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Original Article

Effect of Load on Upper Extremity Muscles of Agricultural Workers of West Bengal

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ABSTRACT

Introduction: Agricultural fields like weed management and horticultural operations are the most common and labor-intensive. Most of these tasks are completed with the help of push-pull-type agricultural machinery. The push-pull tasks are mainly done using agricultural machinery (push-pull type weeders, manually operated rice transplanters or seeders, long-handled agricultural tools, etc.) by farm workers. Since these are manually operated machinery, long working hours in awkward positions are expected, which causes physical stress and musculoskeletal disorders in the operators. An electromyography study for agricultural workers during push and pull operations was conducted in this study.

Methods: For the purpose of evaluating muscle activity, a laboratory test setup was developed based on the ergonomic criteria of the uniform force application. Four loads (50, 100, 150, and 200 N) and the four most used upper body muscles (middle deltoid MD, triceps brachii TR, brachioradialis BR, and biceps brachii BI) during push-pull operations were selected for an electromyographic study on twelve medically fit agricultural workers as subjects. This study attempted to minimize muscle activity, thereby reducing overexertion injuries.

Results: The most activated muscles during the pushing and pulling operations were TR and BR, respectively. The average muscle activation value of the TR during the pushing task was found to be 109 μV, 135 μV, 178 μV and 195 μV at loads of 50 N, 100 N, 150 N, and 200 N, respectively. At the corresponding load, the average muscle activation value of the BR was 51 μV, 66 μV, 80 μV, and 126 μV, respectively, during the pulling task.

Conclusion: For all subjects, a load of 200 N was found difficult to operate compared to other selected loads during push and pull operations. Muscle activation was found to increase with increasing load for each of the selected muscles.

Keywords: Agricultural worker, Maximum Voluntary Contraction, Muscular activity, Pulling and pushing

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Introduction

India is predominantly an agriculture-based country. Most of the villagers' main occupation is agriculture and related work. According to the agricultural census, 2015–16, farmers' operational landholding size is shrinking day by day. Most farmers (68% of the total) have less than one hectare of fragmented land.[1] This needs to be mechanized. A large amount of farm machinery intervention is required to boost agricultural productivity. Several studies suggest that farm productivity is directly related to farm mechanization.[2,3] Agricultural mechanization in India still needs significantly more ergonomically suitable machinery for land operations. Most farmland operations are labor-intensive because of the unsuitability of heavy machinery for small farmland. So, there is a need for small, manually operated agricultural machinery to cultivate fields.

Agricultural fields need different machinery interventions at different stages of cultivation. Weed management and horticultural operations are the most common and labor-intensive agricultural field operations. Most of these tasks are completed with the help of push-pull type of agricultural machinery.[4] The push-pull tasks are mainly done using agricultural machinery (push-pull weeders, manually operated rice transplanters or seeders, long-handled agricultural tools, etc.) by farm laborers.[5] Since these are manually operated machinery, the long working hours in an awkward position are apparent, which causes physical stress and musculoskeletal disorders in the operators.

The musculoskeletal system is over-exerted during the push-pull type of activities in dynamic postures, and there is an elevated risk of tripping or slipping while applying forward or backward translational mass inertia movement.[6] Because of awkward dynamic operating posture, several repetitive injuries were generally observed on farm workers' shoulders, forearms, arms, neck, wrist, upper and lower back. 20% of lower back pain and injuries are related to pushing and pulling operations.[7-8] The relationship between push exposure and lower back pain was studied by multiplying the weight being pushed and everyday efforts in pushing; about 64% of the subjects chosen for this study had severe and moderate lower back pain.[9]

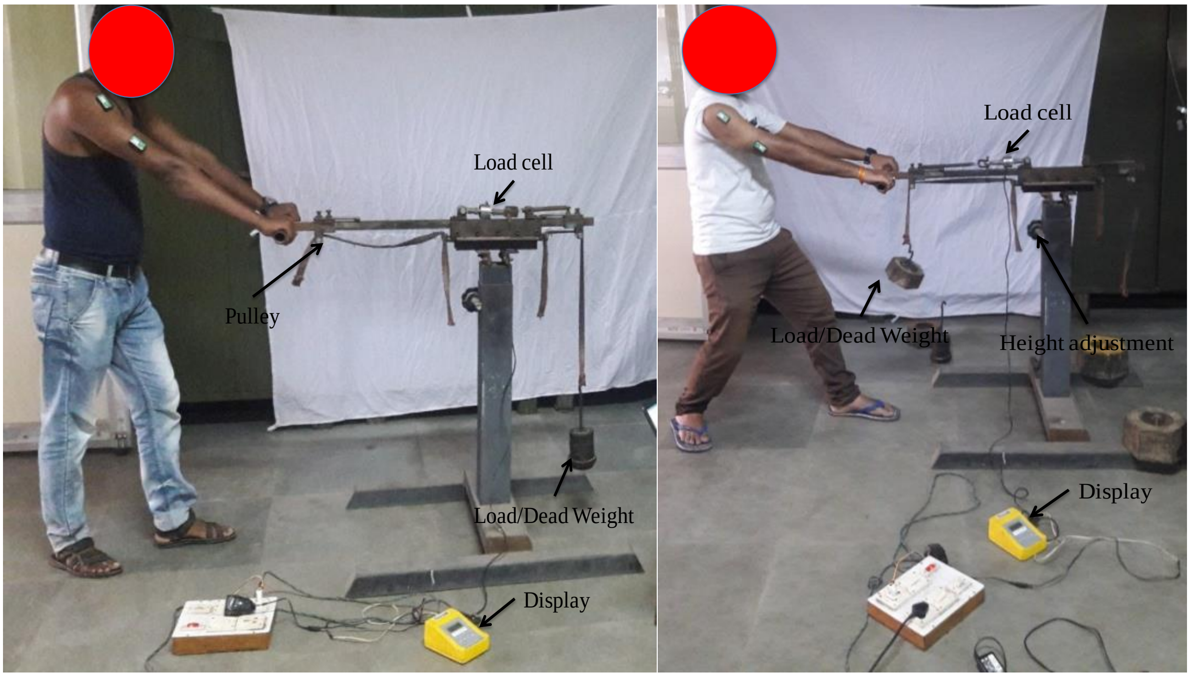
From the perspective of biomechanical studies, several investigations have demonstrated the difference between pushing and pulling activities. The primary focus of these studies was the analysis of hand-related inertial and dynamic forces on the sagittal plane.[7,10] During a dynamic push-pull operation, the hand forces are demarcated into initial, sustained, and ending phases. However, the research findings on pushing and pulling forces have been equivocal. Furthermore, there needs to be more understanding of how these forces acting on hand manifest into the musculoskeletal forces. During work, the importance of muscle activity is well-recognized in ergonomic research.[11] However, these studies typically include pushing or pulling activities; but the level of muscle activation needs to be better understood.[12]

