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The Aerobic Power of Several Groups of Laborers in Colombia and the United States

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Summary. Physiological responses to exercise and anthropometry were measured in several groups of physical laborers. The groups included Colombian sugar cane cutters, sugar cane loaders and general farm laborers. In addition, migrant workers and civil service laborers from the United States were studied. The Colombian populations were generally shorter, weighed less and had less body fat than the United States groups. The nutritional state of the Colombian groups, as measured by the hematocrit, hemoglobin, serum albumin and total blood protein, appeared normal. The aerobic power of the Colombian populations was significantly larger than the United States groups. The larger aerobic power of the Colombian groups is probably related to greater physical fitness associated with the physical demands of their occupations.

Key words: Aerobic power – Oxygen consumption – Exercise laborers – Anthropometric measurements.

Measurements of maximal physiological responses during exercise have become standard procedures in a number of laboratories throughout the world. Determinations of aerobic power have been made in children (Andersen et al., 1974; Shepard et al., 1969), sedentary adults (Andersen and Hermansen, 1965; Michael and Horvath, 1965), athletes (Costill et al., 1971; Cunningham and Eynon, 1973), various "primitive" populations (Rode and Shephard, 1973; Wyndham, 1973), and have been used to evaluate coronary insufficiency (Rosing et al., 1974; Yanowitz et al., 1974), general physical fitness (Åstrand and Ryhming, 1954; Shephard, 1966), the effects of physical conditioning (Cunningham and Faulkner, 1969; Wilmore et al., 1970) and as indices of work capacity (Davies, 1973; Glick and Shvartz, 1974).

Data on the aerobic power of populations representing the manual labor force in developing countries are limited (Wyndham, 1973). It would be useful to have addi-

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tional information on the aerobic power or work capacity in populations where productivity, and therefore economic status, is more closely dependent on physical labor than in more industrialized countries.

During the past several years we have been studying laborers associated with the sugar cane industry in the Cauca Valley of Colombia, South America (Spurr et al., 1975). In the course of these studies, general farm laborers in Colombia not associated with the growing and harvesting of sugar cane, a group of American laborers of European ancestry and a group of Mexican-American migrant farm workers have also been studied for comparative purposes. The data obtained form the basis of the present paper.

Methods

The subjects for this study were three groups of adult males from Colombia and two groups from the United States. The Colombian populations included 55 sugar cane cutters, 28 sugar cane loaders and 18 agricultural workers engaged in general farming. The two United States populations involved 20 Milwaukee County civil service laborers and 15 Mexican-American migrant farm workers. The civil service laborers worked at a variety of tasks including golf course maintenance, snow shoveling, etc. The migrant workers were studied while in Wisconsin during the latter part of the harvest season.

The studies in Colombia and the United States were done by the same investigators utilizing similar equipment. The men reported to the laboratory in small groups. All subjects were given an orientation to treadmill walking and the overall experimental procedure. Heights and weights were measured with the subjects dressed in shorts. Skinfold measurements were made in triplicate at two sites, triceps and subcapsular, using a Lange skinfold caliper. The mean values were used in subsequent calculations. Body density was calculated using the formulae of Pascale et al. (1956) and percent fat according to Brozek et al. (1965).

In the three populations of Colombian agricultural workers, resting 12-lead electrocardiograms were recorded and 4 h postabsorptive venous blood samples were drawn for subsequent measurement of hemoglobin, hematocrit, total blood protein and serum albumin levels.

Resting measurements of heart rate, ventilation and oxygen uptake were made on all groups. The stress test procedure utilized a modification of the Balke and Ware (1959) progressive treadmill test. Following a 3 min warm up period at 3 mph and 2.5% grade, the subjects walked at 3 or 3.5 mph with grade changes of 2.5% every 2 min until termination. According to a proposal by Balke (1974) the decision to walk the subjects at 3.0 or 3.5 mph was based on the heart rate during the warm-up period. If the heart rate was less than 120 beats/min, the subject was exercised at 3.5 mph; if heart rate was 120 beats/min or more, subsequent exercise was performed at 3.0 mph. The general end point was fatigue, as evidenced by the inability to maintain the walking speed despite strong encouragement. Heart rate, ventilation and expired gas concentrations were monitored during the second minute of various submaximal workloads and during the last several minutes of exertion. Hard wire chest leads (CV_5) and Grass or Gilson recorders were used to record the heart rate. Minute ventilation was measured with a Parkinson-Cowan CD-4 gas meter. Aliquots of expired air were drawn from a mixing chamber with oiled glass syringes and subsequently analyzed for oxygen and carbon dioxide concentrations with a QuinTron gas chromatograph using standardized gas mixtures as references. Oxygen consumption (STPD) was calculated using standard open circuit procedures. The total work performed was calculated using the parameters of speed, grade, time and subject weight (Mathews and Fox, 1971).

A one-way analysis of variance was performed on group means. Where a significant F ratio was oberved, the Tukey HSD test (Steel and Torrie, 1960) was applied to determine which group differences were statistically significant at the 0.05 level. Except where indicated otherwise, the data are presented as means and standard deviations.

