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Child Work in Agriculture in West Bengal, India: Assessment of Musculoskeletal Disorders and Occupational Health Problems

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Abstract: Child Work in Agriculture in West Bengal, India: Assessment of Musculoskeletal Disorders and Occupational Health Problems: Banibrata DAS, *et al*. Department of Physiology, South Calcutta Girls' College University of Calcutta, India—Objective: Children are universally considered to be the most important asset for any nation. The main aims of the present study were 1) to investigate the causation of discomfort related to working postures 2) to assess the physiological strain among the child farmers and 3) to assess the thermal stress during work in an agricultural field. **Methods:** For this study, 120 child agricultural workers and 120 control subjects aged 10−16 years were selected randomly, and a detailed posture analysis was performed among them by REBA and OWAS methods. The Modified Nordic Questionnaire was applied to assess the discomfort felt among both groups of workers. Physiological assessment of workload was carried out by recording the heart rate and blood pressure of the workers prior to work and just after work in the field. **Results:** Child agricultural workers suffered from pain especially in the low back (98%), knees (88%), hands (82%), shoulder (77%) and neck (68%). Among the agricultural activities in potato cultivation, the child potato workers, felt discomfort during spading (99%), sprinkling water (90%) and picking crops (87%). The post-activity heart rate of the child agricultural workers was 170.1 beats/min, whereas the systolic and diastolic blood pressures were 129.0 and 67.0 mm/Hg respectively. **Conclusions:** Most of the agricultural activities in potato cultivation were strenuous ones that affect the children, who suffered from acute pain and discomfort for a long period of time, which mainly hampers and restricts their education.
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With more than 350 million economically active children between the ages of 5 and 17 years old, child labor exploitation is a worldwide problem, and almost half of these children are engaged in hazardous work[1)]. In India, especially in West Bengal, children are mainly associated with agricultural work (potato cultivation) in rural areas due to poor socioeconomic conditions. Children have to perform a fair amount of manual, rigorous tasks in the agricultural field. There are some activities that are mainly engaged in during potato cultivation. These are weeding, ridging, carrying seeds, planting seeds, spading, sprinkling water, picking crops and carrying crops.

A large proportion of economically inactive children live in India. That is, 100 million child laborers live in India[2)]. Children under fourteen constitute around 3.6% of the total labor force in India. Of these children, nine out of every ten work in their own rural family settings. Nearly 85% are engaged in traditional agricultural activities. Less than 9% work the manufacturing, service and repair. Only about 0.8% of these children work in factories[3)].

Agricultural workers, especially children, suffer from musculoskeletal disorders (MSDs) in different parts of the body, especially low back pain, during different activities in potato cultivation[4)]. Gangopadhyay *et al*.[4)] stated that preadolescent agricultural workers are continuously exposed to bending posture in different environments, and as a result, they suffer from acute pain and discomfort in different parts of the body. Sekimpi[5)] stated that the hand hoe and other hand tools used by farmers in a stooped posture for a prolonged period in many developing countries are mainly responsible for MSDs, because the machinery used in developing countries is often

not ergonomically designed. According to Sekimpi[5], musculoskeletal pain, especially back pain, is common among agricultural workers. He also believes that new ergonomically designed agricultural hand tools and machinery or equipment will reduce the work load and MSDs among agricultural workers.

Agriculture work is mainly considered to be a highly physically demanding occupation[6]. During potato cultivation, children usually use a variety of different awkward postures while performing various manual tasks for an extended period of time. These awkward postures for prolonged periods may lead to the development of chronic musculoskeletal disorders among child agricultural workers[4]. Holding awkward and stressful postures for a prolonged period of time may lead to MSDs among adult male potato cultivators[7].

Low back problems are common among farmers, and appear to be associated with the frequency of using postures requiring back flexion, carrying and lifting of heavy loads and exposure to whole body vibration[4, 8]. Postures, especially those involving severe flexion or lateral twisting and bending, have been found to be significantly related to low back pain[9]. Posture and the location and weight of a load affect the moment of force required in the lumbar region, which in turn affects muscle loading and compressive forces on the internal vertebral disc[10].

The main aims of the present investigation were (1) to determine the prevalence of musculoskeletal disorders, (MSDs) among agricultural child laborers and compared with sedentary child workers in West Bengal, (2) to analyze the causation of discomfort resulting from awkward postures, (3) to identify unfavorable working conditions and (4) to assess physiological stress among child potato cultivators.

Methods

Selection of subjects

For this study, 120 child agricultural workers (63 male and 57 female) aged 10 to 16 years, were selected by simple random sampling method from the village in Tarakeswar of West Bengal and were considered the Experimental group. In the Control group, 120 subjects (60 male and 60 female) of the same age group (10 to16 years) and of the same socioeconomic status residing in the same village were selected. The subjects in the control group were engaged in domestic work involving a considerable amount of hand-intensive work. Before conducting the study, consent was obtained from the children's parents/legal guardians. Prior permission and ethical approval were also obtained from local community leaders as well as relevant authorities before commencement of the study.

Measurement of physical parameters

The stature and weight of the Experimental group and Control group were measured with a Martin's anthropometer and weighing machine (Crown, Mfg. by Raymon Surgical Co.) respectively. The body surface area (BSA) and body mass index (BMI) of all the subjects were also computed[11, 12].

Assessment of socioeconomic status

For the assessment of socioeconomic status of the subjects, the subjects were asked about socioeconomic status using factors such as level of weekly income, education level, religion, type of family, family size, type of house etc.

