Comparative Study of Physiological and Anthropometric Characteristics of High and Low Productivity Workers in Northern West Bengal, India

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ABSTRACT Lung function, selected hematological traits, blood pressures, and anthropometric dimensions were measured on adult Oraon tea garden laborers of both sexes from two tea gardens of Jaipaiguri district, northern West Bengal, India. The laborers were classified into two groups on the basis of work output or productivity, measured in terms of the quantity of green leaves plucked per day. The groups were similar in income, dietary pattern, and self-reported morbidity. Relationships between the measured variables and productivity were evaluated. The results show several significant relationships, but do not conclusively demonstrate that the independent variables under study have any effects on work output.

The tea industry is of considerable importance in the national economy of India. Therefore, its sustained development through increased production is desirable. The production of tea depends to a large extent on human labor, especially on laborers who pluck green leaves. In India, plucking is done manually and the higher the amount of leaves plucked, the higher the production of marketable tea. It is, therefore, important to inquire into the possible correlates of, or factors affecting, productivity measured in terms of the amount of leaves plucked per unit time.

It is intuitively understood that nutritional and health status are important factors affecting the capacity to perform hard and prolonged physical activity, in addition to socioeconomic and cultural factors (Shepard, 1978). Capacity for prolonged activity is also influenced by other factors, e.g., age, sex, physique, motivation, intensity, duration, rhythm, technique, and skill (Astrand and Rodahl, 1977). This report examines several health-related physiological characteristics of the cardio-respiratory system and anthropometric dimensions of tea garden laborers in relation to the amount of leaves plucked per unit time.

Lung function is defined as the maximal ability to move gas rapidly in and out of the lungs (Cotes, 1979). Measures of lung function are of interest in the study of adaptation (Valasquez, 1976) and in the interpretation and diagnosis of various pulmonary disorders (Sliman et al., 1981). Lung function is influenced by habitual physical activity and smoking (Jones et al., 1977; Adams et al., 1984; Patrick and Patel, 1986). For every liter of FVC, 160 ml O_2/min is added to the $\dot{V}O_2$ max. There is suggestive evidence of a link between customary physical activity and ventilatory capacity, where the latter contributes to the determination of physical working capacity (Ghesquiere, 1972; Ghesquiere and Karvonen, 1979).

The hematological trait of packed cell volume, blood pressures, pulse rate, and anthropometry are also used as indicators of health status and may affect physical work capacity. Several studies have indicated a positive correlation between hemoglobin level and productivity (Basta et al., 1973, 1974; Brooks et al., 1979; Edgerton et al., 1979). Body size also may be expected to affect the ability to pluck leaves.

The objective of the present study was to compare high and low productivity pluckers

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in several physiological and anthropometric dimensions. The underlying assumption is that high productivity pluckers are relatively more healthy in terms of the selected indicators, i.e., high productivity pluckers are functionally more fit in respect to the cardiorespiratory system than low productivity pluckers.

MATERIALS AND METHODS

The present study was conducted in two tea gardens. Birpara and Dalgaon, in Western Duars, Jalpaiguri district, northern West Bengal. The study was restricted to one tribal group, Oraon, to eliminate possible ethnic variation in health-related traits and/or productivity. Linguistically, the Oraons belong to the Kurukh, or Dravidian-speaking group (Risley, 1891). They were mainly brought into this area as tea laborers over the last 100 years or so from the Chotanagpur area and Santal Parganas of Bihar (Choudhury, 1978).

Productive output was measured simply and accurately in terms of the amount of green tea leaves plucked during a given period. The leaves plucked by each individual laborer are weighed four times per day during the plucking season in every garden. The records of weight of tea leaves plucked per person are well maintained. Extra remuneration is paid for amounts plucked over and above the minimal output (25 kg of green leaves) required in lieu of the statutory wage paid. Payment of extra remuneration is likely to enhance motivation for extra plucking for most of the laborers and thereby standardize the motivational effect. The study was restricted to adults who had been plucking leaves for >5 years. The tea garden authority has reported that the period of training required to reach optimal skill in plucking is 4 years. A total of 387 laborers, 227 males and 160 females, volunteered for the study; no statistical sampling was attempted.

The classification of high and low productivity pluckers was done in the following manner. Tea garden authorities consider plucking of 25 kg of green leaves per day per laborer, male or female, as the statutory task. Almost everyone plucked more than 25 kg during the plucking season to earn extra remuneration. A frequency polygon was drawn using the amount of green leaves plucked by each individual, and an antimode was found around 35 kg for both males and females. This figure, i.e., 35 kg, was, therefore, used as the cutoff for classifying low and high productivity pluckers in both sexes. Numbers of laborers in each category are indicated in the results.

