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ENERGY SUPPLEMENTATION AND WORK PERFORMANCE: SUMMARY OF INCAP STUDIES

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PHYSICAL ACTIVITY is a major determinant of dietary energy requirements. Humans tend to maintain an energy balance, such that if there is a dietary deficiency, energy expenditure is reduced, usually by a decrease in energy-demanding activities. This has been clearly shown in young children of preschool age who are not yet subject to social or peer presures that might influence their activities.

It is conceivable that adults who have a chronic dietary energy deficiency will accomodate by reducing their total energy expenditure, either by an adaptive reduction in basal metabolic rate or diminished physical activity. The latter may affect their work performance and productivity or, if social and economic conditions force them to continue working at a high pace, they will either lose weight or must rest and be more sedentary after work. This, in turn, may have a high social cost for the individual, his family and his community.

Non-mechanized agricultural work, which requires high energy expenditure, is the main source of family and national income in most developing countries. In many of those countries, rural populations have suboptimal or deficient dietary energy intakes. Due to this, since the mid-1960's we have studied the relation that diet and nutrition have with physical activity, work performance and productivity, in order to identify problems and propose solutions. These studies have included investigations on physical fitness of children and adults with different nutritional conditions and backgrounds; modifications in indices of work performance with changes in nutritional status; relationship of physical fitness, body composition and work capacity; energy cost of common and usual activities; energy intake and total energy expenditure; and physiological, behavioral and economic consequences of nutritional status and of changes in dietary intake. We will summarize in this paper the results of two studies that illustrate those consequences in groups of agricultural workers with different energy intakes.

STUDIES ON RURAL MEN IN THE GUATEMALAN MIDLANDS

Two groups of 18 men with similar ethnic and cultural backgrounds were studied. One group (SI) worked in a farm that had dairy cattle, at an altitude of 1700 m and average temperature of 22.3°C. Their ages were 17-57 years (median 24). For three years they had received a nutritional supplement (Incaparina gruel, based on 58% corn, 38% cottonseed flour and 4% vitamin and mineral mix with lysine) that provided 500 kcal and 11 g protein/day. They also had milk at a very low price and their wages were higher than their neighbors'. The other group (SAP), worked in similar agricultural chores around a village at an altitude of 700 m and average temperature of 25.4°C. They were 17-27 years old (median 20). Their diet was based on corn, beans, vegetables and small amounts of meat or cheese. Health and nutritional conditions in their community were similar to those in the communities around SI.

The men at SI had an intake of 3,555 $\pm$ 712 kcal and 107 $\pm$ 21 g protein/d

(26% protein with high biological value). The diet at SAP provided 2,693 ± 441 kcal and 82 ± 13 g protein/d (8% with high biological value). The men at SAP were lighter (50.8 ± 4.2 vs. 60.1 ± 5.4 kg) and leaner (92 ± 3 vs 87 ± 2% lean body mass) than the men at SI. Height was similar (159 ± 5 and 161 ± 5 cm) and when body composition was expressed per unit of height, the men from SI had significantly more LBM, muscle mass and adiposity.

The men of SI were more physically fit, based on the regression coefficients of heart rate on VO2 at different workloads and on maximal VO2/min. There were no differences in VO2 max per unit of body weight.

Both groups tended to maintain energy balance with total energy expenditure of 3,694 ± 464 (SI) and 2,700 ± 432 (SAP) kcal/d. When two subgroups of men matched for age and specific agricultural occupations were asked to do heavy standardized tasks for 3-6 days, which included wood-cutting, clearing a stretch of land with a machete and working with a hoe and a sickle, they were able to do the same amount of work but it took the men of SAP considerably more time (397 ± 123 vs 235 ± 40 minutes per day). The intensity of work was slightly greater in SI (5.1 ± 0.2 vs 4.6 ± 0.8 kcal/min), but since they did the work in less time, they spent 1,192 ± 128 kcal to perform the tasks, compared with 1,804 ± 141 kcal by SAP.

Under those conditions, total daily energy expenditure by SI was 3,569 kcal, which allowed maintaining energy balance and body weight. SAP spent 3,396 ± 543, which led to a negative balance of -707 ± 466 kcal/day and a weight loss of 346 ± 740 g in 3 days. This was accompanied by important differences in activity pattern as shown in the Table. The men from SAP took significantly longer to walk back home after work and they spent around 3 hours each day taking a nap and sitting, playing cards or doing other sedentary activities. In contrast, the men in SI did not nap, were active at home and played soccer. The Table also shows that the men at SI remained physically active for a significantly greater proportion of the day than men at SAP.

ACTIVITY PATTERNS OF MEN WITH DIFFERENT DIETARY ENERGY INTAKES

Group	Intake kcal/d	Time (minutes) spent each day in				Distribution of time (%) in:			
		Walking	Walking	Resting or sleeping:		Activities:		Resting or sleeping:	
		to work	from work	Daytime	At night	Work	Other	Daytime	At night
SI	3,555 ± 712	20 ± 4	22 ± 7 **	0 **	498 ± 54	16 ± 3 *	50 ± 15 **	0 **	34 ± 4
SAP	2,693 ± 441	25 ± 13	40 ± 13	173 ± 76	530 ± 42	27 ± 9	24 ± 8	12 ± 5	37 ± 3

Groups differ: * $p < 0.05$; ** $p < 0.01$ Values are means ± standard deviations

In conclusion, the higher energy intake allowed the performance of heavy work at a faster rate and permitted the continuance of physical activity after work. This is very important to support socially desirable and economically productive activities.