Electromyography can determine the activity of a muscle and assess the force or function of a muscle as a measure of muscular tiredness; it helps to analyze performance, especially when examining whether workplace conditions harm specific muscles. During the manually operated vehicle's pushing and pulling tasks, the upper body muscles are mainly involved in static contractions. According to most theories, pushing and pulling reduce workload and, therefore, injuries and their severity; musculoskeletal disorders (MSDs) costs are associated with these activities.[13] Despite this, further detailed investigations are necessary, supporting epidemiological links between MSDs and push/pull operations. Based on the evidence presented here, pushing and pulling activities are mainly involved in MSDs of the upper body, especially the shoulder/neck region and the upper extremities.[7,14,15]

Additionally, self-reports indicate that the back and upper extremities are experiencing significant discomfort during pushing and pulling, although the causes are not fully understood. There still needs to be more clarity in this area, which emphasizes the need for further research. Pushing and pulling operations in agricultural work include handling, implementing, and soil-resisting forces. The ergonomic evaluation of agricultural machines includes anthropometric data, postural discomfort, operating angle, etc. However, EMG analysis would be most appropriate and helpful for identifying potential problems by identifying areas of the body that have been in static work for an extended period. Therefore, the objective of the current study was to measure muscle activity during pushing and pulling activities to ascertain the level of muscular fatigue experienced by agricultural workers.

Methods

A laboratory test setup for push and pull was developed in the workshop of the Agricultural and Food Engineering (AgFE) Department, IIT Kharagpur, West Bengal, India. The developed setup simulates the pushing and pulling task in a controlled environment in the Human Ergonomics and Safety laboratory of the AgFE Department. The setups have provisions for measuring the push and pull effect for the agricultural workers under different loads. Figure 1 depicts the developed laboratory setup for push and pull activities.



(a) Push operation (b) Pull operation

Figure 1: A view of the push-pull operation laboratory test setup

The push-and-pull experimental test setup comprises a supporting stand and a rope-pulley assembly for applying the load. The dimension values were decided based on anthropometric and strength data of agricultural workers. These dimensions were selected from the book "Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment" to design this setup.[16] The dimension for test setup development is shown in Table 1. The experimental test setup was developed to enable the measurement of force during static pushing or pulling tasks of agricultural farm workers. A telescopic height adjustment mechanism was designed to adjust the height of the experimental test setup. The adjustable height range for the push-pull setup was 1000 to 1250 mm. A telescopic height adjustment mechanism allows the handle's height to be set to accommodate different heightened workers. For the convenience of the workers, a handle grip with a cylinder shape was provided. A 125 kg cylindrical load cell (NOVATECH, England, accuracy ± 0.1% of rated load) was mounted between the adjacent ends. The first end was attached to a fixed end of the horizontal bar, and the second was anchored with a spring at other ends for measuring the forces applied by the subjects. By pushing the handle, the second end pulley reversed the direction of the force application. A belt and pulley system at one end was used to apply loads. Hooks and belt arrangements were made for mounting the loads. To attach the load with hooks, the belt was passed over the supporting pulley. With the belt and pulley arrangement, the load was applied to the hook on the front side when pushing and to the hook on the back side when pulling.

