STUDIES ON ENERGY EXPENDITURE OF RICKSHAW PULLERS

By

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INTRODUCTION

Numerous studies have been made on the energy expenditure by persons engaged in different types of physical labour. Walking, running, carrying loads, etc. were the main features of such occupations. Closely similar results of the energy cost of "walking" at varying speeds were reported by Brezina and Kolmer (1912), Douglas and Haldane (1912), Benedict and Murschhauser (1915), Atzler and Herbst (1927), and Margeria (1938). It was reported that the energy cost of walking erect was least when compared with the stooping postures by Moss (1935) and by Bedford and Warner (1955). The expenditure of energy by men and women while walking was determined by Booyens and Keatings (1957). Ogasawara (1934) and Margeria (1933) reported that the energy expenditure of walking and running vary with speed and depend on the efficiency and training of the subjects. One of the classical studies on load carrying was of Bedale (1924), who herself was the subject of her experiment and carried weights in 8 different ways and found that the energy expenditure was minimal with the use of yoke across the shoulders and maximum when carried on the hip under the arm. The energy expenditure of carrying loads were also reported by Glassow and Muller (1951), Dressel *et. al.* (1954) and by Das (1951). It was reported by Dressel (1954) and by Lehman (1953) that there exist relatively little difference in using several types of wheel barrows on a smoothed road or on planks.

The present investigation deals with the studies on the energy cost of different types of activities of the rickshaw pullers of this city, and their daily calorie expenditure.

MATERIALS AND METHODS

The subjects of the experiment were eleven rickshaw pullers of this city, of ages varying between 25 and 35 years. They were medically examined and found healthy.

The "rickshaw" - is a common two wheeled vehicle with a sitting accommodation of two persons and drawn by man.

The diary technique of Garry *et. al.* (1955) for recording the time spent in various activities during the 24 hours period, was not possible because the rickshaw pullers could not read or write. The average time spent in various

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activities during the 24 hours period was recorded by interviewing the subjects. So the exact time-work record was not possible but a very approximate idea of their usual routine work was obtained.

The basal metabolic rate and the energy cost of different activities which occupied the main features of their occupations e.g. lying rest, sitting rest, standing rest, sitting work, standing work, walking, plying rickshaw without and with one, two and three passengers repectively were determined.

Measurements of the energy cost of various activities were made by the "Max-Plank - Institute Fur Arbeitzphysiologie" respirometer (Kofranyi and Michælis, 1940; Muller and Franz, 1952). The respirometer was calibrated according to the method of Durnin (1955). Douglas bag was used only during the determination of basal metabolic rate. The gas samples, from the rubber bladder of the Max Plank respirometer, and from the Douglas bag were collected over mercury in Bailey's bottles. Analysis of the gas samples were done in duplicate using Haldane-Henderson-Bailey's gas analysis apparatus. Energy cost of each activity was calculated from the oxygen consumption at N.T.P. after introducing the necessary corrections for the diffusion of gases from the rubber bladder and from the percentage of aliqouts of gases collected in the rubber bladder taking the calorie equivalent of one litre of oxygen at the particular R.Q. from the table of Lusk (1924).

Surface area was calculated according to the formulae of Du Bois and Du Bois (1916) and of Banerjee and Sen (1955).

RESULTS

The age, height, weight and surface area of the subjects are given in Table I. The age varied between 25 and 54 years, height between 149·3 and 171·3 cms., weight between 38·56 and 57·61 kg., and surface area when measured by the formula of Banerjee and Sen (1955) varied between 1·329 and 1·741 m^2 and between 1·278 and 1·675 m^2 when measured by Du Bois and Du Bois (1916) height weight formula.

The energy cost of lying rest, sitting rest, standing rest, sitting working, standing working, walking and the B.M.R. expressed as Cals/min, Cal/kg/hr. and Cals/m^2/hr. (according to Du Bois and Du Bois (1916) and Banerjee and Sen (1955) are given in Tables 2, 3, 4 and 5.

The energy cost of walking and plying of rickshaw without and with 1, 2, and 3 passengers expressed as Cals/kilometer/hr., Cals/kilometer/hr/m^2 body surface according to Du Bois and Du Bois (1915), Banerjee and Sen (1955) and Cals/kilometer/kg body weight are shown in Tables 6, 7, 8, and 9.