Questionnaire study

A detailed musculoskeletal disorder questionnaire was developed and applied to both the experimental and control subjects. The questionnaire was based on the modified Nordic Musculoskeletal Disorder Questionnaire and was completed by both groups of subjects[13]. It consisted of a number of objective questions with multiple choice answers identifying the subjects' personal view points, pattern of work, duration of work and discomfort levels in different parts of the body.

Repetitiveness of work

Repetitiveness of work was examined among the 120 child agricultural workers (63 male and 57 female workers). A study of repetitiveness was performed through analysis of time spent in and motion involved in the different tasks in potato cultivation. Time-motion studies of the different agricultural activities in potato cultivation during one work cycle were recorded. Different agricultural activities constituting a particular job and the times taken for the completion of each activity were recorded with a stopwatch. A repetitive agricultural activity was considered to be one that took more than 50% of the total time period for that particular job. The results indicated that there was repetitiveness of work in potato cultivation.

Time study of entire work process

A time study of the entire process of child agricultural workers or different types of work in potato cultivation was performed and analyzed in the form of a flow process chart and string diagram[14].

Posture analysis

The analysis of different working postures of the child agricultural workers (63 male and 57 female) was carried out with REBA and OWAS methods. A posture analysis study was performed for only the period in which the different activities were performed

by child agricultural workers in a particular day, and analysis was performed with the most frequent postures adopted by the workers taken into consideration. The REBA (rapid entire body assessment) method was proposed as a means to assess posture for risk of work-related musculoskeletal disorders[15], to consider critical tasks of a job and for each task and to assess the posture factors by assigning a score to each region. Analysis of different working postures of child agricultural workers by the Ovako Working Posture Analysis System (OWAS)[16] was also carried out with the aid of digital photography (Sony Handycam 360X). Stick diagrams were subsequently drawn from freeze frame video records and eventually subjected to analysis.

Measurement of hand grip strength

A physical examination was performed by handgrip dynamometer to measure the handgrip strength of the child agricultural workers and control subjects. The child agricultural workers and control subjects were asked to grip the dynamometer with full force while in a straight and standing position without bending to either side, with their arms at their side, and without touching their body[17]. Measurement with the dynamometer was generally performed twice a day prior to potato cultivation and just after completion of potato cultivation among the child agricultural workers at 90º elbow flexion and 180º elbow flexion, as it has been observed that the highest and lowest values for grip strengths vary in accordance with elbow position[18].

Assessment of physiological parameters

Physiological assessment of workload was carried out by recording the heart rate of the workers prior to work and just after work in the field. The resting heart rate was measured from the radial pulse for one minute with the help of a stopwatch, and the heart rate just after work was recorded from the carotid pulse by the 10 beats method[19]. The blood pressure of the female subjects was measured with a sphygmomanometer and stethoscope before and just after completion of work.

Peak expiratory flow rate (PEFR)

Measurement of PEFR was done with a Mini-Wright peak flow meter (Clement Clarke International, UK). Prior to recording the subjects' PEFR, use of the instrument was repeatedly demonstrated and explained. The PEFR test was performed in the standing position with the peak flow meter held horizontally. The subjects were asked to take as deep a breath as possible and then to blow out as hard and as quickly as possible. The best of three ratings was recorded.

Assessment of environmental parameters

The working environment of the child potato cultivators was assessed in this study. The wet bulb globe temperature (WBGT) index was calculated[20] to estimate the effect of temperature and humidity on child potato cultivators. Mean globe temperature, and wet and dry bulb temperatures were also recorded. The formulas for calculating the WBGT index for indoor and outdoor conditions were WBGT indoor=0.7 NWB + 0.3 GT and WBGT outdoor=0.7 NWB + 0.2 GT + 0.1 DB, where NWB was the natural wet bulb, GT was the globe temperature and DB was the dry bulb temperature. Relative humidity was also estimated from a psychometric chart developed by Weksler Instrument (USA)[21]. But in this study, we only measured WBGT outdoor during performance of various activities in the agricultural field by child agricultural workers.

Statistical analysis

The Student's *t*-test was performed among the two groups of workers to find out whether there was any significant difference between the physical parameters of the groups for the chosen level of significance (*p* value). A two-tail chi-square test of independence was applied to determine whether or not the test item had any significant association with discomfort feeling. To assess the relationship of the various factors with the discomfort felt, their odds ratios (ORs) and 95% confidence intervals (CIs) were computed. The computed χ^2 was next compared with the critical χ^2 values for the chosen level of significance ($p<0.05$). The Student's *t*-test was performed among the child agricultural workers and control group of workers to find out whether there was any significant difference in between the heart rates, blood pressures and PEFRs for the chosen level of significance ($p<0.001$). Statistical analysis was performed using the Primer of Biostatistics software (Primer of Biostatistics 5.0.msi, Msi Version=1.20.1827.0, Primer for Windows, Mc-Graw-Hill).

Results

The physical parameters of the child agricultural workers and control subjects are shown on Table 1. No significant difference in physical parameters (height, weight and BMI) was observed in between the child potato cultivators and control subjects. The daily work schedules of both groups of workers are also presented in Table 1. This study shows that, among the child agricultural workers, only 5.3 percent of male child agricultura workers, works as cheap laborers, whereas 94.7 percent of male child agricultural workers works in agricultural fields for their families. In the case of females, only 3.1 percent work as

cheap laborers, whereas 96.9 works for their families. From the questionnaire study concerning socioeconomic status, it was found that, 86.2 percent of male child agricultural workers and 81.9 percent female child agricultural workers were literate, whereas 86.7 percent male and 80.2 percent female control subjects were literate. The questionnaire study showed that the average weekly incomes of the male and female paid child agricultural workers were both rupees 350/–. The majority of the workers (82%) were Hindus, and the rest (18%) were Muslims. About 74% of the families were nuclear, while about 26% were joint families. The average family size was 5.1. The socioeconomic study showed that, Sixty-one percent of the houses were semi pucca houses and that 38% were kutcha houses, while pucca houses accounted for only one percent. The average duration of work of the child potato cultivators and the average duration of work of control subjects are also presented in Table 1.