Results

The age and anthropometric measurements of the various groups are presented in Table 1. The lowest values for height were observed in the three groups of Colombian laborers and the United States migrant workers. The height differences among the Colombian laborers were not statistically significant, nor were the differences between the migrant workers, the sugar cane loaders and the general farm laborers. The United States civil service laborers were significantly taller than all of the other groups ($P < 0.05$).

The mean body weights for the three Colombian groups are similar, although the differences between the cutters and the farm laborers did reach statistical significance. Statistically, body weights of all of the Colombian groups were lower ($P < 0.05$) than those of the two United States groups. The United States migrant workers also had a statistically lower ($P < 0.05$) mean weight than the civil service laborers. The calculation of the weight/height ratio suggests significant differences ($P < 0.05$) between the Colombian and United States populations, while no significant differences were found between the United States groups.

The calculated fat percentages were similar for the loaders and cutters and were statistically lower than the other groups. The values for the general farm laborers and the migrant workers were also similar and were statistically lower than the civil service laborers. Body fat, normalized for height (kg/m), was lowest in the sugar

Table 1. Anthropometric measurements

		Age (yrs)	Height (cm)	Weight (kg)	Weight/height (kg/m)	Body fat (%)	Body fat (kg/m)	Lean body mass (kg)	Lean body mass (kg/m)
				Colombian groups					
Sugar cane loaders									
$N = 28$	$\bar{x}$	33.1	165.1	60.3	36.5	9.9	3.6	54.3	32.8
	SD	8.4	5.7	6.8	3.3	1.8	0.9	5.6	2.7
Sugar cane cutters									
$N = 55$	$\bar{x}$	29.1	163.0	57.8	35.4	10.3	3.6	52.5	31.7
	SD	7.0	6.3	5.5	2.6	1.3	0.6	5.4	2.3
General farm laborers $N = 18$	$\bar{x}$	25.5	164.8	61.4	37.2	11.6	4.4	54.4	32.8
	SD	4.5	5.0	9.9	5.4	3.1	1.8	7.5	4.0
				United States groups					
Civil service laborers									
$N = 20$	$\bar{x}$	27.4	175.0	75.9	43.7	15.2	6.6	64.2	36.6
	SD	3.0	8.1	9.0	4.9	2.8	1.6	6.6	2.8
Migrant workers									
$N = 15$	$\bar{x}$	22.1	166.7	71.0	42.6	11.7	5.4	62.3	37.0
	SD	4.3	4.8	6.8	4.2	2.6	1.6	5.3	4.1

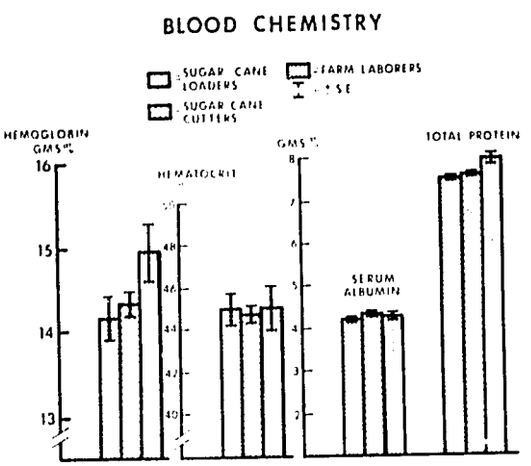

Fig. 1

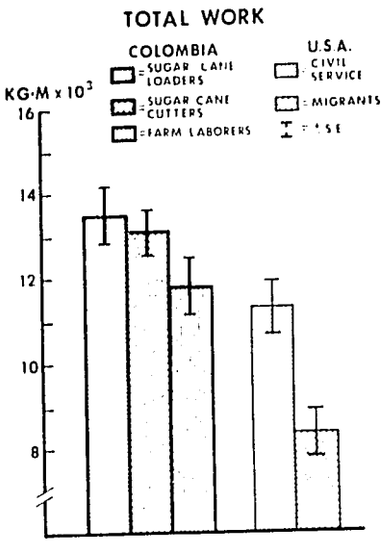

Fig. 2

Fig. 1. Blood chemistry of the various Colombian groups

Fig. 2. Total work performed during treadmill exercise test

cane workers, highest in the United States civil service laborers and intermediate in the Colombian farm laborers and migrant workers. The differences between the loaders and cutters were not significant, however, all other differences did attain statistical significance.

Analysis of the calculated mean lean body mass data, expressed both as percent or kg/m, indicates that the Colombian populations have values that are significantly lower ($P < 0.05$) than the United States groups but not different from each other. There were no statistically significant differences between the two United States groups.

The blood chemistry data is shown in Figure 1. With the exception of total protein, no significant differences were observed among the Colombian groups on the various blood measurements. The total protein levels of the general farm laborers were significantly higher than those of the cane loaders or cutters.

The maximal physiological responses are shown in Table 2. The highest mean values for maximum heart rate were observed with the civil service laborers (198 beats/min) followed by the migrant workers (192 beats/min) and the general farm laborers (190 beats/min). The lowest mean values were observed with the sugar cane loaders and cutters with the mean values of 181 and 182.5 beats/min, respectively. These latter values were statistically lower ($P < 0.05$) than all of the other groups but were not statistically different from each other. The values for the general farm laborers and the migrant workers were statistically lower than those of the civil service laborers but not different from each other.