The average time spent on each activity and the respective energy expenditure during the 24 hrs. period are given in Table 10.

TABLE 1

Age, Height, Weight, and Surface area of Ricksha-pullers.

Subjects.	Age (yrs.)	Height (cms)	Weight (kg)	Surface area (m^2)	
				Banerjee & Sen (1955)	DuBois & DuBois (1916)
B. N. G.	27	161.0	48.76	1.550	1.491
M. C. R.	30	163.2	44.23	1.503	1.445
S. C. A.	26	158.2	41.28	1.427	1.373
M. R.	25	163.0	45.36	1.517	1.460
S. S.	28	161,5	48.42	1.550	1.490
T. M.	25	149.3	38.56	1.329	1.278
J. S.	35	166.4	53.75	1.655	1.592
D. N. S.	32	157.6	44.45	1.468	1.412
A. S.	27	158.5	39.69	1.405	1.352
R. S. S.	29	169.6	55.34	1.699	1.635
H. K. S.	27	171.3	57.61	1.741	1.675
Average	93.27	161.8	47.04	1.531	1.473

TABLE 2

Energy cost of different activities (Cals/min).

Subjects.	B. M. R.	Lying rest	Sitting rest	Standing rest	Sitting work	Standing work	Walking.
B. N. G.	0.822	0.841	0.901	1.124	2.410	2.207	2.666
M. C. R.	0.881	0.894	0.922	0.923	2.379	3 336	2.484
S. C. A.	0.906	0.961	1.012	1.122	2.176	2.323	2.319
M. R.	0.735	0.793	0.815	1.028	1.973	2.198	2.486
S. S.	0.832	0.855	0.993	1.183	2.670	2.198	2.920
T. M.	0.757	0.809	0.872	1.034	1.560	1.916	2.092
J. S.	0.962	1.086	1.141	1.193	2.271	2.635	2 262
D. N. S.	0.701	0.813	0.881	1.194	2.323	2.484	2.947
A. S.	0.807	0.821	0.872	0.891	1.668	2.024	2.715
R. S. S.	0.898	0.959	1.030	1.265	1.734	2.007	3.029
H. K. S.	0.974	1.007	1.277	1.396	1.703	2.326	3.012
Mean	0 843	0.894	0.974	1.123	2.079	2.335	2.630
S. D.	0.087	0.095	0.131	0.131	0.351	0.382	0.312
± S. E.	±0.026	±0.029	±0.039	±0.039	±0.106	±0.115	±0.094

TABLE 3
Energy cost of different activities (Cals/kg/hr).

Subjects.	B. M. R.	Lying rest	Sitting rest	Standing rest	Sitting work	Standing work	Walking.
B. N. G.	1.012	1.035	1.109	1.384	2.967	2.717	3.282
M. C. R.	1.195	1.213	1.251	1.252	3.227	4.567	3.371
S. C. A.	1.317	1.397	1.471	1.631	3.163	3.378	3.370
M. R.	0.972	1.049	1.077	1.360	2.610	2.907	3.290
S. S.	1.031	1.060	1.230	1.466	3.309	2.724	3.618
T. M.	1.178	1.259	1.357	1.609	2.428	2·982	3.254
J. S.	1.074	1.213	1.274	1.331	2.536	2.942	2.524
D. N. S.	0.946	1.097	1.190	1.612	3.136	3.352	3.977
A. S.	1.220	1.241	1.318	1.347	2.523	2.059	4.104
R. S. S.	0.974	1.040	1.117	1.372	1.879	2.176	3.284
H. K. S.	1.014	1.048	1.329	1.454	1.774	2.423	3.137
Mean	1.085	1.150	1.248	1.437	2.687	3.020	3.383
S. D.	0.115	0.117	0.114	0.134	0.501	0.593	0.400
± S. E.	±0.035	±0.035	±0.035	±0.04	±0.151	±0.179	±0.121

TABLE 4.