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Table 1: Design dimensions for push-pull setup

Si. No.	Part	Dimension
1	Mainframe dimension, mm × mm × mm	920 × 750 × 1020
2	Diameter of handle grip, mm	35
3	Length of the cross handlebar, mm	460
4	Handle holding height, mm	1000
5	Adjustable height, mm	250
6	No. of pulley	2

Selection of muscles

Push and pull are the most common tasks involved in many agricultural operations. Mainly, the upper arm is flexed when using these agricultural tools and equipment. These operations require flexion and extension of both the elbow and shoulder. Simultaneously, the hand is used to grip the handle of the tools and equipment. During all the field operations, the worker's regular practice is to operate the tools and equipment with both hands. Most workers use their dominant hand-arm system to operate these types of equipment. Therefore, right-hand muscles were taken for the measurement of fatigue. Four muscles of the upper extremity were identified considering the movement in the upper limb for the present investigation as brachioradialis (BR), biceps brachii (BI), triceps brachii (TR), and middle deltoid (MD) muscles.[17-22] These muscles were related to shoulder and elbow movements during push and pull operations. Because of that, these muscles were chosen for experimental analysis. EMG analysis was used to identify muscle contraction, and the signal obtained by EMG was examined for muscular fatigue.

Participants

For muscle fatigue evaluation, 12 healthy agricultural male workers with working experience in the agricultural field were selected as subjects, and their age group was found to be between 20 to 40 years. Few researchers stated that the maximum percentage of work could be expected from 25-35 years age group people.[23-24] These agricultural workers had average ages (± SD) of 34 (± 4.73) years, with an average weight of 63.17 (±7.36) kg, average stature of 166.83 (±5.77) cm, and BMI of 22.71 (±2.58), all of which were within the normal range according to the World Health Organization (WHO). This indicates that all subjects were in normal health and were medically fit to participate in the study. All the participants were right-handed, and none of them were left-handed. All subjects were instructed to use their dominant arm (right arm) during the tasks performed. The effects of four distinct loading conditions ranging from 50 to 200 N with a 50 N increment of load on muscle fatigue during pushing and pulling forces were examined.[25]

Instruments

This study used precision bipolar EMG sensors LE230 (Biometrics Ltd. London, UK), wireless technology, blue tooth® 1.2, Wi-Fi, and IrDA (FIR) integrated, resolution 16 bit) to evaluate muscle fatigue. It is lightweight and small in size, making it highly suitable for EMG data recording of muscle fatigue. Integral electrodes with a fixed electrode spacing of 20 mm are used in these sensors. To minimize the electrical impedance between the skin and the electrode, bipolar surface EMG sensors were employed. On each subject's right side, four sensors were pasted over the muscles: brachioradialis, deltoid, triceps brachii, and biceps brachii. During the trials, EMG signals were captured in real-time, stored in the micro storage device, kept in the slot available in the DataLOG unit, and sent via Bluetooth to the laptop. The raw EMG data were saved for further analysis. A digital handgrip dynamometer (Takei, Japan, measurement range 5.0 to 100.0 kg, minimum measurement unit 0.1 kg, accuracy ± 2 kg) was used to measure handgrip force. Pushing and pulling forces were measured with the help of a load cell (Nova-Tech, England).

Statistical analysis

Experimental EMG data of pushing and pulling operations were collected and analyzed using a full factorial experimental design. Analysis of Variance (ANOVA) was performed on both push and pull force activity using IBM SPSS 20.0 software. The general linear model multivariate test procedure was used to obtain the significance level of test data.

Procedure for data collection of different body parts

1. Cleaning of upper extremity part: The subject was instructed to wash his right upper extremity with soap and water and was given rest for 30 minutes. Muscle areas were shaved clean and further sanitized with the doctor's spirit.

2. EMG fixing: Electrodes were placed on the selected upper extremity muscles according to the European recommendations for surface electromyography, as per SENIAM (Surface EMG for Non-Invasive Assessment of Muscles) project guidelines.[26] The protocol was created for each subject. EMG signal was checked in each muscle, and the range was adjusted accordingly. Cross-checking of two antagonist muscles was also done to increase the accuracy of the signal.

3. Maximum voluntary contractions (MVC) performance: During the experiment, EMG electrodes were put on the selected muscles, and each subject was then requested to execute MVC for each muscle. Each subject performed three different activities to obtain MVC of upper extremity muscles. Also, three trials, each of five seconds, were recorded, and the average was considered a single trial. In order to avoid fatigue effects, subjects were given at least five five-minute rest periods after completion of each test.[18,20]

4. Data recording: Push and pull operations were carried out by the subjects at four selected loads. For each experiment, when a subject was chosen to perform push and pull, the left foot was staggered forward to ensure uniform foot placement. The EMG data recordings of all selected operations were done. Data were downloaded after the experiment. The experiment was repeated for all the subjects in randomized order. EMG signals during push operation of the upper extremity muscle of a subject at the deltoid, triceps brachii, brachioradialis, and biceps brachii are shown in Figure 2. The Root mean square RMS, which is a measure of the signal power, is used in the analysis of the raw EMG signal in the time domain to measure muscle activation levels.

