Energy expenditure of agricultural workers in an area of endemic schistosomiasis in the Sudan

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ABSTRACT Indices of physiological performance in the field under natural working conditions were measured in 46 Sudanese Gezira villagers and related to exercise performance under controlled laboratory conditions. The effect of *Schistosoma mansoni* infection on energy expenditure in the field was also investigated. A highly significant positive association between the maximal aerobic power output ($\dot{V}O_{2\text{ max}}$) measured in the laboratory with energy expenditure in the field ($r = +0.51$, $p < 0.001$) and with changes in body weight during work ($r = 0.41$, $p < 0.01$) was found. The villagers' energy expenditure in field work amounted to 25–28 KJ/min, which corresponded to more than 50% of their predicted $\dot{V}O_{2\text{ max}}$. They maintained that relative work level for more than an hour. The differences in energy expenditure between moderately infected and non-infected villagers with schistosomiasis did not attain statistical significance but the number of non-infected subjects on which the comparison was based was small.

The energy cost of different occupational activities has been measured by several investigators^{1–3} but only a few studies have been made on men performing self paced physical tasks.^{4–6} In tropical and sub-tropical regions where unsupervised work in farming communities is common, the capacity to perform physical work remains an important component of productivity⁷ which in turn is influenced by the presence of endemic disease.^{8,9} Apart from the investigations reported by Collins *et al*¹⁰ no other attempt has been made to study objectively the effect of schistosomiasis infection on energy expenditure and productivity. Other studies examined the productivity of cane cutters in Tanzania and Cameroon,^{11,12} where schistosomiasis is also endemic, without giving data on actual energy expenditure of the cane cutters under normal working conditions. The present study aimed at assessing the levels of energy expenditure of a rural population performing self paced tasks in their natural working environment on farmland in the Gezira area of the Sudan. Measurements of work performance in the field were related to the potential work capacity of each individual by the laboratory assessment of the phy-

siological response to graded exercise, and also to schistosomiasis infection.

Materials and methods

Forty six men (aged between 18 and 45), eight of whom were non-infected and 38 were infected with *Schistosoma mansoni*, were studied while performing self paced agricultural tasks with minimum interference from the observer. The present work forms part of a more comprehensive study of the effect of *S. mansoni* infection on work capacity.⁸ Under the conditions of the present field study, standardisation of the work was found to be virtually impossible. For this reason the subjects had the option of choosing their own work tasks. The predominant task performed by most subjects was shovelling, either to make new edges or to divide the farming fields into small partitions. Other common tasks were cutting sorghum, clearing grass, clearing and picking ground-nuts, diverting water for irrigation, picking cotton, and pulling cotton plants. Most of these tasks are considered to be among the most difficult and energy demanding manual farming work in the Gezira.

Changes in body weight (to the nearest 50 g) were measured by recording the body weight of the subject before the start and at the end of the task using a

portable beam balance set on a rigid platform. The urine temperature was recorded immediately after the work terminated as described by Fox *et al.*¹³ The rate of work and the time spent by the subject in performing the task were also recorded using a stopwatch (to the nearest second). Heart rates were measured by palpation at the wrist.

For each subject, direct measurements of oxygen intake were made over a minimum period of 15 minutes using a Kofranyi-Michaelis (KM) respirometer, which was carried on the back of the subject. Expired gas was collected in a polyethylene sample bag connected to the respirometer. The polyethylene bags were tested for the loss of expired gases and were found to be virtually impermeable to respiratory gases. The Kofranyi-Michaelis respirometers were checked and calibrated regularly by using a primary standard (water displacement) in the laboratory before their use in the field. The expired air was analysed for O₂ and CO₂ using the Lloyd-Haldane gas analyser. Oxygen consumption was determined from these measurements and converted to an energy expenditure value.

Environmental measurements of dry, wet, and globe temperatures and wind speed were recorded every 20 minutes and the wet bulb globe temperature index (WBGT) was calculated from the equation:

$$\text{WBGT} = 0.7 \text{ WB} + 0.2 \text{ GT} + 0.1 \text{ DB} \\ (\text{for outdoors with solar load})$$

In addition to the energy expenditure measurements in the field the subjects performed a progressive physical exercise test on a stationary bicycle ergometer in the laboratory to determine predicted maximal aerobic power output ($\dot{V}\text{O}_{2\text{max}}$).⁸

The skinfold thickness, body weight, and height were measured and lean body mass (LBM) was obtained by the method of Durnin and Rahaman.¹⁴ Leg volume was estimated by the formula of Jones and Pearson¹⁵ from measurements of the length and circumference of the leg at seven sites from the floor level: gluteal fold, one third subischial thigh, minimum thigh, knee joint, minimum calf, maximum calf, and ankle.

