Working postures of tea pluckers and its interrelationship with their plucking efficiency

Subhra Chattopadhyay, Sandip Mukherjee, Alak K. Syamal, Devashish Sen and Chandan Mitra*

Division of Ergonomics & Work Physiology, Department of Physiology, Presidency College, 86/1 College Street, Kolkata 700 073, India

Abstract. The purpose of this study was to examine posture-comfort-performance interrelationships in plucking-based task in a tea garden. Results of coefficient of correlation between the stature bush height ratio (SBHr) and total yield (TY) (permanent: $r = 0.80$, temporary: $r = 0.81$), and SBHr and body part discomfort frequency and severity (BPDFS) (permanent: $r = -0.78$, temporary: $r = -0.77$) clearly indicated that performance (TY) was correlated both with the SBHr and BPDFS. Similar correlation studies between duration (TT) and BPDFS revealed that BPDFS increased with progression of time. Analysis of joint angle changes (trunk angle 92%, shoulder angle 63% and neck angle 87%) further suggests that both BPDFS and overall postural shifts (in terms of changes in joint angles) increased with the progression of time (time on task – TT). Body part discomfort (BPD) rank order of different body parts of pluckers (upper body part discomfort scores – permanent: 2.00–6.00, temporary: 1.88–5.88; lower body part discomfort scores – permanent: 2.13–2.88, temporary: 1.88–2.75) further revealed that upper body parts were mostly involved in discomfort development. These results suggest that an overall postural shift may be a good indicator of perceived musculoskeletal discomfort in a tea leaf plucking task where a constrained posture is required. Results of independent test series suggest that there was a good agreement between the predicted and observed values of the different variables (89.6–96.3%). The predictive value of the regression equations may be utilized for estimating values of different interacting variables, and thus, the importance of these regression equations in the supervision of workers engaged in tea plucking is evident. It is therefore proposed that to improve performance, these observations can conveniently be utilized while plucking sectors are allotted to pluckers in a tea garden.

Keywords: Tea plucking tasks, posture, performance

1. Introduction

It is well known that the two crucial cost elements of tea industry are labour wages and estate supplies. In fact, as the most costly and yet measurable operation in the tea industry, plucking has been the focus of a productivity – linked approach in respect of wages and incentives. It has been reported that about 60–66% of the total workforce in a tea garden is engaged in plucking operation and this alone accounts for 70–80% of total cost of green leaf production. However, several yardsticks are available by which to judge the production efficiency of the tea industry and its effect on reducing cost. The most important is plucking productivity, which represents the quantity of green leaf harvested /work day, the objective

*Corresponding author: Professor Chandan Mitra, 14/17 A, Golf Club Road, Calcutta-700 033, India. Tel.: +91 033 2413 1383/2417 8645; E-mail: chandan.mitra@presi@yahoo.com.

1359-9364/06/$17.00 © 2006 -- IOS Press and the authors. All rights reserved
being to increase that quantity without detriment to quality. On an average the productivity of the pluckers are below the actual potential due to lack of proper attention [24].

Considerations of comfort in tea industry are not usually seen as important, at least in tea pluckers although their contribution in productivity – linked operation is well-appreciated. Their rapid visual inspection task for a quality and productivity-linked plucking against a fixed monochromatic backdrop, whether or not causes increased visual and physical stress, and postural shifts as well as decrease in performance is not known. Because Bhatnagar et al. [3] have shown that in a visual inspection task poor workplace design caused increases in physical stress and postural shifts as well as decreases in performance. However, there has been a growing concern among the tea managements regarding the safety and work condition comfort of pluckers. In view of this, an ergonomic study seemed necessary to work out how workplace comfort could be given to the pluckers. It is well established that the goal of human factors/ergonomics is to enhance the effectiveness and efficiency with which work is carried out [23]. To achieve this goal, for the pluckers who are engaged in productivity-linked operation, we hypothesized the necessity to explore the interrelationships between posture, comfort and performance (in terms of productivity). This study was conducted in a moderate sized and well managed tea garden of Dooars, West Bengal, India, during the month of June 2004. The garden had permanent and temporary pluckers of both the sexes. However, about 80% of these pluckers were female. Literature survey reveals that there is a lack of similar studies in pluckers and, thus, this study for the first time is an attempt in that direction to demonstrate the interrelationships between posture, comfort and performance (in terms of productivity) in plucking-based task in a tea garden of Eastern India.

