIUS (COCCINELLIDAE)—PREDATORY ON THE RICE PLANT HOPPERS *SOGATELLA FURCIFERA* HORVATH AND *NILAPARVATA LUGENS* STÅL

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TWO species of delphacid plant hoppers, *viz.*, *Sogatella furcifera* Horvath, the white back plant hopper and *Nilaparvata lugens* Stål, the brown plant hopper have assumed major pest status in paddy with the intensive cultivation of high yielding rice varieties under high fertility levels. In addition to direct damage by sucking the sap and injecting toxins into the rice plant, their role as vectors of rice virus diseases has also been recognised recently in many parts of the world.

In the course of routine field observations on the parasites and predators of rice pests at the Central Rice Research Institute, Cuttack, during 1966 and 1967, the authors observed a coccinellid beetle as a predator on the two rice delphacids, *viz.*, *S. furcifera* and *N. lugens*. This has been identified as *Harmonia arcuata*