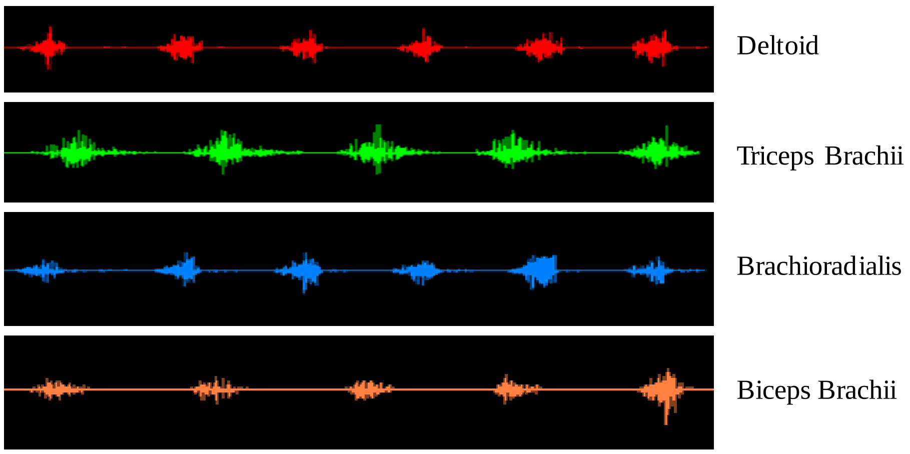

Figure 2: Representative raw electromyogram signals of upper arm of a subject during push operations

Method for assessment of maximum voluntary contraction (MVC) of hand muscles

Subjects performed different activities to obtain MVC. Three different activities for hand muscles were performed to utilize the muscles fully. The subject was instructed to sit on a chair with their forearms horizontal (semi-pronated) on a table's surface and their wrists resting on the edge of the table to measure their MVC of triceps brachii (TR). The table's height could be adjusted, allowing for slight shoulder flexion and an elbow angle of about 120° (Figure 3a). Three maximal handgrip efforts were made using the dynamometer, and the EMG data were captured. This is the same procedure used by a few researchers.[19,27]

MVC values for MD, BR, and BI were recorded with the help of a harness fabricated especially for this purpose. The measurement of MVC of BR and BI muscles is shown in Figure 3b. Here, the subject pulled vertically upward at 120 cm from the ground. The right upper arms were hanging, and the forearm flexed (hanging supinated) at the elbow at an angle of 90º.[21] For MD, subjects pulled against a harness with their right arm. The right upper arm was abducted at 90º, and the forearm flexed at the elbow at an angle of 90º (Figure 3c).[28] Force was obtained by a load cell for the right arm. The MVCs have a force-building phase for 3 seconds (without jerking) followed by a holding phase for 3 seconds before relaxing.[19] The representative raw EMG signals of MVC of the middle deltoid of a subject are shown in Figure 4.

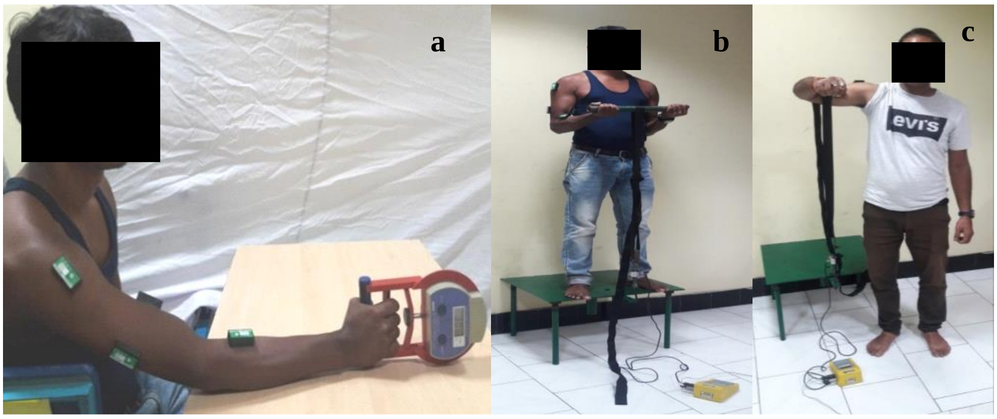

Figure 3: Assessment of MVC of hand muscles at different position: a) triceps brachii, (b) brachioradialis and biceps brachii, (c) middle deltoid

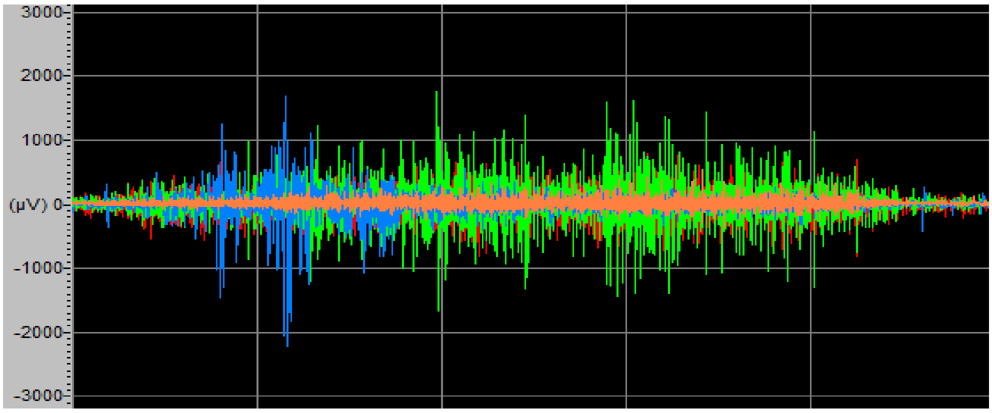

Figure 4: Representative raw Electromyogram signals of maximum voluntary contraction of the middle deltoid of a subject