2. Model

Figure 1 shows the proposed model of this study and its different components. According to this model, we hypothesized that the positions and the angles of the working components of a plucker (e.g. height and diameter of tea bushes, stature of plucker, mechanism of leaf plucking, and load carrying mechanism) define the envelope of body postures achievable by the plucker. It may be predicted that many ergonomic interventions may affect this envelope of body postures, and hence the postures assumed by the tea plucker. Similar idea was proposed earlier in case of VDT workers [15].
There is evidence that tea pluckers are subjected to carry greater load of their collected green leaf with progress of working hours. Moreover, with progression of time, the pluckers bend forward to pluck the leaves from the farthest point of the bush. This they have to do as the bush diameter (106 to 200 cm) was greater than their maximum arm reach (60.4–71.4 cm). Also, to support the greater mass of plucked leaves there was forward bending. Forward bending would require a greater arm excursion to reach the same height due to decreased shoulder height when flexed forward. Also there occurs a continuous change in movements at shoulder and elbow joints in an effort to adjust the height of the plucking points, an increased opening of the elbow and deviation of the wrist with rapid extension and flexion movements of forearm during plucking action up to a rate of 50 to 70/minute. While de-loading of collected leaves from hand to backpack is made, simultaneously there occurs two distinct types of movements at the two shoulder joints, abduction and external rotation of one shoulder is followed by adduction and internal rotation in other. Since many of these movements are identified as risk factors for musculoskeletal discomfort [13,16,18], we hypothesize that similar awkward postures in tea plucking task might result in a higher incidence of musculoskeletal discomfort in a plucker.

Additionally, frequent postural shifts have been linked with an effort on the part of the worker to alleviate musculoskeletal discomfort [3,14]. It has been emphasized that in a particular work these postural shifts are non-work related body movements, other than work-related movements [15]. As the time of leaf collection progresses, we noticed similar non-work related body movements and other activities among the pluckers (e.g. adjustment of head cushion from where the back pack for collection of leaf hangs; scratching of head, neck and other body parts; making of certain habitual movements of the body to get desired comfort; exchange of words with fellow pluckers; even changing of fully-loaded back pack when it causes severe postural discomfort) (data of such non-work related movements are not given).

An earlier report also had suggested that as there is an increase in discomfort with progress of work, the number of postural shifts increases [14]. Discomfort, fatigue in general, and awkward postures can all decrease forces exerted and affect adversely precise movement of coordination [5,20]. Both effects potentially impact performance. Time on task (TT) also plays an important role in the development of discomfort. The longer the work duration, the more severe is the intensity of discomfort [12,14,19].

In the proposed model, we consider the workplace of pluckers (existing height and diameter of the bush) as the key regulator of posture, and corresponding postural shifts. These in turn affect discomfort and performance, which can affect each other. Discomfort is also affected by time on task (TT). The current study was designed according to the above-proposed model to demonstrate the interrelationships between posture, comfort and performance in plucking-based task in a tea garden with an objective how to improve comfort level and increase the performance (in terms of productivity) of tea leaf pluckers.

3. Materials and methods

3.1. Subjects

Sixteen healthy female pluckers (height 1.53 m, $sd = 0.051$; maximum arm reach 0.64 m, $sd = 0.033$; age 28.81 years, $sd = 4.262$; body mass 44.34 kg, $sd = 9.093$; BSA 1.39 m², $sd = 0.143$; BMI 18.87 kg/m², $sd = 2.841$; systolic blood pressure 117.50 mmHg, $sd = 14.720$; diastolic blood pressure 77.13 mmHg, $sd = 10.954$; heart rate 78.44 beats/minute, $sd = 11.282$), eight each from both permanent and temporary groups, were randomly selected for the present study. In the tea garden there are clearly two categories of pluckers. One is the permanent with fixed salary independent of plucking yield and second is the temporary pluckers who are engaged on a daily wage basis. Additionally, the service
benefits of permanent and temporary pluckers are different. So, these two different populations were considered as part of design factors of this study. Two important criteria about these workers were checked from official records before selecting them – (a) the attendance and efficiency of both the groups matched as pluckers, and (b) their health records which met the following requirements: no report of chronic disease and musculoskeletal problems.

