ARCHIVOS LATINOAMERICANOS DE NUTRICION
Organo Oficial de la Sociedad Latinoamericana de Nutrición Vol. 58 Nº 1, 2008

Short stature and food habits as determining factors for the low productivity of sugarcane labourers in the State of Alagoas, north-eastern Brazil

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SUMMARY. Undernutrition, especially in the prenatal period and/or until 5 years of age, can cause stunting. Adults with short stature resultant from this process show a series of functional deficits, amongst which is a reduced capacity to do physical work. The aim of this investigation was to evaluate the dietary pattern, nutritional status and stature of sugarcane cutters, and to determine possible associations with worker productivity. Sixty-two male sugarcane cutters (18-50 y) were selected randomly from a population of 600 workers from a plantation in Alagoas (Brazil), and classified as underweight, normal weight or overweight according to BMI (BMI = 21.5, 21.5 to = 25 and >25 kg/m^2, respectively). Body fat composition (%) was estimated by electrical bioimpedance and dietary intake by the direct weighing of food consumed. Whilst the average productivity was 8.13 ton/day, labourers with normal BMI values were more productive (9.12 ton/dia) and ingested significantly ($p<0.05$) greater amounts of energy (16506.4 kJ/dia) than their underweight (7.48 ± 1.5; 12380.7 ± 4184.1) or overweight (9.12 ± 1.5; 16506.4 ± 6360.0) counterparts, respectively. There were associations (ñ<0.05) between productivity, stature, energy intake and age. The tallest individuals (= 170 cm) had higher productivity and tended to have a higher energy intake, whilst those with the shortest stature (= 160 cm), had a significantly lower productivity, however ingested a similar quantity of energy, and tended to have a large accumulation of body fat. Multiple regression analysis identified stature as the parameter most associated with productivity, independent of age and body fat percentage. Productivity of the tallest individuals was 1.87 ton/day higher than that of the shortest individuals. The results emphasise the importance of good nutritional status throughout life for full development of working productivity.
Keywords: Rural workers, malnutrition , energy intake, productivity.

RESUMO. Baixa estatura e hábitos alimentares como fatores determinantes de baixa produtividade em cortadores de cana do Estado de Alagoas, Nordeste do Brasil. A desnutrição, especialmente durante o período pré-natal e/ou até os 5 anos de idade, pode causar déficit estatural. Adultos com baixa estatura resultante desse processo revelam uma série de deficiências funcionais, tal como uma menor capacidade para realizar trabalho físico. O objetivo deste estudo foi avaliar o padrão dietético, o estado nutricional e a estatura de cortadores de cana e investigar possíveis associações com a produtividade desses trabalhadores. Sessenta e dois homens (18-50 anos) foram sorteados a partir de uma população de 600 trabalhadores de um canavial de Alagoas (Brasil) e classificados pelo Índice de Massa Corporal (IMC, kg/m^2) nas categorias baixo peso (= 21,5), normal (21,5 a = 25) ou sobrepeso (> 25). A proporção de gordura corporal (G%) foi estimada por bioimpedância elétrica e a ingestão dietética por pesagem direta dos alimentos. A produtividade média foi 8,13 toneladas/dia (t/dia). Os trabalhadores com IMC normal foram os mais produtivos (9,12 t/dia) e apresentaram maior ($p <0,05$) ingestão energética (16506,4 KJ/dia) relativamente àqueles com baixo peso (7,48 ± 1,5 t/dia; 12380,7 ± 4184,1 KJ/dia) ou com sobrepeso (9,12 ± 1,5 t/dia; 16506,4 ± 6360,0 KJ/dia). Houve associações (ñ <0,05) entre a produtividade, estatura, ingestão calórica e a idade. Os indivíduos mais altos (= 170 cm) tiveram maior produtividade e apresentaram tendência para uma maior ingestão energética, enquanto aqueles de menor estatura (= 160 cm), tiveram produtividade significativamente menor, ingeriram relativamente a mesma quantidade de energia e tenderam a ter maior acúmulo de gordura corporal. A análise de regressão múltipla identificou a estatura como a variável que mais fortemente associou-se com a produtividade, independentemente da idade e G%. A produtividade dos indivíduos mais altos foi 1,87 t/dia superior à dos indivíduos mais baixos. Esses resultados ressaltam a importância de uma boa condição nutricional ao longo da vida a fim de garantir a esses trabalhadores o pleno desenvolvimento de sua capacidade de trabalho.
Palavras-chave: Trabalhadores rurais, desnutrição, ingestão de energia, produtividade.