Results

Influence of increased load during pushing

The representative raw EMG signals of the upper extremity of a subject at different loads during push operations are shown in Figure 5. The average RMS value of muscle activity at 50 N load for muscle MD, TR, BR, and BI were 41, 109, 34, and 27 µV, respectively (Figure 6a). Similarly, for 100 N load, the RMS value of muscle activity for MD, TR, BR, and BI muscles were 51, 135, 49, and 36 µV, respectively (Figure 6b), while for 150 N load, the corresponding values were 65, 178, 55 and 39 µV, respectively (Figure 6c), and for 200 N load, the values were 71, 195, 61 and 42 µV, respectively (Figure 6d). At all load conditions, it was found that the average RMS value of muscle activity was higher in the TR muscle, followed by the MD muscle, and lower in the BI muscle. Furthermore, muscle activation was increased by increasing the load for all selected muscles.

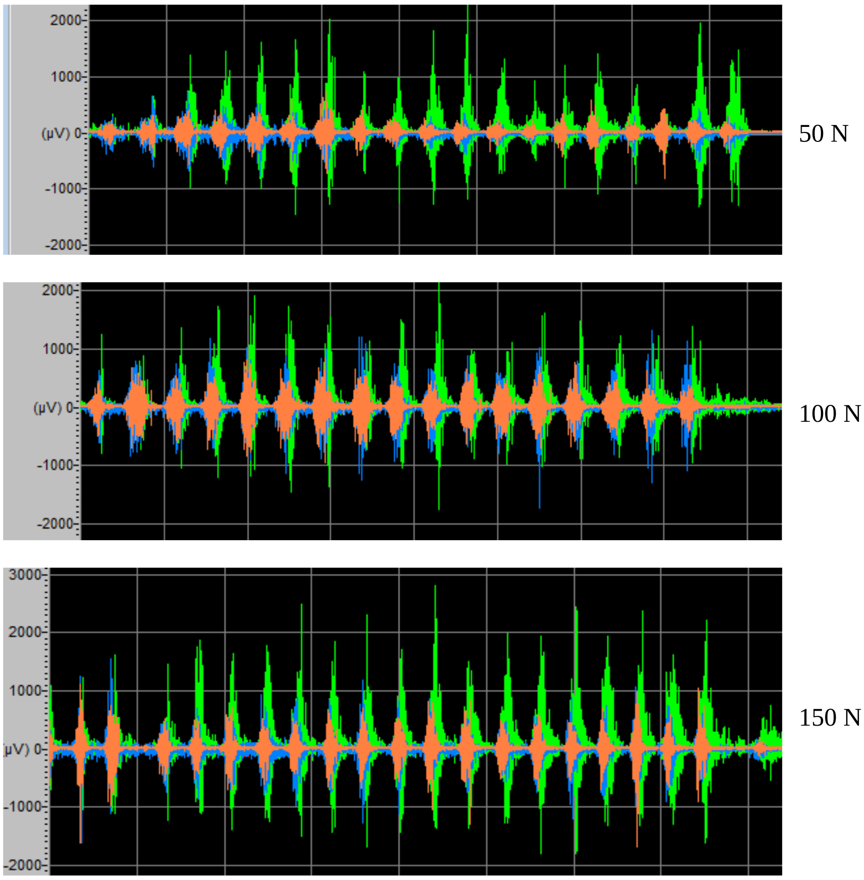

Figure 5: Representative raw electromyogram signals of upper limb of a subject at different loads during push operation