STUDIES ON SUGAR CANE CUTTERS IN THE COASTAL REGION

Two groups of men, 63 in community 1 and 95 in community 2, who lived within the same sugar cane plantation in the Pacific lowlands of Guatemala, were studied longitudinally for about three years. They had similar ages (34 ± 10 and 36 ± 12 years), weights (52.6 ± 5.4 and 53.5 ± 6 kg), heights (160 ± 6 and 159 ± 6 cm) and other anthropometric and body composition measurements. They also had similar lifestyles and worked under the same management for the same wages.

Their heaviest work period was sugar cane harvesting between November and June. The management assigned them to specific fields, where they worked as teams of four men. They would strip the leaves and cut the sugar cane with a machete, and load it on carts. When the carts were full, one team member accompanied them (pulled by a tractor) to the weighing station while the other three continued cutting. Starting time was determined by the management, who

would provide transportation to the cane fields. The number of working hours was decided by the workers themselves, who were payed on a piece-rate (i.e., by the amount of sugar cane cut and delivered to the weighing station). During the off-harvest season, the workers' main labor was to weed with a machete canefield sections assigned by the management. This was done individually and each man was assigned an area of 25 X 25 meters. The workers could choose their own working hours, were payed at a fixed wage rate and they were seldom assigned more than one section in one day. They did other chores during the remainder of the day, such as wood-chopping and planting corn, beans or vegetables for their home use.

Dietary habits were similar among both groups of men and food intake was slightly, but not significantly, greater in community 1 than 2: 3,048 ± 632 kcal and 86 ± 25 g protein/d, with 20 ± 16% animal protein, compared with 2,899 ± 717 kcal and 81 ± 22 g protein/d, 15 ± 15% of animal origin, in community 2.

The men's diets, physical fitness, energy expenditure and productivity were measured for 8 months, which included parts of the off-harvest and harvest seasons. Productivity was assessed in terms of the weight (tons) of cane cut and delivered per day, daily work time, days worked per week, length of cane furrow cut per hour, time needed to complete a standardized weeding task and wages earned (usually payed every 2 weeks).

After that period of time, workers in community 1 began receiving a low-energy supplement (LES) and in community 2, a high-energy supplement (HES). The supplements consisted of a 360-ml bottle of orange-flavored drink with 3.7 mg vitamin A and 16 mg vitamin C. The HES was sweetened with sugar and provided 350 kcal/bottle, and the LES had an artificial sweetener and 15 kcal/bottle. The supplements were cooled and taken to the fields twice daily, 5 days each week, where the men drank them under direct supervision. Supplementation continued for two years and the measurements done in the pre-supplementation period were repeated periodically.

Although the HES provided an average of 447 kcal/day over the whole study period, it had a gradually increasing substitution effect on home diet intake, which decreased to an average of 2,596 ± 726 kcal/d over the two years. Thus, the average total energy intake during the study was 3,043 ± 745 kcal/d, which represented a net increase over pre-supplementation values of only 150-300 kcal/d. The LES group had parallel changes in home diet intake, but of a somewhat lower magnitude and their average energy intake during the study (2,949 ± 761 kcal) did not differ from the pre-supplementation period.

Body weight remained constant with some cyclic fluctuations in both groups, and a slight but non-significant tendency to increase in the HES group. Total energy expenditure measured by either time-motion techniques or heart rate-VO2 relationships, did not change in relation to dietary intakes.

During the first 5 months of supplementation, physical fitness assessed by estimating VO2 max from submaximal tests on a bicycle ergometer, increased in the HES group but decreased afterwards and stabilized at pre-supplementation levels. Productivity increased in both groups in those 5 months, more so in the HES group, who maintained a higher productivity for 10 months. The transient initial increases in both groups can be attributed to the so-called Hawthorne effect., When questioned, the men said that they were not too tired after work, but "it was not worth their while" to cut some additional cane due to the low increase in earnings that it would represent.

By the beginning of the following harvest season, the international price of sugar soared, the workers were payed more for the cane they cut and better transportation was provided to facilitate their work. As a consequence, the amount of cane cut and the wages earned increased markedly and in similar proportions among both groups of men. Thus, the effect of the supplementation program was masked. Other productivity indicators, such as the time required to cut a standardized amount (or furrow length) of cane, or to perform a standard off-season task, were 10-20% better in the HES groups. This, however, could be partly due to differences in the characteristics of the terrains assigned to the two groups.

The 3-year productivity data in terms of sugar cane cut and delivered, was submitted to time series analysis using auto-regressive integrated moving averages. It showed that during the last harvest season studied, when the price of sugar had fallen again, the HES group tended to be more productive than the LES. This, again, could also be partly explained by differences in the cane fields assigned to the two groups and some managerial decisions that affected the workers' productivity.

In conclusion, although there were some subjective manifestations of feeling better and a transient increase in work performance at the beginning of the supplementation, other factors had a more powerful effect on productivity.

FINAL COMMENTS AND CONCLUSIONS

Energy intake is certainly an important determinant of physical activity and, by inference, of work performance. However, social and economic constraints or incentives can overwhelm and surpass the role of dietary conditions.

If a person is motivated and stimulated to work with an energy output that exceeds his/her intake, productivity will increase but a physical or social cost must be payed: the individual will lose body weight and/or become more sedentary, at the expense of decreased social interactions and discretional non-salaried activities. This, most probably, cannot be sustained for a prolonged period of time. In contrast, when economic and social incentives accompany adequate energy intakes, productivity -both during and after working hours- will increase.

In conclusion, good nutrition and health provide the biological basis for good physiological function and performance, but other factors, such as emotional, social and economic incentives, are required to create a proper physical and social atmosphere that will allow the optimal expression of that biological potential.

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