For retesting of regression equations, eight healthy female pluckers (permanent = 4, temporary = 4) were selected following the criteria described in the above mentioned paragraph (height 1.51 m, $sd = 0.050$; maximum arm reach 0.65 m, $sd = 0.033$; age 28.63 years, $sd = 4.211$; body mass 41.06 Kg, $sd = 2.782$; BSA 1.36 m$^2$, $sd = 0.093$; BMI 18.86 Kg/m$^2$, $sd = 1.731$; systolic blood pressure 114.75 mm Hg, $sd = 9.790$; diastolic blood pressure 74.00 mm Hg, $sd = 7.781$; heart rate 72.13 beats/minute, $sd = 8.250$).

3.2. Environmental factors

During the month of June 2004, whole North Eastern India experiences moderate to heavy monsoon shower. External physical influencing factors, viz, relative humidity and WBGT index at the tea garden during that period were as follows: WBGT Index 28.77°C, $sd = 1.36$ and relative humidity 89.67%, $sd = 2.08$. Wet Bulb Globe Temperature (WBGT) Index is one of the simplest and most convenient heat stress index to ascertain the thermal stress in a warm humid environment [25].

Formula: $WBGT \text{ (outdoor)} = 0.7 \left( T_{nw} \right) + 0.2 \left( T_g \right) + 0.1 \left( T_a \right)$

where, $T_{nw}$ = natural wet bulb temperature

$T_g$ = Vernon globe temperature

$T_a$ = dry bulb temperature

3.3. Experimental design

A two-factor design with repeated measures was used in this study. Height of pluck point of bushes (single level) and work duration interval (4 levels) were treated as fixed factors. Subjects were treated as a random factor. Bush height was defined as the vertical distance from the ground level to the existing tip of the pluck points of a bush (Fig. 2), and bush diameter was defined as the horizontal distance from any particular point of an edge of a bush to the exactly opposite farthest point of that bush. A number of researchers have reported the association of poor body postures [10] with pains or symptoms of musculoskeletal disorders [1,2]. Ryan (1989) [22] studied the effects of working time spent in the standing position on the development of lower-back and lower-extremity problems for workers employed in grocery stores. The lower-back and extremity problems started when the percentage of working times were 25% and 45–50%, respectively. Furthermore, it is well known that an elevation of the shoulders in occupational tasks has been shown to cause an increase in neck and shoulder pain [11]. Keeping all these facts in mind as well as the examples of poor body postures, we hypothesize that in operations like tea leaf plucking there also occurs increased muscular load on the neck and shoulders and substantial sustained static followed by dynamic contractions of extensor and flexor groups of muscles of both wrist and fingers with shoulder abduction and opening of elbow. Additionally, the wrist joint develops deviation and internal rotational movements at the time of plucking. Thus, a study was conducted for a total plucking period of initial 120 minutes (7.00 to 9.00 A.M.) and this 2-hour work duration was considered as 4 intervals of 30 minute each from 30, 60, and 90 up to 120 minute. From pilot study and from records of the tea garden, it was found that the first two hours, i.e., 7 to 9 A.M. yield is maximum for both the groups of workers. Thus, first two hours was chosen as the hours of study and this was maintained throughout the study period for both permanent and temporary pluckers.
3.4. Dependent variables

3.4.1. Joint angle

A video technique for joint angle measurements was used because it did not interfere with plucking operation and was able to record postural shifts simultaneously. For the postural analysis during plucking operation, small reflective markers were used on the following anatomical landmarks as reported elsewhere [15]:

- Ear (A): the auditory canal
- Shoulder (B): the acromian process
- Elbow (C): the lateral epicondyle of humerus
- Wrist (D): the styloid process of ulna
- Hand (E): the head of the fifth metacarpal
- Hip (F): the lateral femoral epicondyle

3.4.2. Changes in joint angles

Changes in joint angles with progress of work have been used in our study to measure the intensity of discomfort in plucking operation with constrained postures (e.g. constrained standing and increased forward inclination of head, neck and trunk with increase load of leaf in back pack). Video recording was done continuously for the five randomly selected but matched pluckers (permanent = 3, temporary = 2) for the entire two hour duration of the study for seven days during peak plucking period. From this, first 10 minutes of the two hour study period was selected for the measurement of initial body
angles. During this time the load was minimum and all the angles were minimum. From this 10 minutes’ video recording, ten random freeze situations, i.e., static postures were taken out when the pluckers were engaged only in plucking operation after de-loading the accumulated plucked leaves of their hand in the bag at their back. The joint angles were measured and mean was calculated. This represented the joint angles of any plucker for that particular day and this was repeated for seven days to get the mean angles of one plucker for the study duration. This was repeated on all the five pluckers and averaged to determine the final joint angles. The entire process was repeated in the last 10 minutes of two hours study period to determine the final joint angles and the changes in joint angles were measured accordingly. Figure 6 (inset) depicts such an increase in load of the back pack with progression of plucking operation.