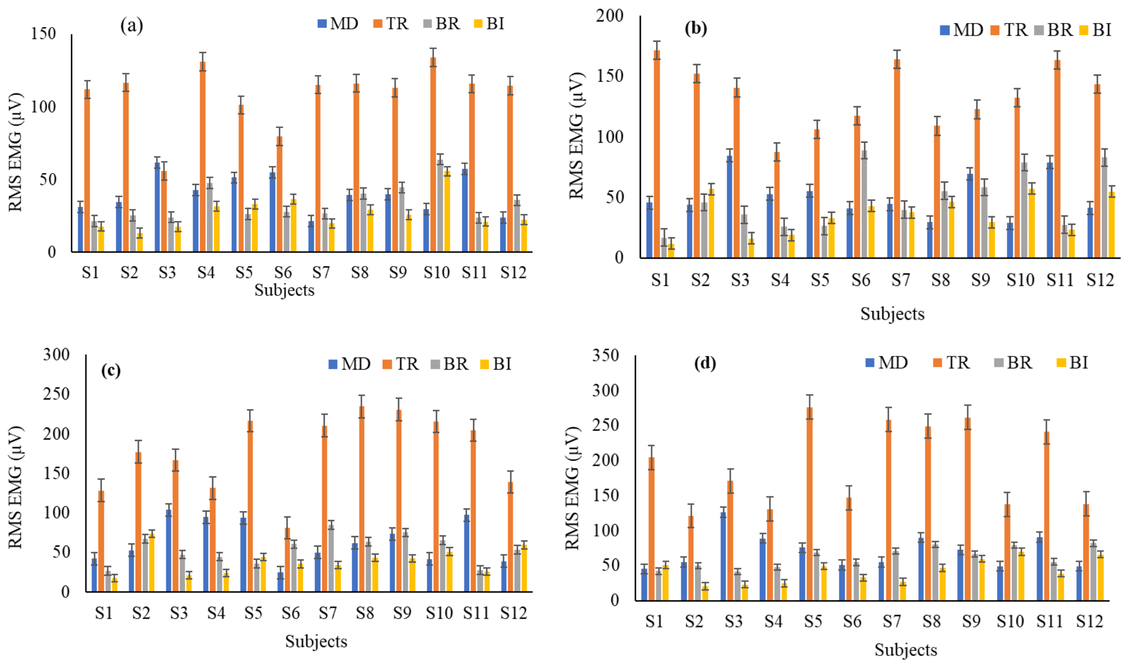

Figure 6: Average RMS EMG value during pushing operation at (a) 50 N (b) 100N (c) 150 N and (d) 200 N load

The muscular activity in real-time on the right upper limb during push force operation is shown in Figure 7. The TR muscle has more muscular activity compared with MD, BR, and BI. However, the BI muscle has less muscular activity than other selected muscles. Muscular activity suddenly increased after 14 seconds of regular push-force operation. This is because of the increased heart rate value of the selected subjects.[4,29] The muscle triceps brachii was activated strongly during the initial pushing phase. Lower limbs produced propulsion power and were transferred to the handle of the push and pull setup through the shoulders and elbows.

Muscle fatigue is determined as the percentage of activation with respect to MVC. The percentage load on MD, TR, BR, and BI muscles was calculated against the MVC to assess the muscle load in pushing operations.

The results indicated a high load on the TR muscle, followed by MD, BR, and BI muscles for pushing operations. TR muscles' average load at 150 N and 200 N was 38.9 and 42.6 %. TR muscle was found above the acceptable range, according to Nag and Chatterjee (1981), which suggested that 20 to 30% MVC could be considered an acceptable range of constant loading in agricultural work. So, the triceps brachii muscle gets more fatigued during pushing because it is responsible for elbow extension, which is a primary movement in pushing.

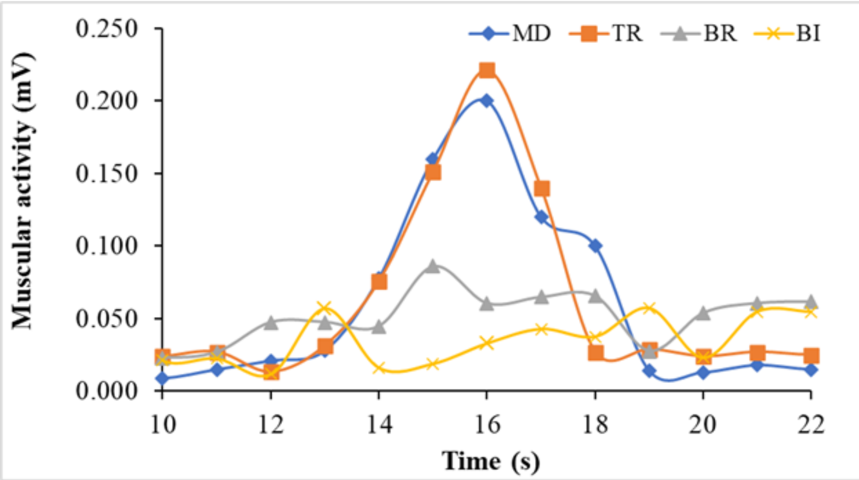

Figure 7: An example of muscular activity on the right side of the upper limb during pushing operation

Influence of increased load during pulling

The average RMS value of muscle activity at 50 N load for muscles MD, TR, BR, and BI were 21, 34, 51, and 38 μV, respectively (Figure 8a). Similarly, for 100 N load, the average RMS value of muscle activity for MD, TR, BR, and BI muscles were 29, 43, 66, and 47 μV, respectively (Figure 8b), while for 150 N load, corresponding the values were 37, 56, 81 and 61 μV, respectively (Figure 8c), and for 200 N load, the values were 46, 80, 126 and 88 μV, respectively (Figure 8d). It was found that at all load conditions, average muscle activity was maximum for the BR muscle and minimum for the MD muscle. The muscle activation increased as the load was increased in all the selected muscles.

The mean value of muscle activation increased with load, which shows that as resistive force application increased from 50 to 200 N, the average muscle activation increased during pull operation. For the BR muscle, the activation force required was more during pull operation than the BI, TR, and MD muscles. The average muscle load at 200 N was 12.2, 17.5, 32.2, and 25.4% for MD, TR, BR, and BI muscles, respectively. This was because, during the pull operation, the BR muscle was more activated than other selected muscles BR muscle at 200 N load was found above the acceptable range, according to Nag and Chatterjee (1981). So this 200 N load should be avoided to reduce muscle fatigue and increase agricultural workers' comfort, safety, and productivity.

The right-side upper limb muscle activity during the pulling task is illustrated in Figure 9. The brachioradialis and biceps brachii muscles were active throughout the entire pulling task. The middle deltoid and triceps brachii muscles were less active during the pulling task than the pushing task. The elbow joints were held in position by muscular activity. When the subject first started to pull, the middle deltoid muscle was engaged to stabilize the shoulder joint.