Blood samples were obtained for haemoglobin estimation and malaria screening and a modified thick smear technique¹⁶ introduced by Kato and Miura¹⁷ was used to detect and count *Smansoni* eggs in stool specimens.

Results

Table 1 shows the physique, lean body mass, leg volume, haemoglobin concentration, and *Smansoni* egg excretion values of the villagers and table 2 the sub-maximal responses to graded exercise. None of the subjects was currently infected with malarial parasites or hookworm. The assessment of physiological performance measured in the field is given in table 3. The mean oxygen cost of different activities was 1.20 SD 0.27 l/min (range 0.62–1.71) which is equivalent to 25.2 SD 5.7 KJ/min. The mean heart rate recorded during KM measurements was 131, SD 14 beats/min, and this was similar to the mean heart rate throughout the working period (133, SD 15 beats/min).

Energy expenditure in the field was positively correlated with the $\dot{V}\text{O}_{2\text{max}}$ measured in the laboratory ($r = +0.51$, $p < 0.001$, $n = 44$; figure) and negatively correlated with the duration of the activity ($r = -0.41$, $p < 0.005$) and cardiac frequency ($\text{fH}_{1.5}$) measured in the laboratory ($r = -0.31$, $p < 0.05$). The mean oxygen uptake in the field corresponded to 52.0, SD 13.3% of the predicted $\dot{V}\text{O}_{2\text{max}}$. There was a high positive correlation between the energy expenditure in the field and the percentage of $\dot{V}\text{O}_{2\text{max}}$ which is represented ($r = +0.79$, $p < 0.001$, $n = 44$).

The mean body weight changes were 507, SD 266 g per hour of work and these were positively associated with the predicted $\dot{V}\text{O}_{2\text{max}}$ ($r = +0.41$, $p < 0.01$, $n = 42$) and negatively associated with the cardiac frequency at an oxygen uptake of 1.5 l/min ($\text{fH}_{1.5}$) ($r = -0.37$, $p < 0.01$). The change in weight was found to be positively correlated with energy expenditure in the field ($r = +0.29$, $p < 0.05$, $n = 44$).

The observed mean WBGT index (table 3) was negatively associated with the relative work level ($\%\dot{V}\text{O}_{2\text{max}}$) ($r = -0.48$, $p < 0.01$). The mean urine temperature recorded from 14 villagers immediately after work was 37.2, SD 0.79°.

Few of the villagers were free of schistosomiasis but when divided into non-infected and infected groups (table 4) the energy expenditure (as measured by KM) of the non-infected ($\dot{V}\text{O}_2 = 1.33$, SD 0.16 l/min equivalent to 28, SD 3.4 KJ/min) was higher than infected villagers ($\dot{V}\text{O}_2 = 1.18$, SD 0.29 l/min equivalent to 24.8, SD 6.1 KJ/min). The corresponding relative work level ($\%\dot{V}\text{O}_{2\text{max}}$) in the non-infected was

Table 1 Physical characteristics, haemoglobin concentration, and *S mansoni* egg excretion rate (eggs/g faeces) of the Gezira agricultural workers (means $\pm$ SD)

No of subjects	Age (years)	Height (cm)	Weight (Kg)	Lean body mass (Kg)	Leg volume (l)	Hb (g/dl)	Egg excretion (eggs/g)
46	26.3 $\pm$ 6.0	166 $\pm$ 7.9	53.8 $\pm$ 6.6	48.1 $\pm$ 4.8	10.7 $\pm$ 1.4	14.2 $\pm$ 1.0	510 $\pm$ 707

Relation between predicted maximal oxygen uptake ($\dot{V}O_{2\max}$) and field energy expenditure ($\dot{V}O_2$) of agricultural workers and cane cutters in the Gezira, Sudan.

Table 2 Submaximal responses to exercise measured in the laboratory. Oxygen uptake at a work output of 900 kpm/min ($\dot{V}O_{2900}$), ventilation at a $\dot{V}O_2$ of 1.5 l/min ($\dot{V}E_{1.5}$), cardiac frequency at an oxygen uptake of 1.5 l/min ($f_{H1.5}$) and predicted maximum oxygen uptake at an f_H of 210–0.65 $\times$ age ($\dot{V}O_{2210-0.65\text{ age}}$) (means $\pm$ SD)

No of subjects	$\dot{V}O_{2900}$ (l/min)	$\dot{V}E_{1.5}$ (l/min)	$f_{H1.5}$ (beats/min)	$\dot{V}O_{2210-0.65\text{ age}}$ (l/min)
46	2.18 $\pm$ 0.23	54.4 $\pm$ 7.6	149 $\pm$ 16	2.41 $\pm$ 0.35

Table 3 Parameters of physiological performance during field work in 46 agricultural workers in the Gezira, Sudan (KM respirometry)

	Means $\pm$ SD	
Wet bulb globe temperature index ($^{\circ}\text{C}$)	21.1 $\pm$	4.3
Energy expenditure (l oxygen/min)	1.20 $\pm$	0.27
Minute ventilation (l/min)	36.1 $\pm$	8.2
Cardiac frequency (beats/min):		
During work	131 $\pm$	14
During KM measurements	133 $\pm$	15
Relative work level (% predicted $\dot{V}O_{2\max}$)	52.0 $\pm$	13.3
Loss of body weight during work (g/h)	507 $\pm$	266
Duration of activity (hours)	1.23 $\pm$	0.48

KM = Kofranyi-Michaelis.