The mean ventilations during maximal exercise, shown in Table 2, range between 106 - 120 l/min (BTPS). The only statistically significant differences were

Table 2. Maximal physiological responses

		Heart rate (beats/min)	$\dot{V}_I$-BTPS (l/min)	$\dot{V}O_2$-STPD (l/min)	$\dot{V}O_2$-STPD (ml/kg · min^{-1})	O_2 pulse (ml/beat)	$\dot{V}_I$ equivalent ($\dot{V}_I$/100 cc $\dot{V}O_2$)
				Colombian groups			
Sugar cane loaders	$\bar{x}$	181.0	111.41	2.971	49.0	16.4	4.0
	SD	10.4	20.12	0.474	7.2	2.4	0.6
Sugar cane cutters	$\bar{x}$	182.5	106.52	2.634	45.3	14.7	3.8
	SD	10.3	21.29	0.366	4.7	2.2	0.7
General farm laborers	$\bar{x}$	190.2	105.60	2.704	44.1	14.4	3.9
	SD	6.6	17.99	0.479	3.9	2.8	0.6
				United States groups			
Civil service laborers	$\bar{x}$	198.0	119.67	3.018	39.8	15.0	3.9
	SD	8.1	20.79	0.485	5.1	2.6	0.7
Migrant workers	$\bar{x}$	191.9	106.30	2.858	40.9	14.7	3.7
	SD	10.2	21.83	0.480	7.0	2.5	0.4

between the civil service laborers and the other groups. Larger ventilations are generally associated with the anthropometric characteristics of height and weight. When ventilation was normalized for height ($\dot{V}_I$/m) there were no significant differences among any of the groups.

The mean aerobic power appears to separate into three "strata". The mean value observed with the sugar cane loaders was significantly higher ($P < 0.05$) than all of the other groups. The cutters and Colombian farm laborers had slightly lower values but were not statistically different from each other. The lowest values were observed in the migrant workers and civil service laborers. The mean values for the latter two groups were not statistically different from each other.

The highest mean oxygen pulse was observed with the sugar cane loaders. This value was significantly higher ($P < 0.05$) than all of the other groups. The oxygen pulse for the remaining four groups ranged between 14.4–15.0 ml/beat and no significant differences were observed between these groups. The values for ventilation equivalent at $\dot{V}O_2$max were generally similar for the various groups with only the difference between the migrant workers and the sugar cane loaders attaining statistical significance.

The total accumulated work for the various groups is shown in Figure 2. The sugar cane loaders achieved the largest total work (13491 kgm). This value was significantly larger ($P < 0.05$) than all of the other groups with the exception of the sugar cane cutters. The work output of the cutters was significantly larger than the

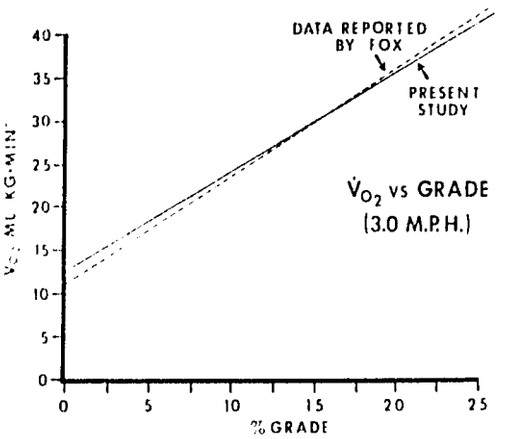

Fig. 3. Regression of $\dot{V}O_2$ on treadmill grade at constant speed of 3 mph

remaining groups. The values for the farm laborers and civil service laborers were not significantly different. All groups had statistically higher ($P < 0.05$) values than the migrant workers.

To compare the "efficiency" of our subjects with previously reported data the relationship between treadmill grade and oxygen uptake was determined for 24 subjects who walked at 3.0 mph. These data are shown in Figure 3 along with data reported by Fox (1974). The calculated regression lines are very similar.

Discussion

Growth and body size may be determined or modified by a variety of factors including ethnic background and nutritional state (Guzman, 1968; Verghese et al., 1969). The height measurements in our groups appear to be related to ethnic background. The tallest group consisted of civil service laborers. These subjects were Caucasians with a European ancestry. The height data for the migrant workers and the Colombian population were similar. In addition, the heights are very similar to data reported by Viteri (1971) for Guatemalan males considered to be in good nutritional state.

The body weight measurements separate into three divisions. The values for the three Colombian groups are similar to each other and to values reported by Viteri (1971) for well nourished Guatemalan males. When the height/weight ratio is calculated, the Colombian groups again have very similar values. The mean values are almost identical to those reported by Viteri (1971) for well nourished military service cadets and supplemented farm workers. The height/weight ratio for the two United States groups are similar to each other.

The calculated percent fat of different populations varies over a wide range and is influenced primarily by dietary patterns (Oscai and Holloszy, 1969) and activity levels (Bjorntorp et al., 1973; Boileau et al., 1975). Physically active populations tend to have less body fat, with athletes engaging in strenuous endurance exercise having very low fat levels (Costill et al., 1970). The lower fat values observed with

the sugar cane workers reflect in part the strenuous demands of their occupational tasks (Spurr et al., in press). The groups work at about 35% of their maximal oxygen uptake approximately 8 h/day year round. The lower fat values may also reflect dietary intake, since the caloric intake for the sugar cane cutters was estimated to be similar to their daily caloric expenditure (Spurr et al., 1975). The percentage fat observed with the general farm laborers and migrant workers are similar to values reported for farm laborers (Ikai et al., 1971). The value observed with the civil service laborers is similar to data generally reported for the American male (Costill et al., 1971). These data suggest that the occupational demands of this group are not sufficient to induce a significant reduction in adiposity.