INTRODUCTION

Agricultural labour in developing countries is carried out by a large number of workers (1-3) whose productivity may be restricted by under-nourishment (4-6). There are few studies, however, concerning the productivity of rural workers involved in activities that demand high energy expenditure. It has been previously reported that the productivity of sugarcane cutters was directly related to his body size, lean mass and percentage of body fat, and that the capacity for intense

strenuous labour was proportional to the maximum consumption of oxygen (7-9). Furthermore, the studies showed that all of these determining factors were significantly diminished by chronic undernutrition.

In the northeast of Brazil, 60 million tons of sugar cane are produced annually, most of which is cut manually by a workforce of approximately 100,000 labourers who toil for an average of 8 h per day (10). Owing to the competitive nature of the sugarcane sector, the demand for intensive labour has increased in such a way that the amount of energy required from workers has doubled within the last few years.

The worldwide consumption of sugar increases annually about 2%. In this context, Brazil has an important role to play since some 900,000 Km^2 of its vast land mass are potentially available for sugarcane plantations (11). For these reasons, it is very important that the dietary pattern and health status of sugarcane labourers be thoroughly investigated.

A previous study of a low income urban population from this area revealed that the prevalence of short stature was 22.4% in adult males (12) and that nutritional habits were simple, consisting mainly of non-industrialised foods with low lipid intake and energy consumption below the recommended limits (13), representing a dietary pattern similar to that reported by Castro (14). The studied population consisted of 315 families from a rural population from Maceió, Northeastern Brazil who had migrated to large shanty towns in urban areas and had begun to present a high incidence of chronic diseases (15). It has previously been demonstrated that short stature (=160cm) is an independent and determining factor associated with obesity, hypertension (16) and increased risk of diabetes (17-19).

Since there is scarce literature concerning the effect of short stature on the productivity of rural workers, the present study investigated the dietary pattern, nutritional status and stature of sugarcane cutters in north-eastern Brazil to determine possible associations with worker productivity.

MATERIALS AND METHODS

Site of study and subjects

The study was conducted during the 2003/2004 harvesting season and involved sugarcane cutters employed by a factory 25 km distant from Maceió, the capital of the State of Alagoas, Brazil. The company employs approximately 1000 workers to process 750,000 tons of sugarcane each season: 600 of the workers are permanent employees and live in the region, whilst 400 are occasional workers.

The criteria for inclusion in the study were (i) male gender, medium brown ethnicity, (ii) permanent status of employment by the company, since the diet of such individuals during harvesting was likely to remain the same as that during the non-harvesting season, and (iii) individuals who claimed to perform intense physical activities during the non-harvesting season, in order to avoid any interference with respect to the studied variables through adaptation to strenuous work. The sample was randomly selected from all the 600 permanent workers of the company for the calculation, to reach percentage of 11%. This percentage allowed a precision of 2.5% at the 95% confidence interval. The selected group consisted of 66 men (18 -50 y), who lived in seven farms in the vicinity. During the study, two men left their jobs and two others changed their occupation at the factory, and hence the final sample population consisted of 62 sugarcane cutters.

Collection of data

Productivity levels were reported at the end of each working day and the results were compiled by the company's supervisor in a table that had to be confirmed by the workers and further verified by the representative of the Sugar Workers Trade Union. Since the remuneration of the labourers was based on the amount (in tons) of harvested sugarcane, it was possible to determine the productivity of each individual from the information provided by the factory, that measures the sugarcane harvest per day in tons. Mean productivity (tons/day) of each individual was determined during the 6 month harvesting period.