Table 4 Physiological performance in field work by Sudanese agricultural workers with or without *S. mansoni* infections (means $\pm$ SD)

Group	No	$\dot{V}E$ (l/min)	$\dot{V}O_2$ (l/min)	% $\dot{V}O_{2\max}$	Mean f_H (Beats/min)	Body wt loss (g/hr)	Duration of work (h)	WBGT ($^{\circ}\text{C}$)
Non-infected villagers	8	39.2 $\pm$ 3.6	1.33 $\pm$ 0.16	56.9 $\pm$ 13.5	135 $\pm$ 12	528 $\pm$ 185	1.20 $\pm$ 0.22	18.8 $\pm$ 5.5
Infected villagers	38	35.8 $\pm$ 8.8	1.18 $\pm$ 0.29	50.9 $\pm$ 13.1	130 $\pm$ 15	503 $\pm$ 281	1.24 $\pm$ 0.32	21.5 $\pm$ 3.9

WBGT = Wet bulb globe temperature index.

also higher than in the infected. Neither of these differences was statistically significant.

Discussion

In the previous field study in the Sudan on 41 cane cutters, energy expenditure measured by KM respirometry during cane cutting was found to correlate with laboratory measurements of maximum work capacity ($\dot{V}O_{2\max}$), though the correlation was not quite at the level of statistical significance.^{9,10} Energy expenditure during cane cutting was higher and there was greater individual variability (mean 1.67, SD 0.34, range 1.02 to 2.37 l oxygen/min) compared with the digging and cutting tasks measured here (mean 1.20, SD 0.27, range 0.62 to 1.71 l/min). In the 44 villagers there is, however, a significant correlation ($p < 0.001$) between the rate of work in the field and potential (predicted) maximum performance. This suggests that predicted maximum aerobic capacity measurements in the laboratory may provide a useful guide to the probable performance of physical tasks in the actual field situation. It should be emphasised, however, that this relation is likely to be less accurate when applied on an individual basis. Submaximal predictive methods are known to be open to substantial individual errors dependent on such factors as habituation to the test, motivation, and sampling bias^{18,19} errors which would also be relevant in the comparative study of a single individual in field and laboratory tests. Group or population comparisons are likely to be more suitable.

Schistosoma mansoni has been shown significantly to impair working capacity in laboratory tests of maximal aerobic power when the intensity of parasitic infection (egg excretion rate) becomes greater than 2000 eggs per gram of faeces.⁸ The present study provides an indication that such an impairment may occur during work in the field, since moderately infected villagers (500 eggs/g of faeces) performed less well than uninfected. The population sample size was, however, small and the groups numerically uneven. Furthermore, the higher energy expenditure during fieldwork by the non-infected villagers could have been due to the lower environmental heat stress which

prevailed at the time of the tests (table 4) for it was observed that overall there was a significant negative correlation between the WBGT index and the relative work level. The decrement in energy expenditure due to schistosomiasis infection did not, however, attain statistical significance and this confirms the result previously reported on field work performed by moderately infected cane cutters.¹⁰

The levels of energy expenditure of work carried out by the groups were comparable and similar to those recorded in other studies⁵ on Sudanese cane cutters and by Spurr *et al* on Colombian cane cutters.⁶ The villagers were capable of maintaining a work rate above 50% of their estimated maximal aerobic power output for more than an hour, which was higher than that recorded for industrial or building workers.^{20 21} Astrand and Rodahl suggested that a 50% load is too high for a steady state if physical activity is continuous for a whole working day.³ The villagers' mean aerobic energy output value of 26–28 KJ/min was similar to that of men at work with pick, shovel, and wheelbarrow; coal-mining; agricultural work; and lumberjacks.²

Changes in body weight recorded in the field were highly correlated with cardiac frequency and maximal oxygen power output in standard laboratory exercise tests, and also with energy expenditure in the field. This is in accord with previous evidence on Sudanese cane cutters.⁵ In conclusion, this study suggests that highly significant associations exist between the physiological indices measured under controlled laboratory conditions (such as $\dot{V}O_{2\max}$ and cardiac frequency) and those measured under natural working conditions (such as energy expenditure and changes in body weight). The level of intensity of infection with schistosomiasis is clearly an important factor in determining the level of impairment of energy expenditure in the field.

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