A review of the results on lean body mass suggests a separation between the Colombian groups and the United States groups. Both in terms of total LBM and LBM/m, the Colombian groups have lower values than the United States groups. The differences are probably due more to body size than the nutritional state. This is supported by the observation that the ratio of LBM to height is very similar to the data of Viteri (1971) on well nourished Guatemalan subjects.

The maximal heart rates (Table 2) show the sugar cane workers to have lower values than the other groups. Several explanations for the significantly lower values of these two groups may be proposed: one possibility is age. The sugar cane workers were older than the other populations (Table 1) and a reduction in maximal heart rate with age has been reported (Astrand and Rodahl, 1970). However, on the basis of predicted maximal heart rate the values would be approximately 187 beats/min for the loaders and 191 beats/min for the cutters. Another explanation may be differences in physical fitness levels. In athletes, maximal heart rates tend to be lower after training (Ekblom et al., 1973; Pollock et al., 1969), although the difference is generally small. One could also speculate that they did not push themselves to maximal effort. This appears unlikely in light of several observations. First, the $\dot{V}O_2max$ attained by these groups was higher than the other groups and the criteria for attaining $\dot{V}O_2max$ were satisfied (Taylor et al., 1955). Secondly, it is apparent from Figure 1 that the total work attained by these two groups was generally significantly greater than the other groups. A further possible explanation may be previous nutritional status. Studies on the effects of acute malnutrition have reported a relative bradycardia (Keys et al., 1950). Whether this phenomena is exhibited at maximal levels of work has not been established. While there was no evidence of clinical malnutrition in these populations at the time of the study, the problem of chronic malnutrition does exist in this rural population of Colombia and the observations may reflect a manifestation of malnutrition earlier in life.

The differences in maximal ventilations observed between the various groups in this study appeared to be related to differences in body size. When the ratio of maximal exercise ventilation to body height is calculated the values are quite similar, varying between 64–68 l/m.

The maximal aerobic power is influenced by a variety of factors including genetic endowment (Klissouras et al., 1973), nutritional state (Keys et al., 1950), environmental factors (Faulkner et al., 1968; Pugh et al., 1964), physical fitness levels (Costill et al., 1971; Saltin et al., 1968) and age (Astrand and Rodahl, 1970). The highest values are generally observed in endurance athletes and a decrease is observed with age (Astrand and Rodahl, 1970). The values observed with the sugar

cane loaders are similar to data reported for other groups of physically-active populations, as reported by Wyndham (1973). The aerobic power of the loaders is significantly higher than the other groups in this study. If one applies an age correction, the difference would be increased further, since the loaders are also the oldest group studied. The values observed for the sugar cane cutters and the Colombian farm laborers, while lower than those seen with the loaders, are also generally typical of workers in physically demanding occupations (Wyndham, 1973). The mean values are slightly higher than values reported by Viteri (1971) for nutritionally supplemented farm laborers in Guatemala.

The aerobic power of the other groups averages about 40 ml/kg · min $^{-1}$. Since these groups are generally younger, the lower aerobic power is probably related to poorer physical fitness levels. This may reflect the level of occupational effort and/or the activity profiles during their leisure. We would speculate that the occupational demands of laborers engaged in civil service occupations in the United States are not physically demanding.

The relatively low aerobic power of the migrant workers is puzzling. This may reflect in part the seasonal nature of the occupations and, perhaps, a higher degree of mechanization than that available to the Colombian workers. All sugar cane cutting and loading is done by hand in Colombia. The sugar cane cutters average 3.52 t of sugar cane per day (Spurr et al., in press), while the loaders attain 9.70 t/day (unpublished data). We have no information on the "productivity" of the United States laborers, but doubt that the tasks are as demanding as those of the Colombian sugar cane workers.

The oxygen pulse, which provides an index of stroke volume (Astrand and Rodahl, 1970), followed the pattern observed for aerobic power. The highest value was observed with the loaders reflecting their higher aerobic power and lower maximal heart rate. This is consistent with the observation that stroke volume is higher in the trained state (Saltin et al., 1968).

The total work performed generally followed the expected pattern with the highest levels attained by the group with the largest aerobic power. The major exception is the population of migrant workers. While their aerobic power was similar to that of the United States laborers, the total workload achieved was significantly lower. One may speculate that the type of work performed by migrant workers, namely, picking various crops, may not enhance peripheral adaptation of the leg musculature; therefore this group would tend to experience leg muscle fatigue earlier. The specificity of training on aerobic power (Hermansen and Saltin, 1969; Rode and Shephard, 1973) and on cellular adaptation has previously been documented (Baldwin et al., 1973; Gollnick et al., 1974).

In summary, the aerobic power of the various groups appears consistent with reported literature on nonathletic populations. Groups engaged in physically demanding occupations have a higher aerobic power than those involved in more sedentary tasks.

