Body Composition of Guatemalan Sugarcane Cutters, Worker Productivity and Different Work Settings and Conditions

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Abstract The objective of the study was to determine whether the body composition of rural workers constitutes a limiting factor in their productivity responses to different work situations. Fifty-six Guatemalan sugarcane cutters were measured thrice (P1, P2, P3), at two-month intervals, each point representing different work conditions. Body composition was estimated from arm muscle circumference and the mean of four skinfolds. Productivity indicators were: daily tonnage of sugarcane cut, number of days worked per fortnight and gross earnings per fortnight. Analysis of variance of repeated measures was used. Findings showed no significant differences in productivity among workers with different P1 body composition. Mean productivity levels differed significantly between periods. Changes in mean skinfold and in arm muscle circumference between periods were generally equal among workers with different P1 body composition, and were the same for workers of different ages and heights. Changes in productivity between periods were equal among workers with different body composition. Body composition played no role in how workers changed their productivity in response to different work settings and conditions.

In an extensive review article dealing with biological factors which relate to agricultural productivity, Spurr (1984) postulates a simple model in which levels of physical activity and nutritional status interact and jointly determine the physical work capacity of workers which, in turn, determines their levels of work productivity. It is recognized in the model, as indeed was suggested by Viteri et al. (1981), that biological and physiological factors interact with the work setting, motivational factors, economic incentives and sociocultural variables in producing different productivity outcomes. Virtually no evidence exists about these interactive effects, and most empirical studies have only dealt with the relationships between nutritional status (body composition), physical work ca-

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pacity and worker productivity. The studies summarized in Spurr (1984), as well as our own work with Guatemalan sugarcane cutters (Flores et al. 1984; Immink et al. 1984) indicate that there exists, in marginally undernourished workers engaged in physically strenuous work, a significant, though not always robust, positive relationship between lean body mass (or muscle mass), and physical work capacity, and between the latter and worker productivity. However, these results were obtained in cross-sectional studies which may provide evidence of long-term relationships, but provide little insight into the underlying dynamics of productivity outcomes.

In the present study we investigated how rural workers with different body composition, while faced with the same wage incentives, changed their productivity levels in response to short-term variation in work demand and intensity. Specifically, we hypothesize that workers with relatively more muscle mass show more pronounced changes in productivity in response to varying work conditions than their colleagues with less muscle mass.

Materials and Methods

A group of 56 male workers who all resided permanently on a sugarcane plantation in the Pacific lowlands of Guatemala were included in the study. These workers were selected because they all participated in a longitudinal study conducted by us in the 1970's (Immink et al. 1984) and had been subjected to a different work regime since then. The principal work activity of these men during the measurement period was cutting burnt sugarcane, and all were experienced cutters. Workers were free to decide on their own working hours and level of daily production, and were paid a piece-rate which itself varied with the level of daily output.

The same workers were measured at three points during the 1983 sugarcane harvesting season with each point representing a different work setting and condition. The first measurement period (P1) was in January at the start of the sugarcane cutting season, a period of relatively low labor demand. The second measurements were taken in March (P2) at the peak of the cutting season, a period of high labor demand and work in high yielding fields. The last measurements were taken in May (P3), the last month of the harvesting season with intermediate labor demand and work in lower yielding fields.

Productivity data were obtained from the company payrolls. Three productivity indicators were constructed from the payroll data: tonnage of sugarcane cut per day, number of days worked per fortnight and gross earnings per fortnight. During each measurement period, data were obtained for a four-week period, and a daily or fortnightly mean was calculated in order to decrease intraworker variability in the productivity indicators.

