INCAP Publication PCI/034

# Influence of physical activity on energy and protein metabolism

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In: "Protein-Energy Interactions"
N.S. Scrimshaw & B. Schürch (Eds.)
Lausanne, Switzerland: International Dietary Energy Consultancy Group (IDECG), 1992.

Most studies of the metabolic and nutritional effects of exercise have been done in relation to sports and, more recently, to discretional increments of physical activity during leisure time. The outcome of several of these studies may also be important for the nutrition and health of persons who are neither athletes nor participants in jogging or physical fitness programs. For example, some issues in Wolfe's discussion on endurance exercise of submaximal intensity (this volume, pp. 221–228) may apply to persons engaged in moderate or heavy physical activity as part of their everyday life. In addition, the interactions of exercise and nutrition are important for people who are becoming aware of the health benefits of regular exercise, as well as for those whose changing lifestyles lead to a more sedentary activity pattern.

To complement Wolfe's presentation, a brief analysis will be made of some aspects of physical activity's influence on energy and protein metabolism, and especially on how they may relate to growth and to the nutrition of individuals and populations whose lifestyle and activity pattern are changing.

## 1. Exercise and efficiency of dietary energy and protein utilization

VITERI (1973) and VITERI and TORUN (1981) evaluated the growth and body composition of malnourished weanling rats that were pair-fed for 4–5 weeks with food limited to about 33, 50 and 75% of the normal daily intake of rats of the same age. Half of the animals on each diet were kept in small individual cages that restricted their movements, except for two hours daily, when they were placed in regular individual cages (Inactive group). The other rats were housed in regular individual cages and ran in a revolving drum daily for two hours (Active group).

With all the restricted diets, active animals grew more in weight and length than their pair-fed inactive counterparts. **Figure 1** illustrates

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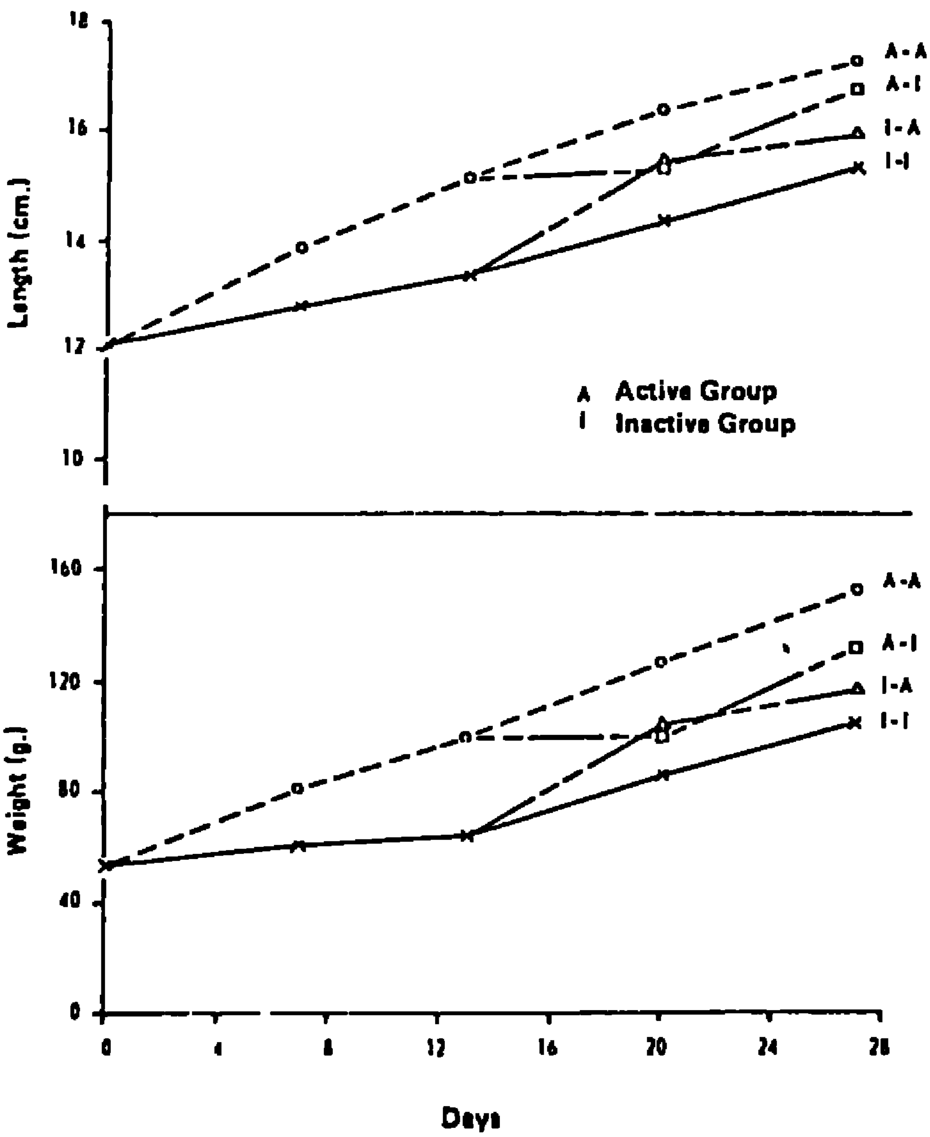