The discomfort felt in different parts of the body among the child potato cultivators and control subjects is shown in Table 2. The questionnaire study revealed that most of the child potato cultivators complained that the maximum discomfort (pain) felt was in the low back region (98%) of the body followed by the knees (88%), hands (82%), ankles (78%), shoulder (77%), neck (68%) and elbow (66%). This discomfort (pain) felt may have been due to the fact that these child potato cultivators had to perform a considerable amount of rigorous and hard tasks in the agricultural field, which may lead to discomfort among them. This study shows that the exposed group had a significantly higher prevalence of discomfort (pain) than the control group in different body parts like the neck (OR=9.3; p=0.000), shoulder (OR=12.5; p=0.000), elbow (OR=9.6; p=0.000), wrist (OR=8.4; p=0.000), hands (OR=9.3; p=0.000), upper back (OR=9.6; p=0.000), lower back (OR=72.1; p=0.000) and knee (OR=6.5; p=0.000).

The present study shows that the child potato cultivators felt discomfort when engaged in various activities in the potato field like spading (99%), sprinkling water (90%), picking crops (87%), planting seeds (85%) and weeding (82%).

Repetitiveness of the different agricultural activities is shown on Table 3. It is evident from this study (Table 4) that the child potato cultivators performed various highly repetitive tasks during potato cultivation, especially spading (88.00%), sprinkling water (83.7%), and ridging (83.24%). Thus, high repetitiveness may be regarded as a causative factor for the musculoskeletal discomfort of these workers. In this study (Table 3), it was also observed that, the number of work cycles per day or the total periods of time for a particular job in different agricultural activities, which were recorded, varied according to the different activities in potato cultivation. The average duration of total work per day is shown in Table 1.

The flow process chart of the time study shows that the child agricultural workers performed different types of activities in potato cultivation (Table 4).

The different types of work in potato cultivation performed by the child agricultural workers were analyzed with the Rapid Entire Body Assessment (REBA) and Ovako Working posture Analysis System (OWAS) to determine the postural load and to categorize the potential harmfulness of the work posture (Table 5). The posture codes of the REBA indicate that, postures in different potato cultivation activities, especially spading, planting seeds, weeding, sprinkling water and picking crops, demand immediate attention (i.e., Work must cease until a safer solution can

Table 1. Physical characteristics of the child agricultural workers and control subjects

Parameters	Child agricultural workers (n=120)		Control group workers (n=120)		*t* value	*p* value
	Mean	SD	Mean	SD		
Age (years)	12.8	± 3.8	12.5	± 2.1	0.75	0.45
Height (cm)	145.4	± 9.5	144.7	± 8.4	0.63	0.53
Weight (kg)	30.0	± 6.9	29.9	± 5.4	0.10	0.92
BSA (m^2)	1.17	± 0.2	1.16	± 0.1	0.44	0.66
BMI (kg/m^2)	14.0	± 1.9	14.2	± 1.5	0.89	0.37
Years of experience (years)	2.7	± 4.4	1.3	± 3.2	2.80	0.005
Duration of work (h/day)	5.1	± 2.2	3.2	± 2.3	6.45	0.000
Number of working days in a week	6.0	± 1.0	4.0	± 0.8	17.1	0.000

BSA: body surface area, BMI: body mass index. SD: standard deviation.

Table 2. Comparative discomfort (pain) in different body parts among child agricultural workers and the control group

Body parts	Child agricultural workers (n=120)	Control group workers (n=120)	OR	95% CI	χ^2	*p* value
Neck	81 (68%)	22 (18%)	9.3	5.0 to 16.9	57.2	0.000
Shoulder	92 (77%)	25 (21%)	12.5	6.8 to 22.9	72.6	0.000
Elbow	79 (66%)	20 (17%)	9.6	5.2 to 17.7	57.8	0.000
Wrist	85 (71%)	27 (23%)	8.4	4.7 to 14.9	54.4	0.000
Hands	98 (82%)	39 (33%)	9.2	5.0 to 16.8	57.2	0.000
Upper back	59 (49%)	11 (9%)	9.6	4.7 to 19.6	44.6	0.000
Lower back	118 (98%)	54 (45%)	72.1	17.0 to 305.3	81.4	0.000
Knee	105 (88%)	37 (31%)	15.7	8.0 to 30.5	77.4	0.000
Ankle	94 (78%)	28 (23%)	11.9	6.5 to 21.7	70.4	0.000
Feet	66 (55%)	19 (16%)	6.5	3.5 to 11.9	38.5	0.000

percentage of total number of subjects in parentheses.

Table 3. Average repetitiveness of different kinds of agricultural work during potato cultivation

Agricultural Activity	Time taken (s)		Total time taken in 1 work cycle (s)		Repetitive/non-repetitive
	Mean	SD	Mean	SD	
Weeding (n=78)	142.5	± 32.3	196.3	± 34.1	72.6% Repetitive
Ridging (n=100)	223.6	± 34.5	288.5	± 36.3	77.5% Repetitive
Carrying seeds (n= 104)	180.6	± 34.8	270.9	± 38.3	66.7% Repetitive
Planting seeds (n=120)	185.4	± 31.4	222.7	± 31.9	83.2% Repetitive
Spading (n=120)	112.8	± 18.2	128.1	± 19.4	88.0% Repetitive
Sprinkling water (n=89)	152.6	± 24.6	182.3	± 28.4	83.7% Repetitive
Picking crops (n=120)	142.7	± 28.2	198.2	± 30.1	72.0% Repetitive
Carrying crops (n=120)	194.6	± 32.7	262.9	± 37.4	74.0% Repetitive

SD: standard deviation.

be found). On the other hand, in the case of OWAS assessment, the above-mentioned postures associated with different activities in potato cultivation demanded immediate attention (i.e., postures needed corrective measures immediately).