Table 1. Initial (P1) Values—Total Sample of Male Workers (n = 56)

Indicator	$\bar{X}$	*S.D.*	*Range*
Age (Yrs)	42.7	8.8	27–63
Height (cm)	158.4	5.6	143.4–169.9
Weight (kg)	54.6	6.8	43.5–70.0
Mean skinfold (mm)	5.7	2.0	3.6–12.3
Arm muscle circumference (mm)	228.7	20.9	178.7–316.4
Sugarcane cut/day (tons)	3.65	0.88	1.97–6.37
Days worked/fortnight	11.9	0.9	6.0–14.0
Total earnings/fortnight (Q)	74.82	20.26	36.20–138.41

The following anthropometric measurements were taken once during each measurement period: mid-upper arm circumference, and biceps, triceps, subscapular and supra-iliac skinfolds. As an indicator of muscle mass, mid-upper arm muscle circumference was computed from mid-upper arm circumference and triceps skinfold values. As an indicator of fat reserves the mean of the four skinfolds was computed for each worker. Each indicator was then dichotomized using the medians as cut-off values, and workers were classified into four subsamples, depending on whether they had "low" or "high" muscle mass and fat reserves values during the first measurement period. The four groups were: low muscle mass and fat reserves (G1); (b) low muscle mass and high fat reserves (G2); (c) high muscle mass and low fat reserves (G3) and (d) high muscle mass and fat reserves (G4). The median of mid-upper arm muscle circumference and the median of mean skinfold were 231.4 mm and 4.88 mm, respectively.

The age of the workers was calculated as of January 1, 1983. The workers ranged in age from 27 to 63 yr with a mean age of 42.7 yr (Table 1).

In addition to descriptive statistics, the principal statistical technique employed was analysis of variance of repeated measures, using the sub-routine BMDP 4V (Dixon et al. 1983). This technique tests for within period effects, and also allows us to test for interactions of body composition and within period effects. The effect of age and height was assessed by introducing these variables as co-variates in the analysis.

Results

During the first measurement period (P1), mean value of the skinfold indicator was 5.7mm with a range from 3.6 to 12.3mm (Table 1). In general, thus, the workers demonstrated relatively low energy stores at the start of the cutting season. The mean of arm muscle circumference was 228.7 mm during

Table 2. Mean Values of Arm Muscle Circumference and of the Mean of Four Skinfolds of Four Subsamples During Period P1

Sub-Samples	*Arm Muscle Circumference (mm)* $\bar{X}$	S.D.	*Mean Skinfold (mm)* $\bar{X}$	S.D.
G1: low muscle mass, and fat reserves	210.7	3.8	4.2	0.1
G2: low muscle mass; high fat reserves	216.0	2.7	6.9	0.6
G3: high muscle mass; low fat reserves	244.3	6.2	4.5	0.1
G4: high muscle mass and fat reserves	243.8	1.8	7.0	0.5

P1, with considerable variation among the workers (range: 178.7-316.4mm). The workers tended thus to be generally lean and muscular, which was to be expected given their occupation, while reflecting a physiological adaptation to the physically strenuous nature of their work.

At the start of the harvest season the workers cut on the average 3.65 tons of cane a day (range: 1.97-6.37 tons/day). The number of days worked during a two-week period averaged 11.9 with a range of 6-14 days. Gross earnings, which is the product of average daily productivity and number of days worked, averaged almost 75 quetzales, ranging from 36 to 138 quetzales per two-week period. (At the start of 1983, the exchange rate between the quetzal and U.S. dollar was officially 1:1.)

The mean arm muscle circumference and skinfold values of the four subsamples as previously defined are presented in Table 2.

The first question that we investigated was whether there were different changes in body composition among the four body composition groups during the cutting season. A different pattern of body composition changes may explain a different pattern of productivity responses. Figure 1 presents the results of the analysis of variance of repeated measures, with the dependent variable in each case a body composition indicator to test for within-period effects (P), and for interactions of first period muscle mass (M) and fat reserves (S) with period effects.

Initially we introduced age (A) as a covariate in the model to test for interactions of age with body composition changes over time. The results of the analysis of co-variance indicated no significant interactive effect of age and period on either body composition indicator ($p > .30$). Furthermore, the interactive effects of $P \times (AS)$ and $P \times (AM)$ were statistically not significant ($p > .30$ and $p > .20$, respectively). Thus, we concluded that age did not play a role in the changes in body composition, and dropped age from the model.