3.4.3. Musculoskeletal discomfort

As this study was conducted at the site of work in plucking sectors, body part discomfort (BPD) questionnaire was administered through an individual interaction and verbal expressions method to assess discomfort or pain in each of 16 body parts. Subjects rated their levels of discomfort in each joint angles using a 7 point response scale on which equal intervals from (0) = nothing at all, to (6) = intolerable were marked. BPD frequency (BPDF) and BPD severity (BPDS) were also measured. BPDF is calculated as the number of body parts rated greater than zero; BPDS is the average of all non-zero ratings [7]. BPDFS is BPDF multiplied by BPDS [8].

3.4.4. Productivity analysis

Productivity was measured by observing green leaf yield (kg)/plucker/30 minute, and also by total leaf yield (kg)/plucker in a 2-hour session.

3.4.5. Measurement of physiological parameters

Individual height (m), maximum arm reach (m), and body mass (kg) were recorded respectively by using anthropometric rod and standard weighing machine. The body surface area (BSA) and body mass index (BMI) were calculated respectively by using the Dubois body surface nomographic chart [9] and BMI formula as given elsewhere [21]. The heart rate (beats/minute), and blood pressure (mm Hg) of the subjects were recorded in resting condition. Heart rate and blood pressure of the subjects were measured respectively by timing 10 beats with a stop watch and sphygmomanometer.

3.4.6. Experimental procedure

First, the pluckers were allotted their respective plucking sections. Small reflective markers were attached to the subject’s skin or to their clothing on the anatomical landmarks as mentioned in the text of joint angle section (3.4.1). The pluckers were then asked to start their plucking operation for 2 hours without any interruption. Their performance (total yield-TY) with time on task (TT) was intermittently (at every 30 minutes interval) recorded during that entire 2-hours session of work. As the posture normally adopted by a plucker during work requires in her a tendency to either stop or making frequent shifts in posture to recover from pain, at every 30 minutes interval throughout 2-hours working period, pluckers were asked through BPD questionnaire to indicate the body area, or areas, which were most painful. Prior to this, detailed record being taken, the subjects were asked for an overall assessment of discomfort.

3.5. Statistical method

For the statistical evaluation of the data, simple and multiple correlation followed by student’s t-test and regression analysis of different relevant parameters were undertaken. \( p < 0.05 \) was chosen as the level of significance.
4. Results

4.1. Stature – bush height ratio (SBHr) and its relation with productivity (total yield -TY) in tea plucking operation

Figure 2 represents the basis for determination of stature and bush height ratio. Results show that the coefficient of correlation between SBHr and TY of plucked leaves in a 2-hour session was $r = 0.80$ ($p < 0.05$) for permanent pluckers and $r = 0.81$ ($p < 0.05$) for temporary pluckers.

Regression relationship between stature-bush height ratio (SBHr) and total yield (TY) of plucked leaves (in kg) of that 8 permanent pluckers and 8 temporary pluckers has been depicted in Fig. 3. The regression equation obtained between SBHr and TY (in kg) in case of permanent pluckers was:

$$\text{Total Yield (TY)} = 5.4872 \times (\text{SBHr}) - 1.838$$

and in case of temporary pluckers, it was:

$$\text{Total Yield (TY)} = 9.6337 \times (\text{SBHr}) - 6.8367$$
4.2. Stature – bush height ratio (SBHr) and postural discomfort in plucking operation

The body part discomfort scores were processed according to Corlett and Bishop (1976) [6] technique. Results of both the groups of pluckers showed a negative correlation in between SBHr and BPDFS which in case of permanent pluckers was \( r = -0.78 \) (\( p < 0.05 \)) and for temporary pluckers was \( r = -0.77 \) (\( p < 0.05 \)).