This study also showed that the resting handgrip strength values (MVC values) at 90º elbow flexion and 180º elbow flexion of the child agricultural workers were both 22.4 (± 9.72). The handgrip strength values at 90º and 180º elbow flexion were 19.2 (± 8.51) and 18.4 (± 8.46) respectively. The resting handgrip strength values (MVC values) at 90º elbow flexion and 180º elbow flexion of the control subjects were 23.7 (± 9.16), whereas the control subject's handgrip strength values just after stoppage of work were 22.5 (± 8.35) at 90º elbow flexion and 22.1 (± 8.14) at

Table 4. Details method of time study of different agricultural work during potato cultivation

Chart No. 1		Summary							
Agricultural work during potato cultivation		Activity		Present	Changed	Saving			
		Operation ○		2					
		Transport ⇨		2					
		Delay D							
Activity: Weeding		Storage ▽							
		Combined ◎							
		Distance (m)							
		Time (s)		196.3					
Description	Labor	Time (s)	Distance (m)	Symbol					
				○	D	⇨	◎	▽	
1. Walking for weeding after removal of garbage	1	26.2	5.2			●			
2. Weeding	1	142.5	*	●					
3. Walking towards the garbage with weeds	1	24.1	5.2			●			
4. Removal of weeds from basket	1	3.5	*	●					
Total	4	196.3	10.4	2	0	2	0	0	

Chart No. 2		Summary							
Agricultural work during potato cultivation		Activity		Present	Changed	Saving			
		Operation ○		1					
		Transport ⇨							
		Delay D							
Activity: Ridging		Storage ▽							
		Combined ◎		1					
		Distance (m)							
		Time (s)		288.5					
Description	Labor	Time (s)	Distance (m)	Symbol					
				○	D	⇨	◎	▽	
1. Walking with ridger	1	223.6	26.9				●		
2. Change and move the ridger to make the groove in another row	1	54.9	*	●					
Total	2	288.5	26.9	1	0	0	1	0	

Chart No. 3		Summary						
Agricultural work during potato cultivation		Activity		Present	Changed	Saving		
		Operation ○		2				
		Transport ⇨		1				
		Delay D						
Activity: Carrying Seeds		Storage ▽						
		Combined ◎						
		Distance (m)						
		Time (s)		270.9				
Description	Labor	Time (s)	Distance (m)	Symbol				
				○	D	⇨	◎	▽
1. Picking seeds	1	64.5	*	●				
2. Carrying seeds	1	180.6	28.0			●		
3. Unloading seeds in the planting area	1	25.8	*	●				
Total	3	270.9	28.0	2	0	1	0	0

Chart No. 4		Summary						
Agricultural work during potato cultivation		Activity		Present	Changed	Saving		
		Operation ○		1				
		Transport ⇨						
		Delay D						
Activity: Planting Seeds		Storage ▽						
		Combined ◎		1				
		Distance (m)						
		Time (s)		222.7				
Description	Labor	Time (s)	Distance (m)	Symbol				
				○	D	⇨	◎	▽
1. Planting seeds in a row or groove of soil	1	185.4	17.6	●				
2. Move to different groove or row with a basket of seeds (potato)	1	37.3	*				●	
Total	2	222.7	17.6	1	0	0	1	0

Chart No. 5				Summary				
Agricultural work during potato cultivation				Activity		Present	Changed	Saving
				Operation ○		1		
				Transport ⇨				
				Delay D		1		
Activity: Spading				Storage ▽				
				Combined ⬭				
				Distance (m)				
				Time (s)		128.1		
Description		Labor	Time (s)	Distance (m)	Symbol				
					○	D	⇨	⬭	▽
1. Spading (to fill in the hole with mud using a spade after planting seeds)		1	112.8	10.5	●				
2. Change the row		1	15.3	*		●			
Total		2	128.1	10.5	1	1	0	0	0

Chart No. 6				Summary				
Agricultural work during potato cultivation				Activity		Present	Changed	Saving
				Operation ○		1		
				Transport ⇨				
				Delay D		1		
Activity: Sprinkling Water				Storage ▽				
				Combined ⬭				
				Distance (m)				
				Time (s)		182.3		
Description		Labor	Time (s)	Distance (m)	Symbol				
					○	D	⇨	⬭	▽
1. Sprinkling water		1	152.6	*	●				
2. Move to a different row		1	29.7	*		●			
Total		2	182.3	*	1	1	0	0	0

• Sprinkling water is a static activity. Generally, no distance is covered by the subjects in this activity.