Each subject was asked to answer a questionnaire concerning personal details (including age), social, economic background and physical activity. Anthropometric parameters were obtained at the start and the end of the harvest season prior to the working day with subjects bare foot and using light clothes, and included weight, stature, skin fold thickness (triceps, biceps, suprailiac and subscapular) and body fat percentage. Body weight (kg) was determined using a Filizola® electronic scale with a maximum tare of 150 kg and a precision of 100 g, whilst height (cm) was determined using a stadiometer consisting of a non-extendable 2 m measuring tape with 0.1 cm subdivisions. Body mass index (BMI) was given by the quotient of body weight (kg) and the square of the height (m^2). In order to classify subjects according to their BMI values, the cut-off points proposed by the World Health Organization (20) were adapted since individuals below 21.5 kg/m^2 are not able to perform high intensity work efficiently. Thus, the cut-off points were: underweight, BMI = 21.5 kg/m^2; normal weight, 21.5 < BMI = 25 kg/m^2; and overweight/obesity BMI > 25 kg/m^2. Skin fold thickness was measured using a Lange calliper. Body fat composition (%) was calculated according to the equation proposed by Womersley & Durnim (21) based on the sum of skin fold thickness values. Body fat percentage was also determined by bioelectrical impedance using a Tanita-TBF 300 (Tanita Corporation of America, Arlington Heights, IL, USA) body fat analyser and the equation proposed by Brozek *et al.* (22). All measurements were carried out by trained professionals and followed the recommendations of Frisancho (22).

The typical physical activity of the sugarcane cutters was determined over a complete working period. Normally labourers left the factory headquarters at 5:00 h and were transported on company lorries to arrive in the fields at 6:00 h where they ate breakfast. Work commenced at 6:30 h and was characterised by continuous and repetitive movements that involved encircling the sugarcane stems, bending down, cutting the base of the canes, lifting the bundle, turning round and placing the material in piles. The labourers stopped at 11:00 h for a 2-h lunch break and then continued to work until 16:30 h when company lorries returned them to their homes.

In order to obtain information concerning the habitual eating habits of the subjects, the food that would normally be eaten by the labourers was weighed directly. Sugarcane cutters typically take their breakfast and lunch in two separate containers. On two random days, the meal containers were collected and transferred to the laboratory for weighing: alternative meals were provided by the researchers. In order to evaluate the evening meal, researchers visited their homes on two arbitrary days and weighed the food that would be consumed at dinner. All food samples were weighed on a Filizola electronic scale with a maximum tare of 1500 g and a precision of 0.05 g. At the same time, details about the composition and methods of preparation of the evaluated meals were obtained.

Since labourers chew sugarcane whilst cutting, researchers observed individuals during one half of a working period (4 hours) and determined their average consumption. The amount of sugarcane chewed was converted into juice equivalents in order to facilitate quantification. The energy values of the macronutrients consumed were calculated using a Brazilian software – Programa de Apoio à Nutrição (Nutrition Support Program) (24).

To calculate the energy requirements (ER) of the labourers, we considered the average values for men 18-60y, applying the following equation indicated by the World Health Organization (25):

$$ER = 0.0557 \times 62.5^{a} + 3.26296 \times 2.1^{b} = 14.162.8 \text{ KJ}$$

a = average current weight in our sample;
b = factor activity

Statistical analysis

The results were expressed in terms of central tendency and dispersion, and were analysed by ANOVA and, where appropriate, the Tukey post-hoc test. The homogeneity of variances was verified using Levene's test and the normality of the data was evaluated using the test of Shapiro-Wilk. Simple linear regression was used to assess the relation between the final values of BMI and the anthropometric variables and energy intake. Multiple regression analysis was performed to establish the main factors (stature, BMI and energy intake) associated with productivity after adjusting for age. All of the statistical analyses were carried out using SPSS 6.0 software (SPSS/PC + Inc., Chicago, IL, USA). A p value of 0.05 was considered statistically significant.