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The Aerobic Power of Several Groups of Laborers in Colombia and the United States

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Summary. Physiological responses to exercise and anthropometry were measured in several groups of physical laborers. The groups included Colombian sugar cane cutters, sugar cane loaders and general farm laborers. In addition, migrant workers and civil service laborers from the United States were studied. The Colombian populations were generally shorter, weighed less and had less body fat than the United States groups. The nutritional state of the Colombian groups, as measured by the hematocrit, hemoglobin, serum albumin and total blood protein, appeared normal. The aerobic power of the Colombian populations was significantly larger than the United States groups. The larger aerobic power of the Colombian groups is probably related to greater physical fitness associated with the physical demands of their occupations.

Key words: Aerobic power – Oxygen consumption – Exercise laborers – Anthropometric measurements.

Measurements of maximal physiological responses during exercise have become standard procedures in a number of laboratories throughout the world. Determinations of aerobic power have been made in children (Andersen et al., 1974; Shepard et al., 1969), sedentary adults (Andersen and Hermansen, 1965; Michael and Horvath, 1965), athletes (Costill et al., 1971; Cunningham and Eynon, 1973), various "primitive" populations (Rode and Shephard, 1973; Wyndham, 1973), and have been used to evaluate coronary insufficiency (Rosing et al., 1974; Yanowitz et al., 1974), general physical fitness (Åstrand and Ryhming, 1954; Shephard, 1966), the effects of physical conditioning (Cunningham and Faulkner, 1969; Wilmore et al., 1970) and as indices of work capacity (Davies, 1973; Glick and Shvartz, 1974).

Data on the aerobic power of populations representing the manual labor force in developing countries are limited (Wyndham, 1973). It would be useful to have addi-

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tional information on the aerobic power or work capacity in populations where productivity, and therefore economic status, is more closely dependent on physical labor than in more industrialized countries.

During the past several years we have been studying laborers associated with the sugar cane industry in the Cauca Valley of Colombia, South America (Spurr et al., 1975). In the course of these studies, general farm laborers in Colombia not associated with the growing and harvesting of sugar cane, a group of American laborers of European ancestry and a group of Mexican-American migrant farm workers have also been studied for comparative purposes. The data obtained form the basis of the present paper.

Methods

The subjects for this study were three groups of adult males from Colombia and two groups from the United States. The Colombian populations included 55 sugar cane cutters, 28 sugar cane loaders and 18 agricultural workers engaged in general farming. The two United States populations involved 20 Milwaukee County civil service laborers and 15 Mexican-American migrant farm workers. The civil service laborers worked at a variety of tasks including golf course maintenance, snow shoveling, etc. The migrant workers were studied while in Wisconsin during the latter part of the harvest season.

The studies in Colombia and the United States were done by the same investigators utilizing similar equipment. The men reported to the laboratory in small groups. All subjects were given an orientation to treadmill walking and the overall experimental procedure. Heights and weights were measured with the subjects dressed in shorts. Skinfold measurements were made in triplicate at two sites, triceps and subcapsular, using a Lange skinfold caliper. The mean values were used in subsequent calculations. Body density was calculated using the formulae of Pascale et al. (1956) and percent fat according to Brozek et al. (1965).

In the three populations of Colombian agricultural workers, resting 12-lead electrocardiograms were recorded and 4 h postabsorptive venous blood samples were drawn for subsequent measurement of hemoglobin, hematocrit, total blood protein and serum albumin levels.

Resting measurements of heart rate, ventilation and oxygen uptake were made on all groups. The stress test procedure utilized a modification of the Balke and Ware (1959) progressive treadmill test. Following a 3 min warm up period at 3 mph and 2.5% grade, the subjects walked at 3 or 3.5 mph with grade changes of 2.5% every 2 min until termination. According to a proposal by Balke (1974) the decision to walk the subjects at 3.0 or 3.5 mph was based on the heart rate during the warm-up period. If the heart rate was less than 120 beats/min, the subject was exercised at 3.5 mph; if heart rate was 120 beats/min or more, subsequent exercise was performed at 3.0 mph. The general end point was fatigue, as evidenced by the inability to maintain the walking speed despite strong encouragement. Heart rate, ventilation and expired gas concentrations were monitored during the second minute of various submaximal workloads and during the last several minutes of exertion. Hard wire chest leads (CV_5) and Grass or Gilson recorders were used to record the heart rate. Minute ventilation was measured with a Parkinson-Cowan CD-4 gas meter. Aliquots of expired air were drawn from a mixing chamber with oiled glass syringes and subsequently analyzed for oxygen and carbon dioxide concentrations with a QuinTron gas chromatograph using standardized gas mixtures as references. Oxygen consumption (STPD) was calculated using standard open circuit procedures. The total work performed was calculated using the parameters of speed, grade, time and subject weight (Mathews and Fox, 1971).

A one-way analysis of variance was performed on group means. Where a significant F ratio was oberved, the Tukey HSD test (Steel and Torrie, 1960) was applied to determine which group differences were statistically significant at the 0.05 level. Except where indicated otherwise, the data are presented as means and standard deviations.