Figure 4 depicts the regression relationship between SBHr and BPDFS of that same 8 permanent pluckers and 8 temporary pluckers. The regression equation obtained between SBHr and BPDFS in case of permanent pluckers was

\[
BPDFS = -25.969 \times \text{SBHr} + 96.84
\]

and in case of temporary pluckers, it was

\[
BPDFS = -44.066 \times \text{SBHr} + 120.52
\]
Table 1 shows mean discomfort scores of 16 body parts [6] of the same 8 permanent and 8 temporary pluckers in descending order after completion of 2-hour time on task. The maximum discomfort experienced by both the groups of workers was in the mid-lower back region, followed by left and right shoulder. Other parts which had high discomfort scores were neck, upper back, right and left hand, right and left lower arm.

Results of both the groups of pluckers showed a negative correlation in between BPDFS and TY. The value of correlation was found to be same in both the groups which was $r = -0.82$ ($p < 0.05$).

Figure 5 depicts the regression relationship between TY and BPDFS of the same 8 permanent pluckers and 8 temporary pluckers. The regression equation obtained between TY and BPDFS in case of permanent pluckers was

\[ TY = -0.1692 \times \text{BPDFS} + 16.374 \]

and in case of temporary pluckers, it was

\[ TY = -0.1705 \times \text{BPDFS} + 17.081 \]

Changes in joint angles also have been used in our study to measure the intensity of discomfort in tasks with constrained postures and activity (e.g. constrained standing, meticulous inspection of pluck points within a restricted area of a tea bush against a fixed monochromatic [green] background, increased load in back pack). Over the 2-hour plucking session there were significant differences in joint angle measurements (mean overall joint angle changes), viz, neck angle, shoulder angle and trunk angle of both groups of pluckers as a function of time as well as adjustment for working posture (Fig. 6, Table 2).

Figure 7 depicts the regression relationship between time on task and mean total yield of the same 8 permanent pluckers and 8 temporary pluckers. The regression equation obtained between time on task (TT) and mean total yield (MTY) for 8 permanent pluckers was

\[ MTY = -0.335 \times \text{TT} + 2.68 \]
and in case of temporary pluckers, it was

\[ MTY = -0.42 \, (TT) + 3.17 \]

In order to verify the applicability of these regressions, independent series of experiments were conducted with four permanent and four temporary pluckers randomly selected from that same sectors where original series of experiments were undertaken. They were required to perform exactly similar work schedule as the experimental groups of pluckers (permanent and temporary). All statistical correlation and regression relationships were analyzed in the same way as it was undertaken in case of original series of experiments. Tables 3 and 4 show the observed and predicted values of different pairs of variables for this independent test series. Also, the percentage of agreement between the observed and the predicted values are given in the tables. The correlation coefficient of the two values with respect to

\[
\begin{array}{cccc}
\text{Body angles (°)} & \text{At the beginning of plucking schedule} & \text{At the end of two-hour plucking schedule} & \text{Percent change (‰)} \\
\text{Trunk angle} & 13° & 25° & 92 \\
\text{Shoulder angle} & 27° & 44° & 63 \\
\text{Neck angle} & 15° & 28° & 87 \\
\end{array}
\]
SBHr and TY in case of permanent and temporary pluckers respectively were $r = 0.66$ and $r = 0.89$, while that between the predicted and observed BPDFS and SBHr in permanent and temporary pluckers were respectively $r = 0.83$ and $r = 0.84$. Similar correlation was found between other pairs of variables, viz, TY and BPDFS (permanent: $r = 0.97$; temporary: $r = 0.93$), MTY and TT (permanent: $r = 0.98$; temporary: $r = 0.99$).

5. Discussion

The most encouraging finding of this study is that if allotment of working segments to pluckers are made with proper stature-bush height ratio (SBHr) justifications, plucking performance may be improved significantly. Such distribution of working segment also may be beneficial for the pluckers as it may improve working posture and decrease discomfort. Identical conclusions may be drawn for both permanent and temporary groups of pluckers.

The proposed model of this study (Fig. 1) depicts the hypothesized workplace – working posture – time on task- discomfort- postural shift-performance interrelationships of a plucking-based task in a tea garden. The objective was to demonstrate the interactions between stature, bush height, work duration, working posture, discomfort as well as performance in a 2-hour plucking task.