Energy cost of different activities (Cals/m² body surface/hr)

Surface area calculated according to Banerjee and Sen (1955)

Subjects.	B. M. R.	Lying rest	Sitting rest	Standing rest	Sitting work	Standing work	Walking
B. N. G.	31.82	32.56	34.88	43.52	93.33	85.49	103.20
M. C. R.	35.17	35.69	36.81	36.84	94.95	134.40	99.19
S. C. A.	38.09	40.40	42.54	47.17	91.47	97.68	97.45
M. R.	29.07	31.36	32.23	40.66	78.05	86.94	98.35
S. S.	32.22	33.10	38.44	45.80	103.40	85.09	113.10
T. M.	34.18	36.54	39.38	46.69	70.44	86.54	94.43
J. S.	34.88	39.38	41.37	43.25	82.35	95.54	81.98
D. N. S.	28.65	33.23	36.00	48.79	94 97	101.50	120.40
A. S.	34.46	35.06	37.25	38.06	71.27	86.42	116.90
R. S. S.	31.71	33.87	36.38	44.67	61.20	70.86	106.00
H. K. S.	33.57	34.69	44.00	48.10	58.70	80.19	103.80
Mean	33.075	35.08	38.110	43.96	81.83	91.88	103.80
S. D.	2.684	2.670	3.396	3.794	14.307	15.638	10.356
S. E.	±0.809	±0.805	±1.024	±1.144	±4.311	±4.715	±3.123

TABLE 5.

Energy cost of different activities (Cals/m^2 body surface/hr)
Surface area calculated according to Du Bois and Du Bois (1916).

Subjects.	B. M. R.	Lying rest	Sitting rest	Standing rest	Sitting work	Standing work	Walking
B. N. G.	33.08	33.84	36.25	45.24	97.01	88.86	107.30
M. C. R.	36.58	37,12	38.28	38.32	98.77	139.80	103.10
S. C. A.	39.59	42,00	44.22	49.03	95.08	101.50	101.30
M. R.	30.20	32.58	33.49	42.25	81.10	90.33	102.20
S. S.	33.51	34.43	99.98	47.63	107.50	88.51	117.60
T. M.	35.55	37.99	40.95	48.55	73.24	89.99	98.19
J. S.	36.26	40.93	43.00	44.95	85.61	99.31	85.21
D. N. S.	29.79	34.54	37.44	50.74	98.74	105.50	125.20
A. S.	35.81	36.43	38.70	39.54	74.04	89.78	120.50
R. S. S.	32.95	35.19	37.79	46.40	63.59	73.62	111.10
H. K. S.	34.89	36.07	45.75	50.00	61.02	83.35	107.90
Mean	34.38	36.47	39.62	45.70	85.06	95.50	107.24
S. D.	2.756	2.718	3.491	3.906	14.907	16.32	10.69
S. E.	±0.831	±0.82	±1.053	±1.175	±4.495	±4.922	±3.224

TABLE 6

The Energy cost of plying of Rickshaw with and without passenger. (Cals/Kilometer/hr.)

Subjects.	Walking without Rickshaw. Load = 0 lbs		Plying Rickshaw without passenger. Load = 160 lbs		Plying Rickshaw with 1 passenger. Load = 281 lbs		Plying Rickshaw with 2 passengers. Load = 400 lbs		Plying Rickshaw with 3 passengers. Load = 530 lbs	
	Speed Kilometer/hr.	Energy Cost	Speed Kilometer/hr.	Energy Cost	Speed Kilometer/hr.	Energy Cost	Speed Kilometer/hr.	Energy Cost	Speed Kilometer/hr.	Energy Cost
B.N.G.	4.787	401.0	5.472	562.8	9.643	850.1	7.890	1028.9	6.575	1243.5
M.C.R.	5.693	314.2	6.019	662.9	7.661	584.8	6.566	708.1	5.472	797.2
S.C.A.	5.176	322.6	7.890	392.9	8.766	628.9	9.691	695.0	7.013	841.1
M.R.	4.658	384.2	5.472	505.4	9.643	810.8	7.889	1039.4	6.575	1125.1
S.S.	4.658	451.3	6.225	480.1	9 338	689.9	8.950	749.5	7.004	838.3
T.M.	4.529	332.6	6.226	403.5	8.950	512.6	7.782	688.4	5.447	978.7
J.S.	5.176	314.7	5.472	512.9	8.748	562.6	7.661	643.6	6.019	823.2
D.N.S.	5.693	372.7	6.226	432.0	6.226	622.8	6.228	823.4	5.448	962.6
A.S.	5.693	343.4	8.171	395.5	10.117	541.5	9.727	605 8	1.560	685.3
R.S.S.	4.668	468.1	5.414	532.3	6.317	707.6	5.414	1054.4	4.512	1164.9
H.K.S.	5.693	380.9	7.219	460.3	7.219	526.6	8.122	696.0	5.414	913.4
Mean =		371.4		476.4		639.8		793.9		943.0
S. D. =		50.6		61.4		108.3		159.9		167.6
S. E. =		±15.2		±18.5		±32.3		±48.2		±50.5