Anthropometric dimensions were made by a single observer (SKR). In addition to age, 13 dimensions were measured: stature, weight, antero-posterior chest diameter, transverse chest diameter, biacromial diameter, biilliac diameter, upper arm and calf circumferences, and skinfolds at the biceps, triceps, and subscapular sites. Surface area (S.A., males = $W^{0.425} \times H^{0.725} \times 74.66$, and females = $W^{0.425} \times H^{0.725} \times 78.28$) and total body fat (body fat (Kg) = fat% × weight (kg)/100, where fat% = 4.201/D-3.813) × 100, and D = 1.0890- (0.0028 × triceps skinfold), were estimated. Blood specimens were collected by finger prick into standard heparinized microcapillary tubes, spun in a hematocrit centrifuge, and read on a microhematocrit reader. Instead of measuring hemoglobin level, packed cell volume (PCV) was used because the latter involved a smaller risk of error than in visual color matching. It also had a high correlation with hemoglobin level.

Lung function was assessed with a Jones Pulmonaire with autograph control and waterless spirometer. The lung function measurements were forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), forced expiratory volume in 0.7 seconds ($FEV_{.7}$), and respiration rate (RR). The subjects were instructed to stand firmly, make a maximal inspiration, place the mouthpiece in the mouth, and blow out with a maximal expiratory effort. The readings used for the analysis were obtained after two practice attempts; the highest of three satisfactory efforts was used. Systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate (PR) were also measured.

The relationship between age and primary variables may be linear or nonlinear; therefore, age^2 and age^3 were computed. Sex-specific stepwise multiple regression analyses, with age, age^2, age^3, and the body mass index (BMI) as independent variables and the functional measures as the dependent variables were used to examine differences between high and low productivity groups. Standardized residuals of the primary functional variables, adjusted for the effects of significant concomitants were then computed, and comparisons between the groups

TABLE 1. Economic conditions (per capita per month in rupees) and nutritional intake of a subsample of tea leaf pluckers[1]

	Male					Female				
	High productive plucker (n = 51)		Low productive plucker (n = 79)		t-value	High productive plucker (n = 84)		Low productive plucker (n = 111)		t-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Income	86.1	37.9	81.4	27.3	0.77	85.4	29.2	86.9	34.5	0.34
Expenditure	82.5	31.4	79.2	21.9	0.64	80.4	25.6	80.5	27.7	0.01
	Male					Female				
	High productive plucker (n = 51)		Low productive plucker (n = 79)		t-value	High productive plucker (n = 84)		Low productive plucker (n = 111)		t-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Calorie (kcal)	3,703.8	1,194.1	3,255.0	1,077.5	2.17*	2,738.1	909.1	2,574.2	873.5	1.27
Protein (g)	89.4	17.1	85.4	19.0	1.34	78.3	18.6	80.6	17.4	0.88
Fat (g)	8.4	3.1	9.1	3.6	1.18	8.7	3.3	8.8	3.9	0.11

[1]$1 = Rs.31.
*$P < 0.05$.

TABLE 2. Anthropometric characteristics of male pluckers

Variable	High productivity (n = 110) Mean	SD	Low productivity (n = 117) Mean	SD	t-values
Age (yrs)	28.7	8.1	28.8	8.1	0.09
Stature (cm)	160.1	6.3	162.1	5.9	2.47*
Weight (kg)	46.7	5.2	47.4	5.4	1.05
Antero-posterior chest diameter (cm)	16.7	1.1	17.0	0.9	2.15*
Transverse chest diameter (cm)	24.3	1.6	24.1	1.4	0.97
Biacromial diameter (cm)	35.5	1.7	35.8	1.6	1.28
Biilliac diameter (cm)	25.7	1.3	26.0	1.3	1.91*
Upper arm circumference (cm)	23.3	1.5	23.1	1.3	1.51
Calf circumference (cm)	29.0	1.9	29.0	1.6	0.15
Biceps skinfold (mm)	0.5	0.1	0.5	0.1	1.08
Triceps skinfold (mm)	0.7	0.1	0.7	0.1	2.39*
Subscapular skinfold (mm)	0.9	0.1	0.9	0.1	2.88*
Surface area (m^2)	1.5	0.1	1.5	0.1	1.34
Total body fat (kg)	4.2	0.8	4.4	0.8	2.46*
Body mass index (k/m^2)	18.2	1.2	18.0	1.6	0.76

*$P < 0.05$.

were made on the basis of the means and standard deviations of the standardized residuals.