Results

The age and anthropometric measurements of the various groups are presented in Table 1. The lowest values for height were observed in the three groups of Colombian laborers and the United States migrant workers. The height differences among the Colombian laborers were not statistically significant, nor were the differences between the migrant workers, the sugar cane loaders and the general farm laborers. The United States civil service laborers were significantly taller than all of the other groups ($P < 0.05$).

The mean body weights for the three Colombian groups are similar, although the differences between the cutters and the farm laborers did reach statistical significance. Statistically, body weights of all of the Colombian groups were lower ($P < 0.05$) than those of the two United States groups. The United States migrant workers also had a statistically lower ($P < 0.05$) mean weight than the civil service laborers. The calculation of the weight/height ratio suggests significant differences ($P < 0.05$) between the Colombian and United States populations, while no significant differences were found between the United States groups.

The calculated fat percentages were similar for the loaders and cutters and were statistically lower than the other groups. The values for the general farm laborers and the migrant workers were also similar and were statistically lower than the civil service laborers. Body fat, normalized for height (kg/m), was lowest in the sugar

Table 1. Anthropometric measurements

		Age (yrs)	Height (cm)	Weight (kg)	Weight/height (kg/m)	Body fat (%)	Body fat (kg/m)	Lean body mass (kg)	Lean body mass (kg/m)
				Colombian groups					
Sugar cane loaders									
$N = 28$	$\bar{x}$	33.1	165.1	60.3	36.5	9.9	3.6	54.3	32.8
	SD	8.4	5.7	6.8	3.3	1.8	0.9	5.6	2.7
Sugar cane cutters									
$N = 55$	$\bar{x}$	29.1	163.0	57.8	35.4	10.3	3.6	52.5	31.7
	SD	7.0	6.3	5.5	2.6	1.3	0.6	5.4	2.3
General farm laborers $N = 18$	$\bar{x}$	25.5	164.8	61.4	37.2	11.6	4.4	54.4	32.8
	SD	4.5	5.0	9.9	5.4	3.1	1.8	7.5	4.0
				United States groups					
Civil service laborers									
$N = 20$	$\bar{x}$	27.4	175.0	75.9	43.7	15.2	6.6	64.2	36.6
	SD	3.0	8.1	9.0	4.9	2.8	1.6	6.6	2.8
Migrant workers									
$N = 15$	$\bar{x}$	22.1	166.7	71.0	42.6	11.7	5.4	62.3	37.0
	SD	4.3	4.8	6.8	4.2	2.6	1.6	5.3	4.1

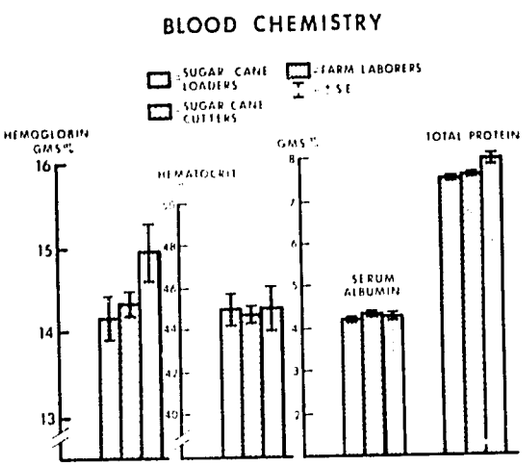

Fig. 1

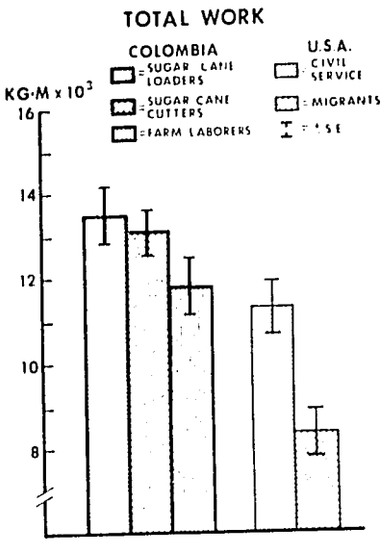

Fig. 2

Fig. 1. Blood chemistry of the various Colombian groups

Fig. 2. Total work performed during treadmill exercise test

cane workers, highest in the United States civil service laborers and intermediate in the Colombian farm laborers and migrant workers. The differences between the loaders and cutters were not significant, however, all other differences did attain statistical significance.

Analysis of the calculated mean lean body mass data, expressed both as percent or kg/m, indicates that the Colombian populations have values that are significantly lower ($P < 0.05$) than the United States groups but not different from each other. There were no statistically significant differences between the two United States groups.

The blood chemistry data is shown in Figure 1. With the exception of total protein, no significant differences were observed among the Colombian groups on the various blood measurements. The total protein levels of the general farm laborers were significantly higher than those of the cane loaders or cutters.

The maximal physiological responses are shown in Table 2. The highest mean values for maximum heart rate were observed with the civil service laborers (198 beats/min) followed by the migrant workers (192 beats/min) and the general farm laborers (190 beats/min). The lowest mean values were observed with the sugar cane loaders and cutters with the mean values of 181 and 182.5 beats/min, respectively. These latter values were statistically lower ($P < 0.05$) than all of the other groups but were not statistically different from each other. The values for the general farm laborers and the migrant workers were statistically lower than those of the civil service laborers but not different from each other.