TABLE 7

The energy cost of Plying Rickshaw with and without passenger.

(Cals/kilometer/m^2 body surface/hr)

(Surface area determined according to Du Bois and Du Bois (1916).

Subject		Walking without Rickshaw load=0 lbs.	Flying Rickshaw without passenger load=160 lbs.	Plying Rickshaw with one pessenger load=281 lbs	Plying Rickshaw with two passenger load=400 lbs.	Plying Rickshaw with three passenger load=530 lbs.
B. N. G.	..	268.9	377.4	570.2	690.1	834.0
M. C. R.	..	217.4	389.5	404.7	490.0	551.7
S. C. A.	..	235.0	286.2	458.1	506.2	612.7
M. R.	..	263.1	346.1	555.2	711.9	770.6
S. S.	..	302.9	322.2	463.0	503.0	562.6
T. M.	..	260.2	315.7	401.2	538.8	765.8
J. S.	..	197.6	322.2	353.4	404.2	517.0
D. N. S.	..	263.9	306.0	441.2	583.2	681.9
A. S.	..	254.0	292.5	400.5	448.1	506.9
R. S. S.	..	286.3	325.5	432.7	644.9	712.4
H. K. S.	..	227.4	274.9	314.5	415.6	445.4
Mean	..	252.4	323.5	435.9	539.6	601.9
S. D.	..	29.525	33.934	72.823	101.244	110.342
S. E.	..	$\pm$8.902	$\pm$10.231	$\pm$21.957	$\pm$30.527	$\pm$33.270

TABLE 8.

The Energy Cost of Plying Rickshaw with and without Passanger.
(Cals/kilometer/m^2 body surface/hr)
(Surface area determined by the formula of Banerjee and Sen (1955).

Subject	Walking without Rickshaw load=0 lbs.	Plying Rickshaw without passanger load=160 lbs.	Plying Rickshaw with one passanger load=281 lbs.	Plying Rickshaw with two passanger load=400 lbs.	Plying Rickshaw with three passanger load=530 lbs.
B. N. G.	258.7	363.1	548.6	663.8	802.3
M. C. R.	209.0	374.4	389.0	471.1	530.4
S. C. A.	226.0	275.3	440.7	487.0	589.3
M. R.	253.2	333.2	534.4	685.2	741.6
S. S.	291.2	309.7	445.1	483.7	540.9
T. M.	250.2	303.6	385.8	518.1	736.4
J. S.	190.1	309.9	339.9	388.9	497.4
D. N. S.	253.9	294.3	424.3	561.0	655.8
A. S.	244.4	281.5	385.8	431.3	487.8
R. S. S.	275.5	313.2	416.5	620·6	685.6
H. K. S.	218.8	264.3	302.5	399.7	524.7
Mean	242.8	311.10	419.30	519.1	617.5
S. D.	28.167	32.224	70.37	97.42	105.97
S. E.	±8.493	±10.018	±21.22	±29.37	±31.95

TABLE 9.

The Energy cost of Plying Rickshaw with and without Passanger.
(Cals/kilometer/kg body weight/hr)

Subject	Walking without Rickshaw load=0 lbs.	Plying Rickshaw without passanger load=160 lbs.	Plying Rickshaw with one passanger load=281 lbs.	Plying Rickshaw with two passanger load=400 lbs.	Plying Rickshaw with three passanger load=530 lbs.
B. N. G.	8.224	11.540	17.440	21.100	25.500
M. C. R.	7.104	12.730	13.220	16.010	18.030
S. C. A.	7.816	9.519	15.250	16.840	20.380
M. R.	8.468	11.140	17.870	22.920	24.800
S. S.	9.322	9.915	14.250	15.480	17.320
T. M.	8.624	10.460	13 290	17.850	25.370
J. S.	5.855	9.543	10.470	11.980	15.310
D. N. S.	8.383	9.718	14.020	18.520	21.660
A. S.	8.652	9.963	13.640	15.260	17.270
R. S. S.	8.459	9.618	12.780	19.050	21.050
H. K. S.	6.612	7.991	9.141	12.080	15.360
Mean	7.956	10.194	13.760	17.008	20.256
S. D.	0.980	1.194	2.460	3.244	3.632
S. E.	±0.295	±0.36	±0.741	±0.977	±1.095