Results of coefficient of correlation between the stature – bush height ratio (SBHr) and total yield (TY) (Fig. 3) and stature – bush height ratio (SBHr) and body part discomfort frequency severity (BPDFS) (Fig. 4) clearly indicated that performance (total yield-TY) was correlated both with the SBHr and development of BPDFS. Results of multiple correlation between SBHr and BPDFS with TY (permanent: $p < 0.05$; temporary: $p < 0.05$) further confirmed that an interaction between the independent
Table 3
Observed and predicted values of different pairs of variables for eight subjects engaged in a plucking operation in independent series of experiments

<table>
<thead>
<tr>
<th>Subject</th>
<th>SBHr</th>
<th>Pair of variables</th>
<th>SBHr &amp; TY (r = 0.66)</th>
<th>BPDFS &amp; TY (r = 0.97)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Observed</td>
<td>Predicted</td>
<td>% Agreement</td>
<td>Observed</td>
</tr>
<tr>
<td></td>
<td>(kg)</td>
<td>(kg)</td>
<td></td>
<td>(kg)</td>
</tr>
<tr>
<td>S-1</td>
<td>1.70</td>
<td>6.00</td>
<td>7.49</td>
<td>75.20</td>
</tr>
<tr>
<td>S-2</td>
<td>1.95</td>
<td>8.75</td>
<td>8.86</td>
<td>98.74</td>
</tr>
<tr>
<td>S-3</td>
<td>1.70</td>
<td>8.00</td>
<td>7.49</td>
<td>93.62</td>
</tr>
<tr>
<td>S-4</td>
<td>1.45</td>
<td>6.75</td>
<td>6.12</td>
<td>90.67</td>
</tr>
<tr>
<td>Mean:</td>
<td>89.56</td>
<td></td>
<td></td>
<td>Mean:</td>
</tr>
<tr>
<td>SD:</td>
<td>10.140</td>
<td></td>
<td></td>
<td>SD:</td>
</tr>
</tbody>
</table>

For temporary pluckers

<table>
<thead>
<tr>
<th>Subject</th>
<th>SBHr</th>
<th>Pair of variables</th>
<th>SBHr &amp; TY (r = 0.89)</th>
<th>BPDFS &amp; TY (r = 0.93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Observed</td>
<td>Predicted</td>
<td>% Agreement</td>
<td>Observed</td>
</tr>
<tr>
<td></td>
<td>(kg)</td>
<td>(kg)</td>
<td></td>
<td>(kg)</td>
</tr>
<tr>
<td>S-1</td>
<td>1.58</td>
<td>9.50</td>
<td>8.38</td>
<td>88.21</td>
</tr>
<tr>
<td>S-2</td>
<td>1.73</td>
<td>10.50</td>
<td>9.83</td>
<td>93.62</td>
</tr>
<tr>
<td>S-3</td>
<td>1.50</td>
<td>7.00</td>
<td>7.61</td>
<td>91.29</td>
</tr>
<tr>
<td>S-4</td>
<td>1.46</td>
<td>8.00</td>
<td>7.23</td>
<td>90.37</td>
</tr>
<tr>
<td>Mean:</td>
<td>90.87</td>
<td></td>
<td></td>
<td>Mean:</td>
</tr>
<tr>
<td>SD:</td>
<td>2.241</td>
<td></td>
<td></td>
<td>SD:</td>
</tr>
</tbody>
</table>

*% Agreement was calculated by taking the observed values as base.

Table 4
Observed and predicted values of MTY as a function of time (TT) for eight subjects engaged in plucking operation in independent series of experiments

<table>
<thead>
<tr>
<th>TT (minute)</th>
<th>Observed MTY (kg)</th>
<th>Predicted MTY (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Permanent (n = 4) (r = 0.98)</td>
<td>2.75</td>
<td>2.20</td>
</tr>
<tr>
<td>Temporary (n = 4) (r = 0.99)</td>
<td>2.94</td>
<td>2.38</td>
</tr>
</tbody>
</table>

*% Agreement was calculated by taking the observed value as base.

variables (SBHr) and musculoskeletal discomfort (BPDFS) finally determines the performance (TY). Thus, these results supported the idea of our model that performance of tea pluckers decreases when considerably higher levels of discomfort are reported, suggesting a link that helps to confirm the discomfort/performance relationship.

To understand the effects of time on task (TT), an attempt was made to find out if any correlation existed between TT and mean total yield (MTY) (Fig. 7). It is evident from Fig. 7 that a very high correlation exists between the TT and performance (MTY) (r = −0.99). Multiple correlation between these variables further revealed that BPDFS increased with progression of time, suggesting that there exists a positive association (permanent: p < 0.05; temporary: p < 0.05) between the prevalence of discomfort with duration, and negative association between duration (TT) and performance (MTY).