The mean ventilations during maximal exercise, shown in Table 2, range between 106 - 120 l/min (BTPS). The only statistically significant differences were

Table 2. Maximal physiological responses

		Heart rate (beats/min)	$\dot{V}_I$-BTPS (l/min)	$\dot{V}O_2$-STPD (l/min)	$\dot{V}O_2$-STPD (ml/kg · min^{-1})	O_2 pulse (ml/beat)	$\dot{V}_I$ equivalent ($\dot{V}_I$/100 cc $\dot{V}O_2$)
				Colombian groups			
Sugar cane loaders	$\bar{x}$	181.0	111.41	2.971	49.0	16.4	4.0
	SD	10.4	20.12	0.474	7.2	2.4	0.6
Sugar cane cutters	$\bar{x}$	182.5	106.52	2.634	45.3	14.7	3.8
	SD	10.3	21.29	0.366	4.7	2.2	0.7
General farm laborers	$\bar{x}$	190.2	105.60	2.704	44.1	14.4	3.9
	SD	6.6	17.99	0.479	3.9	2.8	0.6
				United States groups			
Civil service laborers	$\bar{x}$	198.0	119.67	3.018	39.8	15.0	3.9
	SD	8.1	20.79	0.485	5.1	2.6	0.7
Migrant workers	$\bar{x}$	191.9	106.30	2.858	40.9	14.7	3.7
	SD	10.2	21.83	0.480	7.0	2.5	0.4

between the civil service laborers and the other groups. Larger ventilations are generally associated with the anthropometric characteristics of height and weight. When ventilation was normalized for height ($\dot{V}_I$/m) there were no significant differences among any of the groups.

The mean aerobic power appears to separate into three "strata". The mean value observed with the sugar cane loaders was significantly higher ($P < 0.05$) than all of the other groups. The cutters and Colombian farm laborers had slightly lower values but were not statistically different from each other. The lowest values were observed in the migrant workers and civil service laborers. The mean values for the latter two groups were not statistically different from each other.

The highest mean oxygen pulse was observed with the sugar cane loaders. This value was significantly higher ($P < 0.05$) than all of the other groups. The oxygen pulse for the remaining four groups ranged between 14.4–15.0 ml/beat and no significant differences were observed between these groups. The values for ventilation equivalent at $\dot{V}O_2$max were generally similar for the various groups with only the difference between the migrant workers and the sugar cane loaders attaining statistical significance.

The total accumulated work for the various groups is shown in Figure 2. The sugar cane loaders achieved the largest total work (13491 kgm). This value was significantly larger ($P < 0.05$) than all of the other groups with the exception of the sugar cane cutters. The work output of the cutters was significantly larger than the

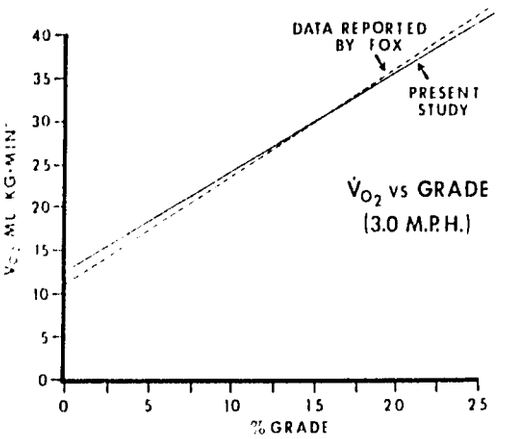

Fig. 3. Regression of $\dot{V}O_2$ on treadmill grade at constant speed of 3 mph

remaining groups. The values for the farm laborers and civil service laborers were not significantly different. All groups had statistically higher ($P < 0.05$) values than the migrant workers.

To compare the "efficiency" of our subjects with previously reported data the relationship between treadmill grade and oxygen uptake was determined for 24 subjects who walked at 3.0 mph. These data are shown in Figure 3 along with data reported by Fox (1974). The calculated regression lines are very similar.

Discussion

Growth and body size may be determined or modified by a variety of factors including ethnic background and nutritional state (Guzman, 1968; Verghese et al., 1969). The height measurements in our groups appear to be related to ethnic background. The tallest group consisted of civil service laborers. These subjects were Caucasians with a European ancestry. The height data for the migrant workers and the Colombian population were similar. In addition, the heights are very similar to data reported by Viteri (1971) for Guatemalan males considered to be in good nutritional state.

The body weight measurements separate into three divisions. The values for the three Colombian groups are similar to each other and to values reported by Viteri (1971) for well nourished Guatemalan males. When the height/weight ratio is calculated, the Colombian groups again have very similar values. The mean values are almost identical to those reported by Viteri (1971) for well nourished military service cadets and supplemented farm workers. The height/weight ratio for the two United States groups are similar to each other.

The calculated percent fat of different populations varies over a wide range and is influenced primarily by dietary patterns (Oscai and Holloszy, 1969) and activity levels (Bjorntorp et al., 1973; Boileau et al., 1975). Physically active populations tend to have less body fat, with athletes engaging in strenuous endurance exercise having very low fat levels (Costill et al., 1970). The lower fat values observed with

the sugar cane workers reflect in part the strenuous demands of their occupational tasks (Spurr et al., in press). The groups work at about 35% of their maximal oxygen uptake approximately 8 h/day year round. The lower fat values may also reflect dietary intake, since the caloric intake for the sugar cane cutters was estimated to be similar to their daily caloric expenditure (Spurr et al., 1975). The percentage fat observed with the general farm laborers and migrant workers are similar to values reported for farm laborers (Ikai et al., 1971). The value observed with the civil service laborers is similar to data generally reported for the American male (Costill et al., 1971). These data suggest that the occupational demands of this group are not sufficient to induce a significant reduction in adiposity.