Chart No. 7		Summary						
Agricultural work during potato cultivation		Activity		Present	Changed	Saving		
		Operation ○		1				
		Transport ⇨						
		Delay D		1				
Activity: Picking Crops		Storage ▽		1				
		Combined ◎						
		Distance (m)		198.2				
		Time (s)						
Description	Labor	Time (s)	Distance (m)	Symbol				
				○	D	⇨	◎	▽
1. Picking crops	1	142.7	19.2	●				
2. Storing the crops	1	30.8	*			●		
3. Move to a different row	1	24.7	*		●			
Total	3	198.2	19.2	1	1	1	0	0

Chart No. 8		Summary						
Agricultural work during potato cultivation		Activity		Present	Changed	Saving		
		Operation ○		1				
		Transport ⇨		2				
		Delay D						
Activity: Carrying Crops		Storage ▽						
		Combined ◎						
		Distance (m)						
		Time (s)		262.9				
Description	Labor	Time (s)	Distance (m)	Symbol				
				○	D	⇨	◎	▽
1. Carrying crops	1	194.6	20.5			●		
2. Unloading crops	1	30.3	*	●				
3. After unloading to back in action	1	38.0	*			●		
Total	3	262.9	20.5	1	0	2	0	0

Table 5. Analysis of working posture in the REBA and OWAS methods during potato cultivation among child agricultural workers

Agricultural activities in potato cultivation	Posture	Posture analysis					
		REBA Method			OWAS Method		
		REBA Score	Risk Level	Action Category	OWAS Code	Action Category	Remarks
Weeding 	Back bent forward and twisted, both arms below shoulder level, both knees bent, weight 10 kg or less.	11	Very high	Work must cease until a safer solution can be found	4141	4	Corrective measures immediately
Ridging 	Back bent forward/backward, both arms below shoulder level, walking or moving, weight/force needed over 10 kg but less than 20 kg.	5	Medium	Further consideration should be given as to how risk can be lowered	2172	3	Corrective measures as soon as possible
Carrying seeds 	Back straight, both arms at or above shoulder level, walking or moving, weight or force needed over 10 kg but less than 20 kg.	10	High	Action needs to be taken very soon	1372	1	No corrective Measures
Planting seeds 	Back bent and twisted or back bent forward and sideways, both arms below shoulder level, both knees bent, weight /force needed 10 kg or less.	11	Very high	Work must cease until a safer solution can be found	4141	4	Corrective measures immediately
Spading 	Back bent and twisted or bent forward and sideways, both arms below shoulder level, both knees bent, weight/force needed over 10 kg but less than 20 kg.	11	Very high	Work must cease until a safer solution can be found	4142	4	Corrective measures immediately
Sprinkling water 	Back bent forward/backward, both arms below shoulder level, both knees bent, weight/force needed 10 kg or less.	11	Very high	Work must cease until a safer solution can be found	2141	3	Corrective measures as soon as possible
Picking crops 	Back bent forward and twisted, both arms below shoulder level, both knees bent, weight 10 kg or less.	11	Very high	Work must cease until a safer solution can be found	4141	4	Corrective measures immediately
Carrying crops 	Back straight, both arms below shoulder level, walking or moving, weight or force needed over 20 kg.	10	High	Action needs to be taken very soon	1373	2	Corrective measures in the near future

180º elbow flexion. This study was also revealed that there was a significant difference in handgrip strength measured at 90º elbow flexion and 180º elbow flexion between the resting condition (MVC values) and just after stoppage of work among the potato cultivators and control subjects ($p<0.05$).

Physiological stress of the child potato cultivators and control group is shown on Table 6. This table illustrates that the resting heart rate of both groups did not show any significant change, whereas in the case of just after stoppage of work, the heart rates of both child potato cultivators and control subjects showed significant change. In the same manner, the resting blood pressures (systolic and diastolic) of both the groups did not show any significant change. On the other hand, it was observed that both the groups of subjects (experimental and control) did significantly differ in terms of just after completion of work blood pressure (systolic and diastolic).

This study also compared the PEFR values of the experimental group (child agricultural workers) and control group. It is evident that the mean values of PEFR in the child agricultural workers (284.7 ± 31.3) were lower than those in the control group (312.9 ± 33.6) and that PEFR differed significantly ($p<0.01$) among both groups.

The present study also examined the thermal stress in different potato cultivation activities among the potato cultivators. It was observed that the potato cultivators were suffering from heavy thermal stress in the second stage of potato cultivation, mainly during the picking crops and carrying crops activities (WBGT Index 36.5ºC and relative humidity 75%), which were generally performed in the month of March (start of the summer season).

The present study also showed the different types of discomfort felt among child potato cultivators. The predominant type of discomfort was pain (98%) throughout the body for prawn seed collectors followed by tingling (54.0%), numbness (43.0%), stiffness (12.0%) and swelling (06%). The controls also suffered from pain (45%), tingling (17.0%), numbness (11.0%), stiffness (5.0%), and swelling (1%).

Discussion

Child labor is a socioeconomic phenomenon. Socioeconomic backwardness followed by poverty, illiteracy, unemployment, demographic expansion, deep social prejudices and above all Government apathy are commonly considered the most prominent causative factors for large-scale employment of children.

Agriculture is one of the few industries in which children and adolescents are considered an integral component of the workforce. These workers often perform the same tasks as adult males who work in this industry[22]. This study shows that, among the paid child agricultural workers, most of the workers are from 15 and 16 years age, because the national legislation and policies against child labor in India state that no child below 14 years of age shall be employed in any unorganized sector. So most of the children in this study worked mainly in their agricultural field for their families. The national legislation also states that the state should provide free and compulsory education to all children aged 6 to 14 years. So it was observed that most of the children were literate in the present study. They at least attended the school in the first part of the day and

Table 6. Physiological and physical workload among child agricultural workers and the control group