Figure 1. Effect of activity and inactivity in the growth of rats pair-fed a balanced diet restricted to 60% of normal intake. Half the rats were either active (A-A) or inactive (I-I) throughout the study, whereas the other half were switched from the active to the inactive protocol (A-I) or vice versa (I-A) after two weeks.

this in a study where a crossover design was followed at 2-week intervals (VITERI and TORUN, 1981). Body composition analyses showed that the active rats in each dietary group also had more body nitrogen, muscle and visceral mass. Therefore, malnourished active animals utilized dietary energy and protein more efficiently.

Based on these results, a program of games and activities that involved light and moderate physical exercise was incorporated in the daily routine of a group of preschool children (Active group) who were being treated for severe protein-energy malnutrition (VITERI and TORUN, 1981; TORUN *et al.*, 1976; 1979). During the wakeful hours of the day, their mean energy expenditure was 50 kcal (209 kJ)/h and average heart rate exceeded resting values by 26 beats/min. Another group of children, who followed the usual routine at the nutrition rehabilitation center (Control group), had a mean energy expenditure of 38 kcal (158 kJ)/h during wakeful hours and their heart rate exceeded resting values by 17 beats/min. Both groups had similar dietary intake (2.51±0.11 g protein and 94±9 kcal [393±38 kJ]/kg/d).

Mean dietary intake and total weight gain over a 6-week period were similar in both groups. However, as shown in Table 1, the active children gained more weight per unit of dietary energy retained and their longitudinal growth was greater. Although mean nitrogen retention was similar to that of the Control children, the increase in length, urinary creatinine excretion and basal metabolic rate, and the amount of energy retained per unit of weight gain, indicated that the active group grew more in lean body mass. As in the rat experiments, these findings indicate that physical activity can modify the efficiency of dietary energy and protein utilization.

Investigators from Berkeley (Butterfield and Calloway, 1984; Todd *et al.*, 1984) studied the effects of changes in energy balance on nitrogen retention of young men with marginal or adequate protein intakes (0.75 or 0.8 g/kg/d, respectively). Energy balance was made

**Table 1.** Comparison of children recovering from protein-energy malnutrition during six weeks with different patterns of physical activity (Mean ± SD)

| | ACTIVE (n=11) | | CONTROL (n=9) |
|---|---|---|---|
| ENERGY* | | | |
| Expenditure (kJ/kg/d) | 393±38 | ** | 310±33 |
| | (94±9) | | (74±8) |
| Retention (kJ/kg/d) | 109±38 | ** | 192±33 |
| | (26±9) | | (46±8) |
| Energy retained/wt gain (kJ/g) | 21±14 | ** | 39±12 |
| | (5.0±3.3) | | (9.3±2.9) |
| Initial BMR (kJ/h/m²) | 218±25 | | 192±30 |
| | (52.0±6.0) | | (46.0±7.2) |
| Final BMR (kJ/h/m²) | 250±24 | ** | 207±25 |
| | (59.8±5.7) | | (49.4±6.0) |
| NITROGEN | | | |
| Retention (mg/kg/d) | 145±37 | | 139±30 |
| URINARY CREATININE | | | |
| Increase in 6 weeks (mg/d) | 42±13 | ** | 31±12 |
| BODY LENGTH (mm) | | | |
| Initial | 799±33 | | 805±30 |
| Final | 821±32 | | 819±33 |
| Mean growth | 22 | ** | 14 |

* In parentheses: kcal.