Since muscle mass may partially be a function of body size, we introduced height as a covariate in the model. Height did not reach a statistically significant level as an explanatory variable of changes in body composition over time ($p > .25$ and $p > .90$ for muscle mass and fat stores, respectively), and height was also dropped from the model.

The pattern that emerges is that there were significant within-period effects among the four groups. But the changes in mean skinfold were statistically significant between periods one and two (P1 and P2) only for those workers with relatively high P1 mean skinfolds (G2 and G4). Thus, as the work intensified, G2 and G4 workers tended to loose some fat reserves which were not replaced as the work intensity diminished. The fat reserves of workers with low initial fat reserves did not change over the course of the cutting season.

The same analysis for changes in arm muscle circumference is presented in the second panel of Figure 1. The results show a marginally significant within period effect, with a significant change between P1 and P2 for those workers with relatively high muscle circumference and low skinfold values (G3). In all four groups there was a tendency to increase muscle mass towards the end of the cutting season as work intensity diminished particularly in workers with low muscle mass values (G1 and G2). However, none of these differences were statistically significant.

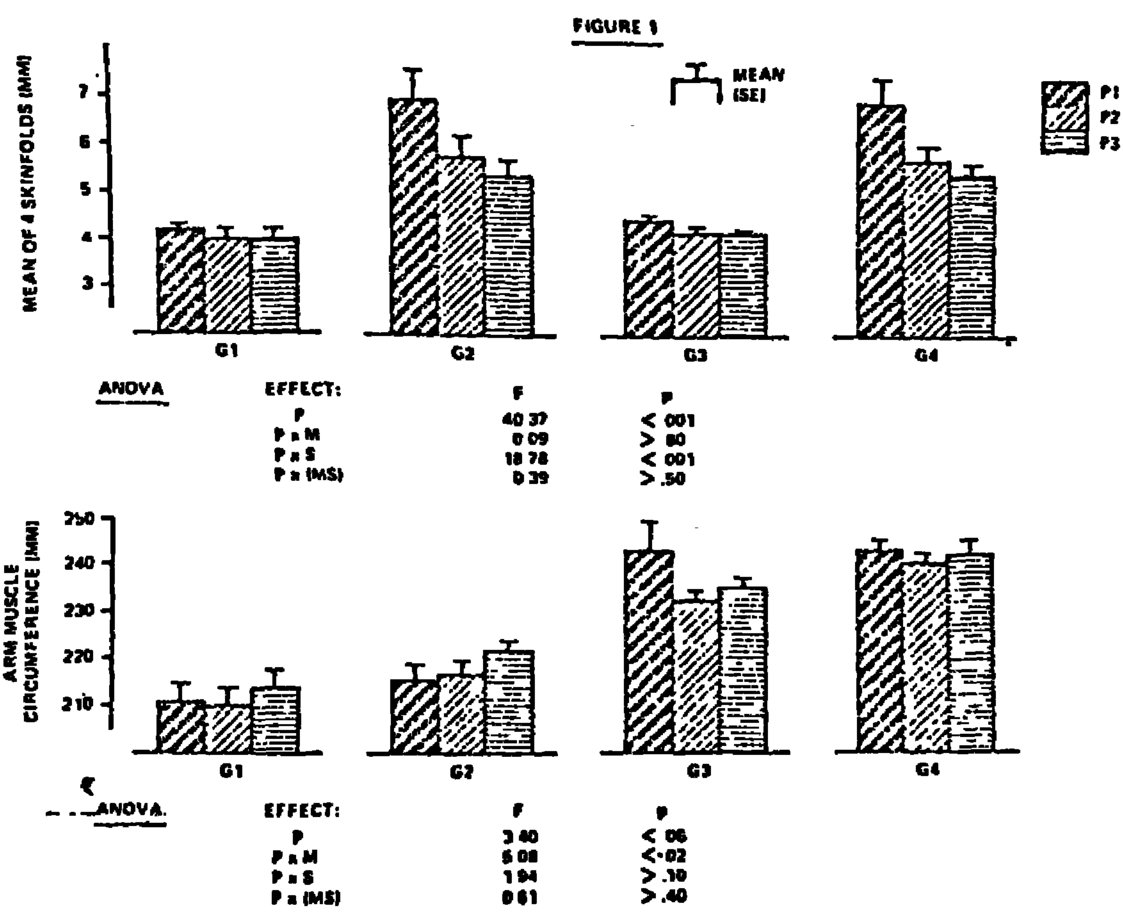
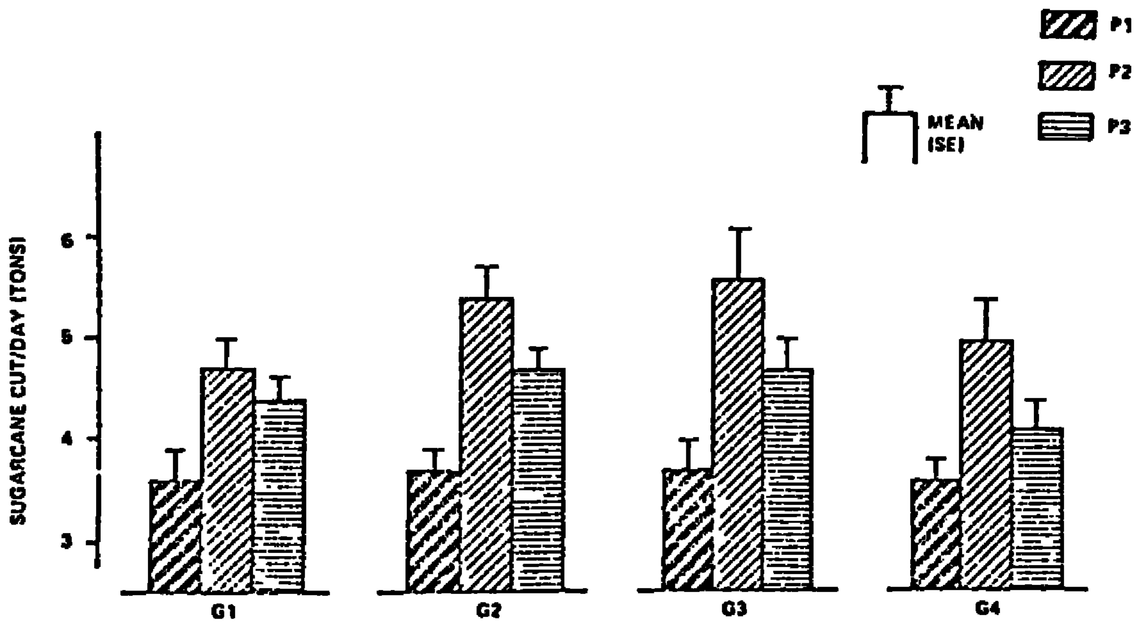


Figure 1. Analysis of Variance of Repeated Measures of Changes in Body Composition During One Harvest Season of Four Groups of Sugarcane Cutters.



ANOVA:

EFFECT	F	P
P	·35 40	< .001
P x M	0.59	> .50
P x S	0 10	> .80
P x (MS)	1.25	> .20

Figure 2. Analysis of Variance of Repeated Measures of Changes in Tonnage of Sugarcane Cut by Four Body Composition Groups.