Physiological parameters			Child agricultural workers		Control groups		*t* value	*p* score
			Mean	SD	Mean	SD		
Heart rate (beats/min)		Resting	88.6	(± 6.88)	89.9	(± 7.74)	1.4	0.170
		Just after work	170.1	(± 7.32)	122.7	(± 8.54)	45.1	0.000
		Change of heart rate	81.5	(± 6.82)	32.8	(± 7.74)	51.7	0.000
Blood pressure (mm/Hg)	Systolic	Resting	94.0	(± 2.97)	93.2	(± 3.32)	2.0	0.050
		Just after work	129.0	(± 4.61)	112.5	(± 5.21)	26.0	0.000
		Change of systolic blood pressure	35.0	(± 3.31)	19.3	(±3.52)	35.6	0.000
	Diastolic	Resting	60.0	(± 2.57)	60.9	(± 3.37)	2.3	0.021
		Just after work	67.0	(± 2.59)	65.2	(± 3.88)	4.2	0.000
		Change of diastolic blood pressure	7.0	(± 2.18)	4.3	(± 2.94)	8.0	0.000
PEFR	(*l*/min)		284.7	(± 31.28)	312.9	(± 33.62)	6.7	0.000

SD: standard deviation. PEFR: peak expiratory flow rate.

generally worked in the afternoon. This study shows that child agricultural workers suffered from discomfort in different parts of the body, especially the lower back, knee, shoulder, hand and neck. This result is in agreement with that of Allread *et al.*[23].

The present study shows that among the agricultural activities in potato cultivation, spading is the most strenuous activity. This result corroborates the work of Das and Gangopadhyay[24]. According to them, child laborers face lot of discomfort during spading due to working in an awkward posture with a high amount of repetition. Planting seeds, sprinkling water, carrying crops and weeding are also activities that cause discomfort (pain) among child agricultural workers.

Pushing, pulling and carrying are the most common human activities in several occupations involving manual material handling. During potato cultivation, child agricultural workers perform several kinds of manual material handling that may be causative factors for the development of musculoskeletal disorder among them. The present study deals with manual material handling in which iron band wheels (ridger) that rotate freely are pulled along the soil to force the soil upwards before potato seeds are planted. In the irrigated farming system, water is fed into the ditches between the ridges. Ridges are also formed for the purpose of water and soil conservation[25]. Many agricultural activities such as the operation of manual ridgers, push/pull weeders and, long-handled tools involve pushing and/or pulling in a standing posture[26]. Kumar *et al.*[27], also added that nearly half of all manual material handling activities involve pushing and/or pulling forces.

The most significant potential risk factors for MSDs in youth are heavy lifting and carrying and working in stooped or awkward postures[28]. Prolonged extreme trunk flexion is commonly found in farm tasks such as pruning, weeding, labelling and harvesting crops. Child potato cultivators have to carry heavy loads when carrying seeds for planting in grooves in the soil and during harvesting, which may be the causative factor for musculoskeletal disorders. The study of Fulmer *et al.*[29] also supports this result; they stated that carrying heavy bags while picking fruit from a ladder would create significant static compressive loads on the low back, especially when workers lean away from the ladder to reach for fruit. Fruit harvesters have also been found to have significant exposure to back stress due to work in severe trunk flexion. The study of Chapman *et al.*[30], also supports the result of the present study showing that transferring containers of fruits, vegetables and plants has been identified as a risk factor for low back pain. Farm children and adults have been studied to determine the effects of different bucket-carrying tasks on upper extremity and low back moments[31].

Another significant potential risk factor for children working in agriculture is upper extremity pain resulting from work in extreme wrist postures, highly repetitive action, high magnitude hand forces, plant propagation and weeding[28]. Using the arms above the shoulder significantly increases the risk of shoulder pain.

According to Silverstein *et al.*[32], an activity is said to be repetitive if 50% of the work cycle involves similar motion patterns. Child agricultural workers perform highly repetitive actions during different agricultural activities associated with potato cultivation. Thus high repetitiveness may be regarded as a causative factor for the development of MSD in upper limbs (wrist, hand and shoulder) of these agricultural workers. These findings corroborate those of other researchers[33–35]. High repetitiveness of work may be regarded as a causative factor for the development of MSD in the upper limbs (wrist, hand, and shoulder) of the male potato cultivators[7], they indicated that high repetition in a job, deviated wrist postures, flexion, extension, and forceful exertion with heavy tool use for long periods are the main causes of upper-extremity cumulative trauma disorder.

Considering the above facts and the analysis of working postures in the child agricultural laborers, it was evident that, according to REBA action categories, use of most of the working postures must cease until a safer solution can be found, whereas in the case of OWAS codes, most of the working postures used by child agricultural workers during potato cultivation require corrective measures required immediately. Thus it is clear that the child agricultural laborers adopt awkward postures at work and suffer from musculoskeletal disorders because they remain in such awkward postures for a prolonged period of time.

A significant difference in handgrip strength just after completion of work was observed between the child agricultural workers and control group of workers. This result corroborates the work of Gangopadhyay *et al.*[35]. According to them, brass metal workers are constantly engaged in hand intensive jobs that may lead to discomfort in the upper parts of the body and lead to a significant change in handgrip strength in contrast to the control group. So it was clear in the present study that there was a significant decrease in handgrip strength just after work compared with before work. The present study also showed that there was a change in handgrip strength among the child agricultural workers and control subjects.

In the present study, the heart rate and blood pressure of the child potato cultivators just after work

were enhanced due to severe physiological stress generated due to different working conditions in stressful postures during potato cultivation. These higher physiological parameters just after work may be due to constant movement of the body. In addition when a child potato farmers bends forward to perform various activities in potato cultivation, the muscles of the abdomen contract and muscles of back stretch. This contracting and stretching of the muscles requires energy. Therefore, the heart has to beat faster to supply more blood to the muscle to provide energy. The present findings are supported by the findings of Guyton[36], who also emphasized that stretching of muscles caused vasoconstriction in the muscles, which resulted in restriction of blood flow and in turn increased systolic blood pressure. The physiological parameters (heart rate and blood pressure) of the experimental subjects were also increased just after completion of work due to performance of highly repetitive actions during work (spading, planting seeds and sprinkling water) and high environmental temperature (especially when picking crops and carrying crops).