The study was approved by the Ethical Committee of the Federal University of Alagoas. Appropriate informed consent was obtained in writing from each participant prior to the study.

RESULTS

The anthropometric and nutritional profile is shown in Table 1. The average stature was 168.0 cm, the mean BMI was within the normal range, and the average body fat composition was 13.4%. The typical diet of the workers was composed of only 12 different types of food (Table 2) and provided a balanced content of macronutrients. The average consumption of sugarcane juice was 240 mL/day, and of water drank was 10 L/day (The amount of energy ingested was equivalent to 13774 kJ/day. The average productivity of each sugarcane cutter was 8.13 ± 1.6 ton/day.

TABLE 1
Characteristics of sugarcane cutters studied at a plantation in Marechal Deodoro (Alagoas, Brazil).

(n = 62)	Mean values ± SD (range)
Age (years)	34.7 ± 10.8 (18 – 50)
Weight (kg)	62.5+ 9.4 (53.5 – 71.5)
Stature (cm)	168.0 ± 7.4 (158.0 – 179.0)
Initial body fat (%)	13.4 ± 3.5 (8.3 – 19.2)
Final body fat (%)	13.0 ± 3.7 (7.8 – 18.0)
Productivity (ton/day)	8.13 ± 1.6 (4.2 – 12.0)
Energy requirements (kJ)	14162.8
Energy consumption (kJ/day)	13773.7 ± 5435.7 (10987.1 – 16.506.4)
Daily protein intake (g / kg body weight)	2.10 ± 0.6 (1.1 – 2.9)
Protein contribution to total energy value (TEV) (%)	15.0
Daily carbohydrate intake (g / kg body weight)	8.5 ± 2.5 (7.2 – 9.8)
Carbohydrate contribution to TEV (%)	64.0
Daily lipid intake (g / kg body weight)	1.2+0.3 (0.8 – 1.7)
Lipids contribution to TEV (%)	21.0

TABLE 2
Dietary composition and main types of food consumed by the sugarcane cutters studied at a plantation in Marechal Deodoro (Alagoas, Brazil)

Macronutrients	Types of food	Quantity (%) ± SD
Proteins	Roast beef, fried fish, minced chicken, boiled eggs	15.0 ± 6.9
Carbohydrates	Brown beans, boiled rice, pasta in oil and garlic sauce, boiled manioc, manioc flour, maize cuscus, sugar cane juice, coffee and sugar	64.0 ± 10.6
Lipids	Soy oil	21.0 ± 9.2

The labourers whose BMI values were within the normal range presented higher productivity and ingested significantly greater amounts of energy than underweight or overweight workers (Table 3). Individuals older than 40 years of age were less productive and ingested lower amounts of energy and proteins than their younger colleagues (Table 4). Although individuals aged between 30 and 35 years were the most productive, the actual differences in productivities were quite small (about 13%) for workers within the age range 18 to 40 years. A highly significant ($\tilde{n} < 0.0005$) association between age and productivity was found.

TABLE 3
Productivity, energy intake and nutrients according to body mass index (BMI) of sugarcane cutters studied at a plantation in Marechal Deodoro (Alagoas, Brazil)

BMI (kg/m^2)	Number of individuals n (%)	Average (±SD) productivity (ton/day)	Average (± SD) energy intake (kJ/day)	Average (± SD) daily nutrient intake (g/kg body weight)		
				Proteins	Carbohydrates	Lipids
< 21.5	25 (40.3%)	7.48 ± 1.5	12380.7 ± 4184.1	2.0 ± 0.5	7.4 ± 3.6	0.8 ± 0.6
21.5 – 25	30 (48.4%)	9.12 ± 1.5*	16506.4 ± 6360.0*	2.1 ± 1.5	9.8 ± 4.1*	1.7 ± 0.7*
> 25	7 (11.3%)	7.80 ± 1.7	13215.1 ± 1251.4	2.0 ± 0.5	8.5 ± 1.4	1.2 ± 0.3