Figures 2-4 present the analysis of variance of repeated measures of the three productivity indicators that test the main hypothesis of this paper. The results were as follows. There were no significant differences in each of the productivity indicators among workers with different body composition at the start of the cutting season. For each productivity indicator there was a significant within-period effect ($p < .001$): mean productivity levels differed significantly between measurement periods. But the pattern of change during the cutting season is different for the various indicators. As the work intensity and demand for labor services increased, the workers responded by increasing their daily output, but compensated by decreasing the number of days they worked per fortnight. The net effect, nevertheless, was a significant increase in gross earnings between P1 and P2. The opposite pattern in productivity changes took place during the second half of the cutting season: daily output diminished and number of days worked per fortnight increased, with a small negative effect on gross earnings.

The interactive effects between the body composition indicators and periods were not statistically significant for any of the productivity indicators. The pattern of changes in productivity during the cutting season were equal among workers with different body composition at the start of the season. Even though the fat reserves of workers with relatively high initial mean skinfold values decreased between P1 and P2, the pattern of change in their productivity was not different from workers with initially low mean skinfold values. The same holds true for workers with relatively high P1 muscle circumference and low skinfold values, whose muscle mass decreased between P1 and P2. The analysis of variance of overall group differences showed no significant body composition effects, and interactive effects between muscle mass and body fat measures, for any of the productivity indicators.

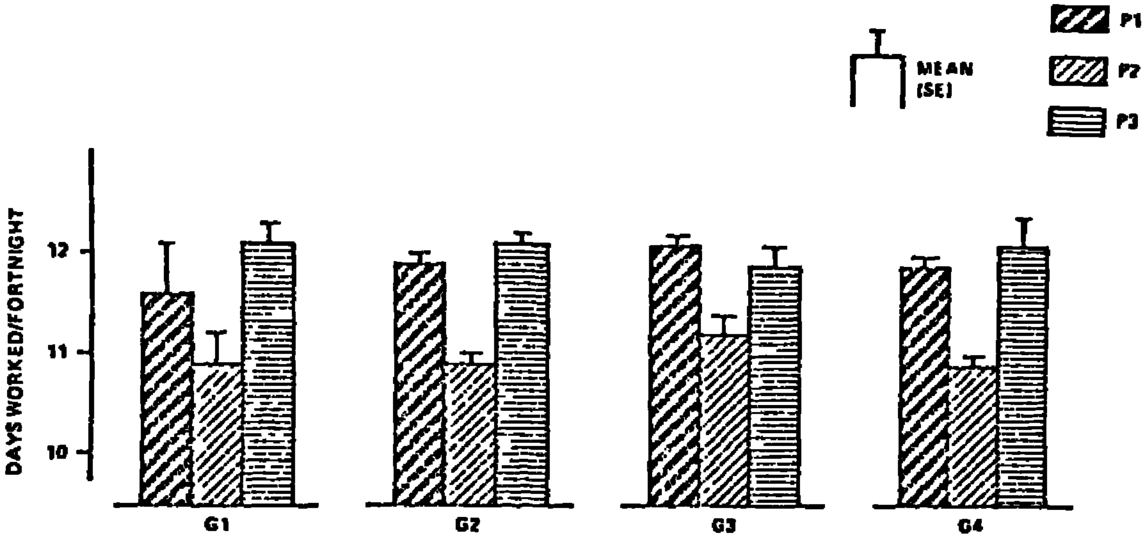
It appears then that body composition at the start of the cutting season, as measured in the present study, was unrelated to the patterns of productivity changes during the season. Furthermore, any changes between measurement periods in body composition in some of the sub-groups, were also unrelated to the changes in productivity during the cutting season.

Discussion

The findings of the study may be summarized as follows. The workers were generally muscular and lean at the start of the cutting season. They tended to have similar body composition as reported for Colombian sugarcane cutters (Spurr et al. 1975). Jamaican and Tanzanian cutters were reported to have higher arm muscle circumference values, adjusted for height (Heywood 1974; Davies 1973). The level of daily productivity of the workers in the present study was similar to that reported for Colombian sugarcane cutters (3.45 tons/day) and for highly productive Tanzanian cutters (3.51 tons/day), but lower than daily productivity levels reported for sugarcane cutters in Jamaica (4.78 tons/day) and in Zimbabwe (3.0-7.0 ton/day) (Spurr et al. 1977; Davies 1973; Heywood 1974; Morrison and Blake 1974). Differences in ages, work incentives and environmental conditions may at least in part explain productivity differences between these groups.