This study shows that the experimental group (child agricultural workers) had a lower PEFR than the control group. This result corroborates the studies of Das and Gangopadhyay and Das *et al.*[37, 38]. According to them, the PEFR was markedly decreased in agricultural workers compared with their control groups of healthy subjects. Inhalation of dust during performance of different activities in potato cultivation (especially in spading) has been observed. Due to inhalation of dust, there is release of histamine and leukotrienes from human lung tissue by a non-immunological mechanism. This non-immunological mechanism has been suspected to cause of acute vasoconstriction in some farmers, but it also affects the PEFR due to vasoconstriction.

Limitations of the study

The present study had some limitations. In this study, we were unable to perform an electromyographic examination during different activities in potato cultivation among the child agricultural workers, which would have allowed us to assess muscle fatigue during work. We were also unable to record the details of a lung function test among the child agricultural workers. There are also other factors that have not been investigated, such as the causes of accident and psychological factors of the child potato cultivators. The Nordic Musculoskeletal Disorder-Questionnaire, REBA and OWAS posture analysis were developed for use in adult workers. However, they were applied to child agricultural workers. This is one of the important limitations of this study with regard to child worker posture analysis.

Ergonomics interventions

The following are possible ergonomic interventions that we identified to increase the value of this investigation.

1. Add a short rest break to their work schedule during potato cultivation to avoid excessive physical stress.
2. Job rotation should be performed during potato cultivation, which should benefit the child potato cultivators by reducing their workload. A Job or work rotation policy should be implemented in potato cultivation to reduce muscle fatigue so that activities like spading and planting seeds, which require severe bent postures, can be rotated with tasks like carrying seeds/crops and ridging, which do not require bent postures. In addition, job rotation reduces the boredom and monotony of a job and also reduces fatigue. Raina and Dickerson[39] stated that job rotation reduces muscle fatigue and the monotony of a job.
3. Repetition of work (spading, planting seeds, sprinkling water manually, weeding), which causes musculoskeletal disorders, should be avoided. Kogi[40] also recommended brief intra-work pauses to decrease fatigue in repetitive work in which the muscles can rest after experiencing a static load and a break after a period of continuous work.
4. Proper knowledge and education should be provided to the parents and children for the betterment of their health for the working in the agricultural field.
5. Advice should be given to them about carrying loads (carrying seeds and carrying crops) within the recommended weight limit.
6. Water and salt must be consumed during performance of agricultural activities (especially picking and carrying crops) to prevent dehydration when the environmental temperature is high.

Conclusions

The conclusions reached from this investigation are as follows:

1. This study mainly indicates that child potato cultivators are mainly suffering from musculoskeletal disorders (especially in the lower back, knee, shoulder, hand and neck) due to awkward (stooped, squatting and twisting) postures held for a prolonged period of time with a high amount of repetitiveness.
2. A questionnaire indicated that among all the agricultural activities in potato cultivation, spad-

ing, sprinkling water, planting seeds, carrying crops and weeding causes the maximum discomfort.

3. REBA and OWAS posture analysis indicated that activities like spading, sprinkling water, planting seeds and weeding must cease until a safer solution can be found and that corrective measures are needed immediately respectively. So a performance of these activities by the child agricultural workers fatigues them and restricts them their education permanently.
4. Child agricultural workers have lower handgrip strength due to performance of more strenuous work in an agricultural field in comparison with control subjects.
5. Child potato cultivators suffer from severe physiological and thermal stress due to hazardous working conditions that affect their health and overall work performance.
6. The PEFR value of child potato cultivators decreased in comparison with the control subjects due to continuous working in an agricultural field. The dust particles emitted during spading and other agricultural activities lower the PEFR values of the child farmers, whereas the control group remained unaffected.

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References

1) International Labour Organization. Every child counts: new global estimates on child labour. Geneva (Switzerland): ILO; 2002; p.55.
2) Kurosaki T, Ito S, Fuwa N, Kubo K, Sawada Y. Child labor and school enrollment in rural india: whose education matters? The Developing Economies 2006; 44: 440–64.
3) Self S, Grabowski R. Economic development and the role of agricultural technology. Agricultural Economics 2007; 36: 395–404.
4) Gangopadhyay S, Das B, Das T, Ghoshal G. An ergonomic study on posture related discomfort feeling among the pre-adolescent agricultural workers of west bengal, India. Int J Occup Saf Ergon 2005; 11: 315–22.
5) Sekimpi DK. Occupational health services for agricultural workers. In: Jeyaratnam J, editor. Occupational Health in Developing Countries. New York: Oxford University Press; 2007. p.31–61.
6) Das B, Gangopadhyay S. An ergonomics evaluation of posture related discomfort and occupational health problem among rice farmers. Occup Ergon 2011; 10: 25–38.
7) Das B, Gangopadhyay S. Prevalence of musculo skeletal disorders and physiological stress among adult male potato cultivators of West Bengal, India. Asia Pac J Public Health [published online ahead of print January 13, 2012]. (doi: 10.1177/1010539511421808).
8) Penttinen J. Back pain and Sciatica in Finnish Farmers. Helsinki: Publication of the Social Insurance Institution; 1987.
9) Punett L, Fine L J, Keyserling WM, Herrin GD, Chaffin DB. Back disorders and non-neutral trunk postures of automobile assembly workers. Scand J Work Environ Health 1991; 17: 337–46.
10) McGill SM, Norman RW. Dynamically and statistically determined low back moments during lifting. J Biomech 1985; 18: 877–85.
11) Bannerjee S, Sen RN. Determination of the surface area of the body of Indians. J Appli Physiol 1955; 7: 585–8.
12) Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000; 320: 1–6.
13) Dickinson CE, Campion K, Foster AF, Newman SJ, O'Rourke AMT, Thomas PG. Questionnaire development: an examination of the Nordic Musculo Skeletal Questionnaire. Appl Ergon 1992; 23: 197–201.
14) International Labor Office (ILO). Introduction to work study. 3rd revised ed. Geneva (Switzerland): ILO; 1981.
15) Hignett S, McAtamney L. Rapid entire body assessment (REBA). Appl Ergon 2000; 31: 201–5.
16) Kivi P, Mattila M. Analysis and improvement of work postures in the building industry: application of the computerized OWAS method. Appl Ergon 1991; 22: 43–8.
17) MacDermid JC, Kramer JF, Woodbury MG, McFarlane RM, Roth JH. Interrater reliability of pinch and grip strength measurement in patients with cumulative trauma disorders. J Hand Ther 1994; 7: 10–4.
18) Su CY, Lin JH, Chien TH, Cheng KF, Sung YT. Grip strength: relation to shoulder position in normal subjects. Arch of Physical and Mental Rehabilitation 1994; 75: 812–5.
19) Astrand P, Rodhall K. Textbook of work physiology, 3rd edition, McGraw-Hill (New York): 1986.
20) Yaglou CP, Minard D. Control of heat casualties at military training centers. Am Med Asso Arch Ind Health 1957; 16: 302–16.
21) Tayyari F, Smith JL. Occupational ergonomics. London: Chapman and Hall; 1997.
22) Marlenga B, Pickett W, Berg RL. Agricultural work activities reported for children and youth on 498 North American farms. J Agric Safety Health 2001; 7: 241–52.
23) Allread WG, Wilkins 3rd JR, Waters TR, Marras