** $p<0.05$

negative by decreasing dietary energy intake or by increasing expenditure through exercise while maintaining a fixed dietary intake. As expected, nitrogen balance fell with the decrease in energy balance, but it fell less when the reduction in energy balance was due to increased exercise than to lower energy intake. This suggests that sustained physical activity has a protein-sparing effect.

It is possible that the beneficial influence of physical activity on energy and protein utilization and on catch-up growth of children recovering from malnutrition also applies to healthy children undergoing periods of rapid growth, such as in infancy, early preschool age and puberty. In addition, these observations lead to questions related to the influence of changes in lifestyle on dietary requirements, as discussed below.

## 2. Effects of reduced physical activity on energy and protein metabolism

A marked restriction in physical activity can lead to growth impairment and a more inefficient use of dietary energy, as shown experimentally by VITERI (1973) and VITERI and TORUN (1981) in the studies with rats described above. It has also been shown that limb immobilization reduces protein synthesis and produces local muscle atrophy in rats (BOOTH, 1977; BOOTH and SEIDER, 1979). This was also demonstrated in men who were immobilized for several days in a plaster cast (SCHOENHEYDER *et al.*, 1954). Inactivity reduced their rate of protein synthesis and produced a marked negative nitrogen balance.

Another aspect of this negative effect of restricted movement on protein metabolism was demonstrated by MUSSACCHIA *et al.* (1980), who found that rats had a marked increase in the urinary excretion of 3-methylhistidine after one day of inactivity, and this metabolic response was sustained for at least the seven days of the experiment. This is contrary to the effects of exercise, which depresses the degradation of proteins that contain 3-methylhistidine and reduces the urinary excretion of that amino acid (MILLWARD *et al.*, 1982).

These studies indicate that inactivity has a catabolic effect on body proteins, which may be avoided or reduced by some form of exercise. This is clear under conditions where movement is severely limited, but it may also be relevant under less restrictive circumstances, as suggested by the studies on children recovering from malnutrition (VITERI and TORUN, 1981; TORUN *et al.*, 1976; 1979).

## 3. Energy substrates and changes in exercise pattern

The role of energy substrates on muscle and intermediary metabolism during exercise have been addressed at this meeting (by Wolfe, pp. 221–328, and Jéquier, pp. 123–138). The proportions of such substrates in habitual diets are changing in many parts of the world. For example, the diets in most industrialized countries and in urban areas of the developing world provide as much as 40% of energy from fats and only 45–65% from carbohydrates (WHO, 1990). A reduction in fat intake to less than 30% of dietary energy is being advocated, together with an increase in physical activity (WHO, 1990; BENGOA *et al.*, 1989; Food and Nutrition Board, 1989). This recommendation is based mainly on the role of saturated fats as risk factor for cardiovascular diseases. Whether it will influence energy and protein metabolism remains to be shown.

This issue may be more important for population groups whose intake of dietary fat is increasing. For example, the diet in rural areas of many developing countries usually provides 70–80% of energy as carbohydrates and only 10–15% as fats. However, urbanization and increased availability of industrially processed foods are increasing their fat intake to 25% or more of total energy. Since the protein-sparing effect of dietary energy is greater when carbohydrates, rather than fats, are the main energy substrate (MUNRO, 1964; RICHARDSON *et al.*, 1979; 1980), a question that can be asked is whether the protein needs of these populations may be increasing.

This question is more pertinent when dietary changes are accompanied by a decrease in physical activity. Many adults and adolescents in rural areas of developing countries perform every day activities that may be classified as endurance exercise of moderate and heavy intensity, such as walking long distances, sometimes on rugged terrain, carrying heavy loads, and many forms of non-mechanized agricultural work and household chores. Many of these people are migrating to urban areas (WHO, 1986; POPKIN and BISGROVE, 1987) and, in the process, becoming more sedentary. Therefore, in them the beneficial effects of exercise on protein metabolism will decrease. This can be especially important when dietary protein intake becomes marginal due to the high cost of foods rich in proteins of good nutritional quality. Thus, the question concerning an increment in dietary protein requirements is highly appropriate.