As the work intensified, only the fat reserves of workers with relatively high initial fat reserves decreased, while the muscle mass of workers with relatively high muscle mass and low fat reserves initially decreased. Any changes in arm muscle circumference and in mean skinfolds during the cutting season were unrelated to the workers' age. Workers with different body composition at the start of the cutting season did not differ in their level of daily output and number of days worked per fortnight. Mean productivity levels differed significantly at different points of the cutting season. Changes in productivity (all three indicators) between measurement periods were equal among workers with different body composition. Thus, the body composition of these workers played no role in how they changed their productivity in response to different conditions of work availability.

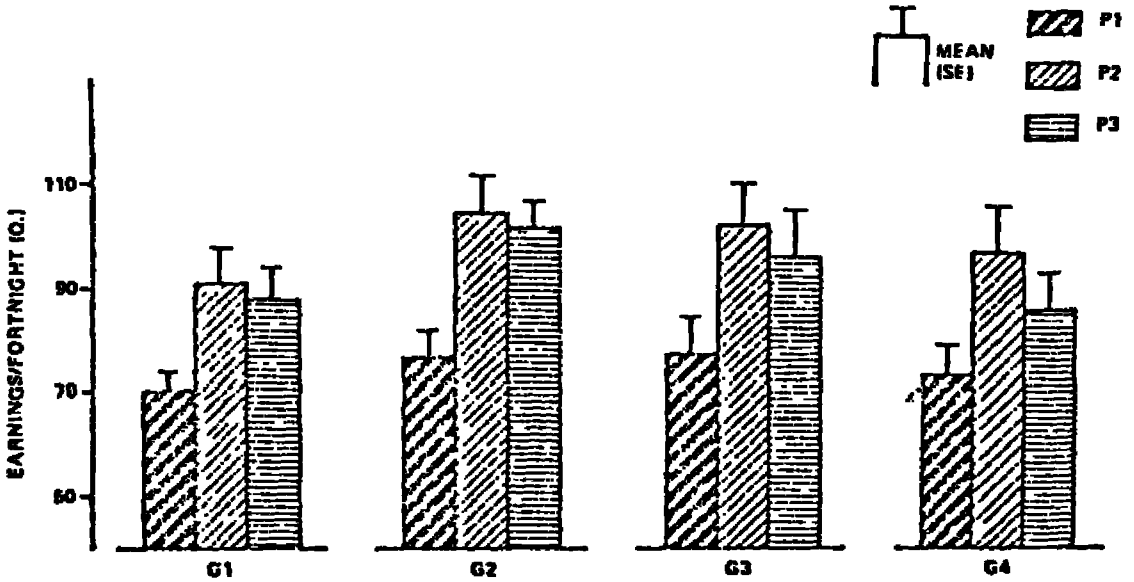
Given the above findings it is useful to speculate about what adjustments these workers made in response to increased/decreased demand for their labor



ANOVA:

EFFECT	F	p
P	28 08	< 001
P x M	0 36	> .60
P x S	0 40	> 60
P x (MS)	0 85	> 40

Figure 3. Analysis of Variance of Repeated Measures of Changes in Days Worked/Fortnight by Four Body Composition Groups.