* $\tilde{n} < 0.05$

TABLE 4
Productivity and intake of energy and proteins according to age groups of sugarcane cutters studied at a plantation in Marechal Deodoro (Alagoas, Brazil)

Age groups (years)	Number of individuals n (%)	Average productivity (ton/day)	Average daily energy intake (kJ/kg body weight)	Average daily protein intake (g/kg body weight)
18 – 24.9	16 (25.8%)	8.21 ± 1.1	245.6 ± 46.1	2.3 ± 0.4
25 – 29.9	10 (16.1%)	8.38 ± 1.7	252.3 ± 107.7	2.4 ± 0.7
30 – 34.9	9 (14.5%)	8.60 ± 1.6	241.0 ± 107.5	2.3 ± 0.8
35 – 39.9	10 (16.1%)	8.43 ± 2.0	223.4 ± 45.0	2.1 ± 0.6
40 – 44.9	9 (14.5%)	7.90 ± 1.8*	197.5 ± 63.5*	1.8 ± 0.6*
45 – 50	8 (12.9%)	7.25 ± 1.3*	177.8 ± 86.6*	1.7 ± 0.6*

* $\tilde{n} < 0.05$

There were statistically significant associations ($\tilde{n} < 0.05$) between productivity, stature, energy intake and age (Table 5). The tallest individuals had higher productivity and tended to have a higher energy and protein intake. Those with short stature (Height = 160 cm) had relatively higher protein and energy intake and tended to have a larger accumulation of body fat but not higher productivity. Older men tended to be of shorter stature than their younger counterparts and presented higher percentages of body fat and lower productivities. On the other hand, young men were taller, exhibited lower percentages of body fat and higher productivities. The loss of body fat during the harvesting season was minimal within all age groups and the mean differences were not statistically significant.

TABLE 5
Productivity, intake of energy and proteins, body fat composition and average age of sugarcane cutters at a plantation in Marechal Deodoro (Alagoas, Brazil) distributed according to stature groups

Stature (cm)	Number of individuals n (%)	Average age (years)	Average productivity (ton/day)	Average daily energy intake (kJ/day)	Average daily protein intake (g/ kg body weight)	Body fat composition		
						Initial (a) (%)	Final (b) (%)	Loss Δ = a - b
158 – 159.9	12 (19.4%)	42 ± 12.3	7.14 ± 1.6*	14292.5 ± 4300.3	2.2 ± 0.7	17.7 ± 4.3	16.6 ± 5.7	1.1
160 – 164.9	16 (25.8%)	35 ± 10.7	7.90 ± 1.7	11593.9 ± 4449.4	1.8 ± 0.7	13.7 ± 2.2	12.9 ± 2.0	0.8
165 – 169.9	12 (19.4%)	37 ± 10.3	7.95 ± 1.5	12041.6 ± 3969.6	1.9 ± 0.7	13.3 ± 3.6	12.4 ± 4.3	0.9
170 – 174.9	12 (19.4%)	30 ± 8.6	9.01 ± 1.5*	15388.8 ± 5217.7	2.4 ± 0.5	12.3 ± 3.5	11.4 ± 2.5	0.9
= 175	10 (16.1%)	26 ± 7.4	8.65 ± 1.4	15551.9 ± 6758.2	2.2 ± 0.7	9.8 ± 2.5	9.5 ± 1.9	0.3

* $p<0.05$

Multiple regression analysis of the results identified stature as the parameter most associated with productivity, even after adjusting for age and proportion of body fat. In this context, the tallest individuals (= 170 cm) cut 1.87 tons of sugar cane per day more than the shortest (= 160 cm) individuals.

DISCUSSION

In order to attain the production targets established by the sugar and alcohol industries, rural labourers must be able to endure intense physical activity during the long hours of work demanded throughout the harvesting season. The present results indicate that 48.4% of the total of sugarcane cutters studied presented BMI values above 21.5Kg/m^2, whilst their body fat percentages were similar to those found in athletes. Their productivity was 2-fold higher (8.13 ton/day) than that determined some decades earlier for Guatemalan and Colombian workers (7, 8, 26), with similar nutritional status. It is likely that the increment in productivity depends on the current wages system, based on worker productivity.