WS. Physical demands and low-back injury risk among children and adolescents working on farms. J Agric Saf Health 2004; 10: 257–74.
24) Das B, Gangopadhyay S. An Ergonomic Evaluation of Spading Activity among the Child Labours in Agricultural Sector in West Bengal, India. In: Ergonomic For Everyone, Chapter X Ergonomics in Intervention and Design (978-81-910303-0-3). Gangopadhyay S, editor. HWWE 2009 Department of Physiology, University of Calcutta; 2010: p.235–46.
25) Mathews MDP. Seed-bed preparation in tools for agriculture: A buyer's guide to appropriate equipment 3rd edition, I.T. publications in association with GTZ/GATE; 1985. p.5–30.
26) Tiwari PS, Gite LP, Majumder J, Pharade SC, Singh VV. Push/pull strength of agricultural workers in central India. Int J of Indus Ergon 2010; 40: 1–7.
27) Kumar S, Narayan Y, Bacchaus C. Symmetric and asymmetric two-handled pull-push strength of young adults. Human Factors 2004; 37: 854–65.
28) Das B. Prevalence of work related musculoskeletal disorder among the brick field workers of West Bengal, India. Arch Environ Occup Health (On line posted 8th March 2013).
29) Meyers JM, Miles JA, Faucett J, Janowitz I, Tejeda D, Kubashimi J. Ergonomics in agriculture: workplace priority setting in the nursery industry. American Industrial Hygiene Association Journal 1997; 58: 121–6.
30) Fulmer S, Punnett L, Slingerland DT, Earle-Richardson G. Ergonomic exposures in apple harvesting: preliminary observations. Am J Ind Med 2002; 42: 3–9.
31) Chapman LJ, Newenhouse AC, Meyer RH, et al. Evaluation of an intervention to reduce musculoskeletal hazards among fresh market vegetable growers. Appl Ergon 2004; 35: 57–66.
32) Gillette JC, Stevermer CA, Meardon SA, Derrick TR, Schwab CV. Upper extremity and lower back moments during carrying tasks in farm children. J Appl Biomechanics 2009; 25: 149–55.
33) Silverstein BA, Fine LJ, Armstrong TJ. Occupational factors and CTS. Am J Ind Med 1987; 11: 343–58.
34) Wells R, Moorie A, Potyin J, Norman R. Assessment of risk factors for development of work related musculoskeletal disorders (RSI). Appl Ergon 1994; 25: 157–64.
35) Gangopadhyay S, Ray A, Das A, et al. A study on upper extremity cumulative trauma disorder in different unorganised sectors of West Bengal, India. J Occup Health 2003; 45: 351–7.
36) Das B, Ghosh T, Gangopadhyay S. Assessment of Ergonomical and Occupational Health Related Problem among the Female Prawn Seed Collectors of Sunderban, West Bengal, India. Int J Occup Saf Ergon 2012; 18: 531–40.
37) Guyton AC. Text Book of Medical Physiology, 8 th edition. Bangalore (India): Prism book (Pvt.) Ltd; 1991. p.362–65.
38) Das B, Gangopadhyay S. Comparative study of peak expiratory flow rate among the child labour in West Bengal, India. In: Proceedings of HWWE 2005; International Ergonomics Conference, IIT, Guwahati (India): 2006. p.297–304.
39) Das B, Ghosh T, Gangopadhyay S. Peak expiratory flow rate among child laborers in West Bengal, India. Ind Pediat 2011; 48: 487–88.
40) Raina SM, Dickerson CR. The influence of job rotation and task order on muscle fatigue: a deltoid example. Work 2009; 34, 205–13.
41) Kogi K. Finding appropriate work-rest rhythm for occupational strain on the basis of EMG and behaviour changes, In: Kyoto Symposium: Electroencephanolography and Clinical Neurophysiology, Buser PA, Cobb WA, Okuma T, editors. Amsterdam: Elsevier, Biomedical Press; 1982. p.738–49.