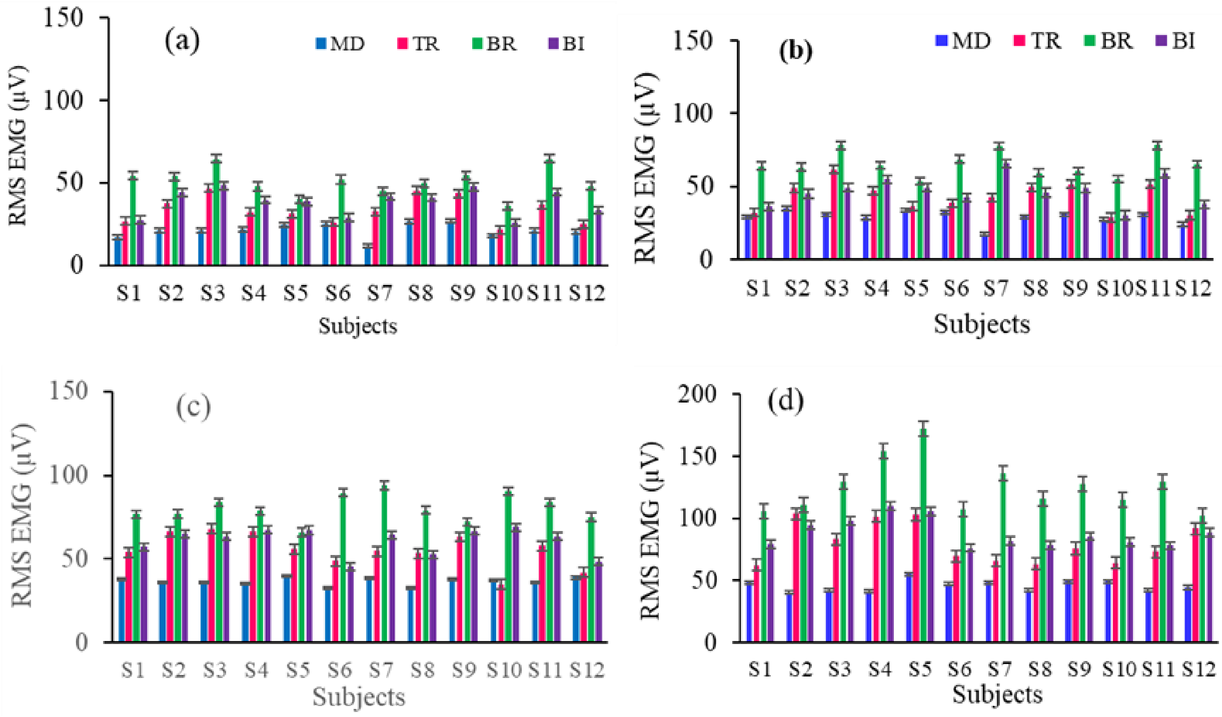

Figure 8: Average RMS EMG value during pulling operation at (a) 50 N, (b) 100 N, (c) 150 N and (d) 200 N load

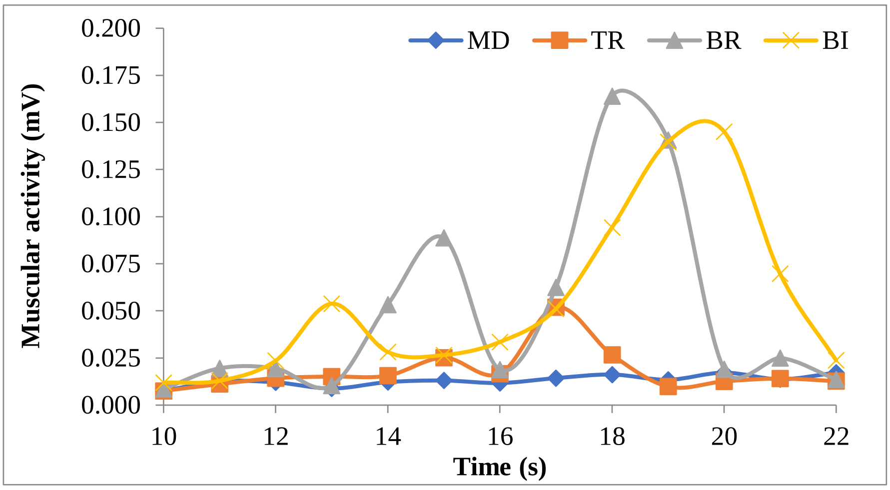

Figure 9: An example of muscular activity on the right side of the upper limb during pulling operation

Table 2: Analysis of variance to study the effect of load on subjects during pushing operation

Source		Sum of Squares	df	Mean Square	F
Corrected Model	MD	25638.044[a]	47	545.490	48.938
	TR	229473.296[b]	47	4882.411	65.669
	BR	16345.552[c]	47	347.778	41.814
	BI	8135.952[d]	47	173.105	18.061
Intercept	MD	465798.743	1	465798.743	41788.486
	TR	3413462.865	1	3413462.865	45911.435