The diet of the studied labourers was monotonous but well-balanced in terms of macronutrients. The quantities of food consumed in each meal were small in accordance with the low level of earnings of the workers. Meals were characterised by ingredients rich in carbohydrates, and consisted basically of maize, beans, rice and manioc preparations, together with easily accessible animal products such as fish, free-range chicken and eggs. Drinking coffee with sugar was also common. Fruits and vegetables were rarely found in the evaluated meals. It is likely that this dietary profile amongst the rural population has been responsible for the high prevalence of short stature (27-29). It is well known that inadequate nutrition in early life and growth deficit can produce deleterious effects in adult life, including obesity and other symptoms associated with metabolic syndrome (30,31).

Studies involving different categories of manual workers have demonstrated that only well-nourished individuals are able fully to develop their productive potential (6, 32-35). The present investigation revealed that mean energy intake was 13773.7 kJ/day, whilst the ideal daily intake should be 14162.8 k according to the WHO (25) recommendations for highly active men or 15062.4 kJ/day (9). Underweight labourers ingested 12380.7 kJ/day only.

The average amount of protein ingested by workers was similar to that recommended for elite athletes, i.e. 1.5 to 2.5 g/kg weight (36). However, it is important to consider that when energy needs are not fully met, part of this protein can be used to overcome energy deficiency, especially in the case of underweight workers, rather than being channelled into normal dynamic and structural functions (26). According to Ferreira et al. (37), the daily intake of carbohydrate by individuals who perform intense physical exercise should be 10 g/kg body weight in order to restore muscle glycogen and to preserve muscle protein. This implies that to reach an adequate consumption of carbohydrate, these workers should ingest about 625g/day. The well-nourished (BMI = 21.5 kg/m$^{2)}$ ingested 612 g/day of carbohydrate, which is comparable with the recommended value. With respect to lipid nutrients, the undernourished workers (BMI < 21.5 kg/m^2) received amounts that were below the recommended daily intake of 1 g/kg body weight (38).

In the present study, highest productivity was associated with young (30 – 35 year old) and well-nourished (BMI = 21.5 < 25 kg/m^2) labourers, and this finding demonstrates the negative effect of underweight and overweight on productivity. A negative correlation between productivity and age was also established, and this was attributed to the diminished aerobic capacity of older workers, as previously suggested (39-41).

The present work demonstrated that men of short stature, although ingesting adequate energy amounts, exhibit increased body fat percentages and lower productivities compared with their taller workmates. Although it is not possible to affirm that the short stature of all the workers studied was determined by under-nutrition in the phases of growth and development,

as genetic factors can also be involved, the body of evidence seems to indicate that growth retardation is responsible for low productivity.. A study of sugarcane cutters in Australia and Zimbabwe (42) observed that the tallest men presented the highest aerobic capacities and were the most efficient workers. Moreover, a study in India reported that rural labourers ingesting higher amounts of energy and having larger chest girths (at inhalation) were the most productive (6).

In a previous study, we have shown that the prevalence of short stature amongst men living in a shanty town was 22.4 %. Since, most people living in this area are rural migrants, it may be that those with short stature were induced to migrate because of their low productivity, among other reasons (12).

Stepwise multiple regression analysis revealed a significant relationship between productivity, stature, BMI and energy intake, and emphasised the importance of nutritional status, during the early life of the individual to development of working capacity. The most productive workers were those with BMI = 21.5 kg/m^2, of high stature and with balanced energy intake (16506.4 kJ): moreover, their wages were higher implying that they could afford a better quality of life. Chronic undernutrition must be eradicated if an enhancement in rural productivity is to be achieved, and this goal will only be possible through an improvement in the quality of the diet of the workers.

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Recibido: 28-08-2007
Aceptado: 18-12-2007