RESULTS

Table 1 summarizes the economic and nutritional characteristics of a subsample of the pluckers. Except for estimated energy intake in males, there are no differences between the subsamples in each sex. Table 2 shows the anthropometric characteristic of high and low productivity male pluckers. There are significant differences between high and low productivity male pluckers in five of the 12 anthropometric characteristics. Table 3 shows the corresponding characteristics of high and low productivity female pluckers. There are no significant difference between the groups and there is no consistent trend to higher mean values in either group. Table 4 summarizes the functional characteristics of high and low productivity male pluckers. There are significant differences between the groups in SBP, PR, and the three lung function measurements (FVC, FEV_1, $FEV_{.7}$). Mean values are higher in low

TABLE 3. Anthropometric characteristics of female pluckers

Variable	High productivity (n = 73)		Low productivity (n = 87)		t-values
	Mean	SD	Mean	SD	
Age (yrs)	32.4	10.5	32.2	10.1	0.12
Stature (cm)	150.2	4.9	149.4	5.3	1.02
Weight (kg)	39.6	4.4	39.5	4.6	0.42
Antero-posterior chest diameter (cm)	15.9	1.1	16.0	1.1	0.45
Transverse chest diameter (cm)	21.8	1.1	22.0	1.1	1.23
Biacromial diameter (cm)	32.3	1.7	32.1	1.4	1.12
Biilliac diameter (cm)	25.6	1.1	25.1	1.1	1.06
Upper arm circumference (cm)	21.4	1.5	21.2	1.7	0.67
Calf circumference (cm)	27.6	1.7	27.3	1.8	1.27
Biceps skinfold (mm)	0.5	0.1	0.5	0.1	0.30
Triceps skinfold (mm)	0.8	0.1	0.9	0.2	0.26
Subscapular skinfold (mm)	1.0	0.1	1.0	0.2	0.50
Surface area (m^2)	1.4	0.1	1.4	0.1	1.30
Total body fat (kg)	4.8	1.3	4.8	1.4	0.06
Body mass index (k/m^2)	17.6	1.5	17.7	1.9	0.32

TABLE 4. Functional characteristics of male pluckers

Variable	High productivity (n = 110)		Low productivity (n = 117)		t-values
	Mean	SD	Mean	SD	
Systolic blood pressure (mm/Hg)	123.5	11.7	129.1	15.6	3.05*
Diastolic blood pressure (mm/Hg)	75.3	8.7	76.3	10.7	0.79
Pulse rate (b/min)	74.4	12.0	79.1	14.1	2.70*
Packed cell volume (%)	39.1	6.7	38.9	7.1	0.25
FVC (l)	3.1	0.7	3.3	0.6	2.86*
FEV 1 (l)	2.4	0.6	2.6	0.5	2.52*
FEV .7 (l)	2.2	0.6	2.3	0.4	2.47*
Respiration rate (#/min)	20.5	7.7	21.2	6.1	0.75
Plucking output (kg/day)	48.7	9.9	25.0	6.2	21.49*

$^*P < 0.05$.

TABLE 5. Functional characteristics of female pluckers

Variable	High productivity (n = 73)		Low productivity (n = 87)		t-values
	Mean	SD	Mean	SD	
Systolic blood pressure (mm/Hg)	126.4	22.1	129.9	21.7	1.01
Diastolic blood pressure (mm/Hg)	80.0	13.2	82.1	14.9	0.95
Pulse rate (b/min)	89.1	11.8	86.9	12.3	1.18
Packed cell volume (%)	32.8	5.8	32.9	6.7	0.15
FVC (l)	2.0	0.4	1.9	0.4	1.45
FEV 1 (l)	1.6	0.4	1.5	0.4	0.57
FEV .7 (l)	1.4	0.4	1.4	0.4	0.44
Respiration rate (#/min)	19.8	4.8	18.9	5.2	1.26
Plucking output (kg/day)	45.0	6.7	22.7	7.8	19.41*

$^*P < 0.05$.

productivity male pluckers. Table 5 shows the corresponding statistics for high and low productivity female pluckers. None of the differences between groups are significant.

Standardized residuals for male and female pluckers are given in Table 6. All of the means show values close to 0 and standard deviations close to 1. Because the residuals are assumed to be distributed independently of the concomitants, the assumption of nor-

TABLE 6. Residual values of the functional characteristics of pluckers[1]