To understand further the effects of time on task (work interval), mean overall joint angle changes...
were correlated with body part discomfort (BPD) and body part discomfort frequency severity (BPDFS) of both groups of workers. Results show that overall joint angle changes (Fig. 6) possibly has correlation with development of body part discomfort (BPD) (Table 1). To be specific, overall joint angle changes were highly correlated with BPD in the mid-lower back (BPD rank order 1), left shoulder (BPD rank order 2), right shoulder (BPD rank order: permanent 3; temporary 2), neck (BPD rank order 3), upper back (BPD rank order 4), right and left hand (BPD rank 5), right and left lower arm (BPD rank order 6), relative to BPD in other body parts. This suggests that development of BPD and BPDFS in these body parts possibly were responsible for the resultant overall joint angle changes (Fig. 6). Analysis of data further suggests that as both overall joint angle changes and BPDFS increased with progression of time, there was a positive association between the prevalence of body part discomfort and increase in overall joint angle changes. BPD rank order of different body parts further revealed that upper body parts were mostly involved in discomfort development and thus may be one of the contributing factors for the observed upper body joint angle changes. These results suggested that overall joint angle changes increased with development of discomfort with time on task. Also, these results supported the earlier studies of Maeda et al. (1980) [17] and Cantoni et al. (1984) [4], who suggested an association between postural changes and higher local postural discomfort. Thus, overall joint angle changes may be a good indicator of perceived musculoskeletal discomfort in a tea leaf plucking task where a constrained posture is required.
The applicability of these regression was tested by an independent series of experiments. Results of Tables 3 and 4 of the independent test series suggest that there was a good agreement between the predicted and observed values. It is, therefore, speculated that these observations may be effectively utilized in tea industry while plucking fields are allotted to the tea pluckers. Furthermore, the predictive value of the determined regression equations may be utilized for estimating values of different interacting variables, viz, stature-bush height ratio (SBHr), total yield (TY), body part discomfort frequency severity (BPDFS) and total yield (TT) in a particular population of pluckers to a range of scores from which equations were derived. However these equations, in order to be effective, need to be drawn on a larger sample with greater range of scores. But the utility of the equation have clearly been demonstrated in the present study. Thus it is speculated that while plucking sections are allotted to pluckers, these observations can be effectively utilized in designing similar regression equations in any tea garden of India.

6. Conclusions

In summary, the conclusions derived from this investigation are:

1. Stature Bush Height Ratio (SBHr) of pluckers in a tea garden may be a crucial factor to influence their performance and discomfort as evidenced from the results of correlation study between stature bush height ratio (SBHr) and total yield (TY) (for permanent pluckers $r = 0.80$; for temporary pluckers $r = 0.81$) and between stature bush height ratio (SBHr) and body part discomfort frequency severity (BPDFS) (for permanent pluckers $r = -0.78$; for temporary pluckers $r = -0.77$).

2. Also, the overall changes in the joint angle of the plucker increased with the duration of work which ultimately increases the BPDFS.

3. Increase of BPDFS with the duration of work may further be responsible for the decrease in total yield as evidenced from the result of correlation study between BPDFS and TY (for permanent pluckers $r = -0.82$; for temporary pluckers $r = -0.82$).

4. Thus, allotment of working segment to pluckers with proper SBHr justification may improve plucking performance (i.e., total yield) and will also reduce the discomfort of the pluckers.

5. The results of the independent test series was in good agreement between the predicted and the observed values. This suggests the utility of the regression equations of different interacting variables derived in our study for supervision of the tea pluckers engaged in plucking operation in tea gardens.

7. Future research

To enhance the value of this investigation, future research is needed as follows:

1. Similar study should be repeated in other tea gardens of India. By repeating such study with greater sample size drawn from different parts of the country may help in determining a more applicable regression equation in Indian context.

2. Further work study and method study including modification of work rest cycle may be attempted to help in ameliorating the problem of the pluckers and plucking.
Acknowledgements

This work was made possible through a grant from National Tea Research Foundation (NTRF), India. The authors would like to thank Mr. Amitava Palchoudhuri, the Director and the senior and junior managers of Washabarie Tea Estate, Dooars, West Bengal, India for their assistance with this work. Thanks are due to Mr. Asankur Sekhar Das for his kind help in preparing this manuscript.

References