ANOVA:

EFFECT	F	p
P	25 35	< 001
P x M	0 30	> .60
P x S	0 09	> .80
P x (MS)	0.53	> .50

Figure 4. Analysis of Variance of Repeated Measures of Changes in Gross Earnings of Four Body Composition Groups.

services. This knowledge is important within the context of agricultural/rural development which effectively creates new opportunities for economic activities and employment. Furthermore, there are implications for the energy requirements of rural workers and for the aggregate food demand in rural areas. In the present case, several adjustments can be hypothesized to have taken place. As energy expenditure at work increased, workers with low fat reserves remained in energy balance during the cutting season. This means that they either increased their energy intake and/or decreased energy expenditure in non-work activities. Results from a previous study (Viteri et al. 1971) suggest that these workers may have decreased energy expenditure in after work activities. An increase in energy intake by workers may have been possible through an intra-household redistribution of a given energy supply, and/or an increase in household energy supply as the result of an income effect. Workers with relatively high fat reserves went into negative energy balance first before making any further adjustments. During the second half of the cutting season, workers tended to maintain energy balance independently of their level of fat reserves, pointing towards new adjustments in energy expenditure and intake levels in response to decreasing work intensity. The data available in the present study do not allow us to investigate these questions.

The findings that in this group of workers body composition was unrelated to levels of productivity is contrary to findings reported elsewhere in the literature (see Introduction). At the start of the cutting season when labor demand is relatively low, body composition was not a limiting factor in productivity. But neither was body composition a limiting factor during the period of high work intensity and labor demand. As pointed out before, the findings showing a positive relationship between body composition, physical work capacity and productivity were obtained from cross-sectional studies which generally provide evidence of a more long term relationship. The results of this study suggest, therefore, that in the short-run, workers with a history of having been employed in physically demanding occupations, respond positively to new work incentives as long as energy availability places no restriction on energy to be expended to maintain a certain level of productivity. The optimal body composition for sugarcane cutting may be muscular and lean. The reduction in fat reserves at the start of the cutting season by workers with relatively high fat reserves perhaps reflects purposeful behavior to obtain a more optimal body composition for the high intensity cutting period.

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Literature Cited

Davies, C.T.M. 1973 Relationship of maximum aerobic power output to productivity and absenteeism of East African sugar cane workers. Brit. J. Industr. Med. 30:146-154.

Dixon, N.J., M.B. Brown, L. Engelman, J.W. Frane, M.A. Hill, R.I. Jennrich and J.D. Toporek 1983 BMDP statistical software. University of California Press, Berkeley, CA.

Flores, R., M.D.C. Immink, B. Torún, E. Díaz and F.E. Viteri 1984 Functional consequences of marginal malnutrition among agricultural workers in Guatemala. Part I. Physical work capacity. Food and Nutrition Bulletin, 6:5-11.

Heywood, P.F. 1974 Malnutrition and productivity in Jamaican sugar cane cutters. Ph.D. dissertation, Cornell University, Ithaca, New York.

Immink, M.D.C., F.E. Viteri, R. Flores and B. Torún 1984 Microeconomic consequences of energy deficiency in rural populations in developing countries. In: Energy intake and activity. E. Pollitt and P. Amante (eds.), Alan R. Liss, New York.

Morrison, J.F. and G.T.W. Blake 1974. Physiological observations on cane cutters. Europ. J. Appl. Physiol. 33:247-254.

Spurr, G.B. 1984 Physical activity, nutritional status, and physical work capacity in relation to agricultural productivity. In: Energy intake and activity. E. Pollitt and P. Amante (eds.), Alan R. Liss, New York.

Spurr, G.B., M. Barac-Nieto and M.G. Maksud 1977 Productivity and maximal oxygen consumption in sugar cane cutters. Am. J. Clin. Nutr. 30:316-321.

Spurr, G.B., M. Barac-Nieto and M.G. Maksud 1975 Energy expenditure cutting sugarcane. J. Appl. Physiol. 39:990-996.

Viteri, F.E., B. Torú, M.D.C. Immink and R. Flores 1981 Marginal malnutrition and working capacity. In: Nutrition in health and disease and international development. A.R. Harper and G.K. Davis (eds), Alan R. Liss, New York.

Viteri, F.E., B. Torún, J.C. Galicia and E. Herrera 1971 Determining energy costs of agricultural activities by respirometer and energy balance techniques. Am. J. Clin. Nutr. 24:1418-1430.