TABLE 10

Average Time Spent and Energy Cost per day.

Activity	Time spent. Hrs. Mins.	Energy cost.
Sleep	6 — 48	343.9 Cals.
Lving rest	1 — 20	71.5 „
Sitting rest	4 — 13	246.4 „
Standing rest	0 — 58	65.1 „
Sitting work	0 — 31	64.5 „
Standing work	0 — 52	121.4 „
Walking	1 — 1	160.4 „
Plying empty rickshaw	0 — 55	227.6 „
Plying rickshaw with one passanger	2 — 57	1331.7 „
Plying rickshaw with two passanger	4 — 0	2047.2 „
Plying rickshaw with three passanger.	0 — 25	199.8 „
Total	24 — 0	4879.5 Cals.

DISCUSSION

The B.M.R. of these subjects as shown in Tables 4 and 5, is 33·08 and 34·38 Cals/m²/hr. according to the formulae of Banerjee and Sen (1955) and Du Bois and Du Bois (1916) respectively. The recorded data are slightly higher than the values for laboratory workers (Banerjee *et. al.* 1959), who had B.M.R. of 30·87 and 33·33 Cals/m²/hr. according to the formulae of Banerjee and Sen (1955) and Du Bois and Du Bois (1916). This increase of B.M.R. in rickshaw-pullers may be attributed to the muscle tone induced by harder work and is in accordance with the findings of Granati and Busca (1942).

The B.M.R. is taken as the metabolic cost of sleep as suggested by Passmore and Durnin (1955). The rise of metabolic rate due to S. D. A. of food tends to cancel the lowering of the metabolic rate during sleep.

The energy cost of lying, sitting rest and standing rest are in ascending order as shown in Tables 2, 3, 4, and 5. No significant difference is observed when these results are compared with those of laboratory workers. (*loc. cit.*)

Sitting working of the subjects consisted of washing utensils and clothes, cooking etc. and standing working, of washing rickshaw and bringing water in buckets etc. The energy cost of sitting work is less than standing working in all cases except in B. N. G. and S. S., who might have exerted more strength during washing of utensils.

Walking, expressed as Cals/min. could not be as precise as when expressed in Cals/km/hr., because of the obvious effects of speed and load (Atxler and Herbst 1927; Benedict and Muschhauser 1915). All the subjects walked on the same track, so that the effects of track surface on walking was common (Granati and Busca, 1945). Their speed of walking varied from 4·5 to 5·69 km/hr.

The expenditure of energy of plying rickshaw without and with loads (passenger) are also expressed in Cals/km/hr. for the reasons given above. From the tables 6, 7, 8, and 9 it is found that the energy expenditure increases with increasing load even when the speed of walking is less (when carrying three passengers). It appears, therefore, that walking is influenced more by loads than by speed.

For obvious practical reasons it was unfortunately not possible to obtain an accurate time record of the activity. However, the time spent in different activity was recorded by frequent interviews of the subjects individually. This naturally entails some inaccuracy in their 24 hours energy expenditure (Table-10) but it certainly gives a fair approximate.

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From the results it is apparent that there exists a great interindividual variability in the energy cost of the same activity. This finding confirms our previous results (Banerjee *et. al.* 1959) and so also of Booyens and McCance (1957), Ferres *et. al.* (1954), Garry *et. al.* (1955) and Edholm *et. al.* (1955).

SUMMARY

1. The energy expenditure of the various activities of the ricksha-pullers has been determined by the use of K.M. respirometer.
2. The energy cost of walking varies more with loads than speed.
3. There is a great interindividual variability in the energy cost of same activity.
4. The average daily energy expenditure has been found to be 4880 Cals. approximately.

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