Adjusted traits	High productivity Mean	SD	Low productivity Mean	SD	t-values
Males	(n = 110)		(n = 117)		
SBP eliminating the effect of age, BMI	−0.2182	0.8261	0.204	1.113	3.2556*
DBP eliminating the effect of age^3	−0.0530	0.8812	0.051	1.108	0.7871
PR eliminating the effect of age^3, BMI	−0.1784	0.8639	0.168	1.096	2.6575*
PCV eliminating the effect of age^2	0.0170	1.0405	−0.0158	0.9687	0.2454
FVC eliminating the effect of BMI, age^3	−0.2527	0.9966	0.2370	0.9519	3.7816*
FEV1 eliminating the effect of age^3, BMI	−0.2320	0.9681	0.2183	0.9893	3.4647*
FEV7 eliminating the effect of age^3, BMI	−0.2266	1.0073	0.2132	0.9543	3.4397*
Females	(n = 73)		(n = 87)		
SBP eliminating the effect of age^2	−0.109	1.084	0.0913	0.9309	1.2401
DBP eliminating the effect of age	−0.093	0.978	0.078	1.024	1.0794
PCV eliminating the effect of age^3	−0.017	0.912	0.014	1.077	0.1974
FVC eliminating the effect of age^2, BMI	0.159	1.009	−0.133	0.985	1.8409
FEV1 eliminating the effect of age^2	0.069	0.962	−0.058	1.041	0.7982
FEV7 eliminating the effect of age^2	0.056	0.928	−0.046	1.067	0.6467

[1]Residuals = observed-expected (fit).
*$P < 0.05$.

mality of the residuals is required for the test of significance. In males, even after eliminating the effects of all concomitant variables from the primary variables, the t-values show significant differences in SBP, PR, FVC, FEV_1, and FEV_7. In females, after eliminating the effects of concomitant variables from the primary variables, none of the differences between groups are significant.

DISCUSSION

The present study examined cardiorespiratory functions and anthropometric characteristics of ethnically/genetically similar population subgroups in regard to work output. Factors standardized in the study included climate, habitual activity, skill, motivation, and test protocol.

Few anthropometric dimensions have important relationships with productivity in tea pluckers. The results are in contrast to related studies in different work environments. In Guatemala, Immink et al. (1987) showed a positive correlation among body weight, stature, fat-free mass and $\dot{V}O_2$ max, and productivity, and suggested that the taller and heavier men are more physically fit and better producers than short workers. In Kenya, Wolgemuth et al. (1982) found productivity related to arm circumference in road construction workers. In India, Satyanarayana et al. (1977) found a positive relationship between work output (in terms of number of fuses produced per day) and body size among the industrial workers engaged in the preparation of safety fuse wires for detonation.

In contrast, the present study corroborates the work of Spurr et al. (1977), who observed a significant negative correlation with percentage body fat and productivity among the Colombian sugarcane workers, and Basta et al. (1973), who found no relationship with arm circumference, weight, and height with work capacity (using physiological tests rather than actual productivity) among Indonesian road construction workers. In India, Sukhatme (1988) also failed to find any relationship between the work output of women (in terms of number of *chapatis,* a type of handmade bread, produced per hour) and body weight. It is of interest that the low productivity male pluckers have significantly higher estimated body fatness compared to high productivity male pluckers. Fatness may limit or restrict the quicker movements of the limbs for potential plucking. However, the results obtained for females are not consistent with those for males. None of the differences between the low and high productivity female pluckers are significant. It is possible that the various biological and cultural factors that differ between the sexes affect the relationship between the anthropometric and physiological traits under study and the plucking ability. However, data are not presently available to document this possibility.

There are no comparable data in India on the relationship between cardiorespiratory function and productive output. There are also no health standards for cardiorespiratory traits for any population groups in India.

However, comparison of the present study with several non-Indian studies in respect of cardiorespiratory fitness and productivity shows similar trends. Spurr et al. (1977) related cardiac frequency, oxygen consumption, pulmonary ventilation, $\dot{V}O_2$ max, and heart rate with work productivity among sugarcane loaders and noted no significant correlation between productivity and cardiorespiratory fitness. Duncan and Scammell (1977) also found the absence of any significant correlation between cardiorespiratory fitness measured in terms of ventilatory capacities, heart rate, and $\dot{V}O_2$ max, and physical work capacity.

Several studies have demonstrated relationships between hemoglobin concentration and productivity, particularly, iron-deficiency anemia, which is associated with lower productivity. Studies on intervention trials with iron supplements to raise hemoglobin concentration have shown that anemic subjects treated with iron tablets significantly improved work output measured on the Harvard step test or a treadmill test (Gardner et al., 1977; Basta et al., 1979; Edgerton et al., 1979). The present study, however, failed to show any significant effect of blood pressure and packed cell volume on worker productivity.

The few trends that appear in the present data should not, however, be overlooked because in small scale anthropological studies, such trends may provide important indications that may not often assume statistical significance. For instance, the higher values of blood pressures and pulse rate, and lower PCV possibly suggest poor health status of the low productivity pluckers. In contrast, the lung function measurements (FVC, FEV_1, $FEV_{.7}$) are significantly higher among low productivity pluckers, which perhaps suggest that lung function capacities are not important or have minimal importance in tea leaf plucking. Similar results are obtained even after the effects of the concomitant variables are removed. The results, therefore, possibly suggest, but do not conclusively prove, that relatively lower body fat and high cardiovascular fitness are related to high productivity plucking at least in male pluckers.

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