In conclusion, the changes in diet and activity patterns that characterize current modifications in the lifestyle of large population groups warrant a closer look at the nutritional and metabolic changes that might take place as a result.

## References


Bengoa, J.M., Torun, B., Behar, M., Scrimshaw, N.S.: Nutritional goals for health in Latin America. Food Nutr. Bull., *11*, 1, 4–20 (1989).

Booth, F.W.: Time course of muscular atrophy during immobilization of hind limbs of rats. J. Appl. Physiol.: Respir. Environ. Exerc. Physiol., *43*, 656–660 (1977).

Booth, F.W., Seider, M.J.: Early change in skeletal muscle protein synthesis after limb immobilization of rats. J. Appl. Physiol: Respir. Environ. Exerc. Physiol., *47*, 974–978 (1979).

Butterfield, G.E., Calloway, D.H.: Physical activity improves protein utilization in young men. Br. J. Nutr., *51*, 171–184 (1984).

Food and Nutrition Board/National Research Council: Diet and Health. National Academy Press, Washington, DC, 1989.

Millward, D.J., Davies, C.T.M., Holliday, D., Wolmen, S.L., Matthews, D., Rennie, M.: Effect of exercise on protein metabolism in humans as explored with stable isotopes. Fed. Proc., *41*, 2686–2691 (1982).

Munro, H.N.: General aspects of the regulation of protein metabolism by diet and by hormones. In: Mammalian Protein Metabolism, pp. 381–481, H.N. Munro, J.B. Allison (Eds.). Academic Press, New York, NY, 1964.

Mussachia, H.J., Deavers, D.R., Meininger, G.A., Davies, T.P.: A model for hypokinesia. Effects of muscle atrophy in the rat. J. Appl. Physiol. Environ. Exerc. Physiol., *48*, 479–486 (1980).

Popkin, B.M., Bisgrove, E.Z.: Urbanization and nutrition in low income countries. Carolina Population Center, University of North Carolina, Chapell Hill, NC, 1987.

Richardson, D.P., Wayler, A.H., Scrimshaw, N.S., Young, V.R.: Quantitative effect of an isoenergetic exchange of fat for carbohydrate in dietary protein utilization in healthy young men. Am. J. Clin. Nutr., *31*, 2217–2226 (1979).

Richardson, D.P., Scrimshaw, N.S., Young, V.R.: The effect of dietary sucrose on protein utilization in healthy young men. Am. J. Clin. Nutr., *33*, 264–272 (1980).

Schoenheyder, F., Heilskov, N.C.S., Olesen, K.: Isotopic studies and mechanism of negative nitrogen balance produced by immobilization. Scand. J. Clin. Lab. Invest., *6*, 178–188 (1954).

Todd, K.S., Butterfield, G.E., Calloway, D.H.: Nitrogen balance in men with adequate and deficient energy intake at three levels of work. J. Nutr., *114*, 2107–2118 (1984).

Torun, B., Schutz, Y., Bradfield, R., Viteri, F.E.: Effect of physical activity upon growth of children recovering from protein-calorie malnutrition (PCM). In: Proc. 10 Internat. Congr. Nutr, pp. 247–249. Victory-sha Press, Kyoto, Japan, 1976.

Torun, B., Schutz, Y., Viteri, F.E., Bradfield, R.B.: Growth, body composition and heart rate/$VO_2$ relationship changes during the nutritional recovery of children with two different physical activity levels. Bibl. Nutr. Dieta, *27*, 55–56 (1979).

Viteri, F.E.: Efecto de la inactividad sobre el crecimiento de ratas alimentadas con una dieta adecuada, a niveles de ingestion calorica restringidos. In: Nuevos Conceptos sobre Viejos Aspectos de la Desnutricion, pp. 207–229. Academia Mexicana de Pediatria, Mexico, 1973.

Viteri, F., Torun, B.: Nutrition, physical activity and growth. In: The Biology of Normal Human Growth, pp. 265–273, M. Ritzen *et al.*, (Eds.). Raven Press, New York, NY, 1981.

WHO: Intersectorial Action for Health. World Health Organization, Geneva, 1986.

WHO: Diet and Nutrition and the Prevention of Chronic Disease. WHO Technical Report Series No. 797. World Health Organization, Geneva, 1990.