A review of the results on lean body mass suggests a separation between the Colombian groups and the United States groups. Both in terms of total LBM and LBM/m, the Colombian groups have lower values than the United States groups. The differences are probably due more to body size than the nutritional state. This is supported by the observation that the ratio of LBM to height is very similar to the data of Viteri (1971) on well nourished Guatemalan subjects.

The maximal heart rates (Table 2) show the sugar cane workers to have lower values than the other groups. Several explanations for the significantly lower values of these two groups may be proposed: one possibility is age. The sugar cane workers were older than the other populations (Table 1) and a reduction in maximal heart rate with age has been reported (Astrand and Rodahl, 1970). However, on the basis of predicted maximal heart rate the values would be approximately 187 beats/min for the loaders and 191 beats/min for the cutters. Another explanation may be differences in physical fitness levels. In athletes, maximal heart rates tend to be lower after training (Ekblom et al., 1973; Pollock et al., 1969), although the difference is generally small. One could also speculate that they did not push themselves to maximal effort. This appears unlikely in light of several observations. First, the $\dot{V}O_2max$ attained by these groups was higher than the other groups and the criteria for attaining $\dot{V}O_2max$ were satisfied (Taylor et al., 1955). Secondly, it is apparent from Figure 1 that the total work attained by these two groups was generally significantly greater than the other groups. A further possible explanation may be previous nutritional status. Studies on the effects of acute malnutrition have reported a relative bradycardia (Keys et al., 1950). Whether this phenomena is exhibited at maximal levels of work has not been established. While there was no evidence of clinical malnutrition in these populations at the time of the study, the problem of chronic malnutrition does exist in this rural population of Colombia and the observations may reflect a manifestation of malnutrition earlier in life.

The differences in maximal ventilations observed between the various groups in this study appeared to be related to differences in body size. When the ratio of maximal exercise ventilation to body height is calculated the values are quite similar, varying between 64–68 l/m.

The maximal aerobic power is influenced by a variety of factors including genetic endowment (Klissouras et al., 1973), nutritional state (Keys et al., 1950), environmental factors (Faulkner et al., 1968; Pugh et al., 1964), physical fitness levels (Costill et al., 1971; Saltin et al., 1968) and age (Astrand and Rodahl, 1970). The highest values are generally observed in endurance athletes and a decrease is observed with age (Astrand and Rodahl, 1970). The values observed with the sugar

cane loaders are similar to data reported for other groups of physically-active populations, as reported by Wyndham (1973). The aerobic power of the loaders is significantly higher than the other groups in this study. If one applies an age correction, the difference would be increased further, since the loaders are also the oldest group studied. The values observed for the sugar cane cutters and the Colombian farm laborers, while lower than those seen with the loaders, are also generally typical of workers in physically demanding occupations (Wyndham, 1973). The mean values are slightly higher than values reported by Viteri (1971) for nutritionally supplemented farm laborers in Guatemala.

The aerobic power of the other groups averages about 40 ml/kg · min $^{-1}$. Since these groups are generally younger, the lower aerobic power is probably related to poorer physical fitness levels. This may reflect the level of occupational effort and/or the activity profiles during their leisure. We would speculate that the occupational demands of laborers engaged in civil service occupations in the United States are not physically demanding.

The relatively low aerobic power of the migrant workers is puzzling. This may reflect in part the seasonal nature of the occupations and, perhaps, a higher degree of mechanization than that available to the Colombian workers. All sugar cane cutting and loading is done by hand in Colombia. The sugar cane cutters average 3.52 t of sugar cane per day (Spurr et al., in press), while the loaders attain 9.70 t/day (unpublished data). We have no information on the "productivity" of the United States laborers, but doubt that the tasks are as demanding as those of the Colombian sugar cane workers.

The oxygen pulse, which provides an index of stroke volume (Astrand and Rodahl, 1970), followed the pattern observed for aerobic power. The highest value was observed with the loaders reflecting their higher aerobic power and lower maximal heart rate. This is consistent with the observation that stroke volume is higher in the trained state (Saltin et al., 1968).

The total work performed generally followed the expected pattern with the highest levels attained by the group with the largest aerobic power. The major exception is the population of migrant workers. While their aerobic power was similar to that of the United States laborers, the total workload achieved was significantly lower. One may speculate that the type of work performed by migrant workers, namely, picking various crops, may not enhance peripheral adaptation of the leg musculature; therefore this group would tend to experience leg muscle fatigue earlier. The specificity of training on aerobic power (Hermansen and Saltin, 1969; Rode and Shephard, 1973) and on cellular adaptation has previously been documented (Baldwin et al., 1973; Gollnick et al., 1974).

In summary, the aerobic power of the various groups appears consistent with reported literature on nonathletic populations. Groups engaged in physically demanding occupations have a higher aerobic power than those involved in more sedentary tasks.

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