	BR	354492.328	1	354492.328	42621.382
	BI	187997.470	1	187997.470	19614.761
Subject	MD	2971.176	11	270.107	24.232
	TR	34893.675	11	3172.152	42.666
	BR	670.726	11	60.975	7.331
	BI	1197.251	11	108.841	11.356
Load	MD	19530.730	3	6510.243	584.057
	TR	167850.506	3	55950.169	752.536
	BR	14702.436	3	4900.812	589.235
	BI	4745.715	3	1581.905	165.048
Subject * Load	MD	3136.138	33	95.034	8.526
	TR	26729.114	33	809.973	10.894
	BR	972.390	33	29.466	3.543
	BI	2192.986	33	66.454	6.934
Error	MD	1070.072	96	11.147	
	TR	7137.491	96	74.349	
	BR	798.455	96	8.317	
	BI	920.111	96	9.584	

a. R Squared = .960 (Adjusted R Squared = .940), b. R Squared = .970 (Adjusted R Squared = .955)
c. R Squared = .953 (Adjusted R Squared = .931), d. R Squared = .898 (Adjusted R Squared = .849)
df = degree of freedom, F-value: index of significance of the coefficient of determination

Table 3: Analysis of variance to study the effect of load on subjects during pulling operation

Source		**Sum of Squares**	**df**	**Mean Square**	**F**
Corrected Model	MD	12654.158[a]	47	269.237	60.770
	TR	52308.384[b]	47	1112.944	79.153
	BR	126806.110[c]	47	2698.002	134.744
	BI	56612.958[d]	47	1204.531	115.328
Intercept	MD	159267.906	1	159267.906	35948.872
	TR	406828.278	1	406828.278	28933.683
	BR	938253.440	1	938253.440	46858.499
	BI	495985.434	1	495985.434	47488.298
Subject	MD	298.405	11	27.128	6.123
	TR	5699.649	11	518.150	36.851
	BR	2192.276	11	199.298	9.953
	BI	2772.849	11	252.077	24.135
Load	MD	11840.447	3	3946.816	890.848
	TR	43117.846	3	14372.615	1022.182
	BR	112732.118	3	37577.373	1876.699
	BI	51266.673	3	17088.891	1636.182

Subject * Load	MD	515.305	33	15.615	3.525
	TR	3490.890	33	105.785	7.523
	BR	11881.715	33	360.052	17.982
	BI	2573.436	33	77.983	7.467
Error	MD	425.318	96	4.430	
	TR	1349.829	96	14.061	
	BR	1922.220	96	20.023	
	BI	1002.660	96	10.444	

a. R Squared = .967 (Adjusted R Squared = .952), b. R Squared = .975 (Adjusted R Squared = .963)
c. R Squared = .985 (Adjusted R Squared = .978), d. R Squared = .983 (Adjusted R Squared = .974)
df = degree of freedom, F-value: index of significance of the coefficient of determination

The statistical effect of load variation between the subjects for push and pull operation are shown in Tables 2 and 3, respectively, at 95% confidence interval. It shows that the selected load, subjects, and their interaction were found to significantly affect the push and pull force for fatigue in the selected muscle. The main effects of load on subjects were found to be highly significant at $p < 0.05$. ANOVA results indicated that the main effects of load during pushing and pulling were significant.

Discussion

Influence of increased load during pushing

The mean value of muscle activation increased with the increase in load, which shows that as resistive force application increased from 50 to 200 N, the average muscle activation increased during the push operation. For the TR muscle, the activation force required was more during push operations than for MD, BR, and BI. This was because, during the push operation, the TR muscle was more activated than other selected muscles for all subjects. Most upper extremity muscles have evidence of increased activation when pushed at higher loads. Root mean square (RMS) values for EMG activity increased with increasing load in all the selected muscles, indicating that muscular loads were affected by the external load. The participants found that the 200 N load was more difficult to operate than other loads.

The subject pushed the handle forward while facing a backward reaction force. Because the subject's shoulder was higher than the hand, this reaction force caused the shoulder joint to extend. Additionally, during the pushing activity, the subject put a lot of pressure on the floor to prevent slipping, which caused an upward force on the handle. As a result, the subject received a downward reaction force from the handle. The external adduction moment was applied to the shoulder joint by the inward reaction force. To counter the external extension moment, the middle deltoid muscle generated a flexion moment. The triceps brachii is the muscle that extends the elbow, and the biceps brachii is the muscle that flexes the elbow.

As a result of the downward reaction force, this muscle was contracted in opposition to the external extension moment at the elbow. The biceps brachii, and deltoid muscles were contracted, stabilizing the shoulder and elbow joints. The backward reaction force produced the external flexion moment at the elbow joint. This was momentary because the subject was pushing while holding the handle at elbow height. In this investigation, we examined the initial pushing phases, and the findings indicate that the subject could easily transmit pushing force. The handles were only being pushed forward in the horizontal plane when force was applied to them. The force applied to the handles was not directly measured due to significant interference between the axes of the force transducers.

Influence of increased load during pulling

The brachioradialis and biceps brachii muscles were more active during the pulling task than the pushing task. Muscle activity in upper body musculature was more strongly related to the pushing task than the pulling task.[18] This finding shows that the subjects only used their upper body muscles when pulling to maintain their arms stretched since their shoulder position could give them enough space from their bodies. At first, the subjects pulled the handle and moved their center of mass backward during the pulling task. Therefore, the subject received a forward reaction force. The biceps brachii and triceps brachii muscles were contracted simultaneously during the entire pulling task for the elbow. To lock the elbow joints against the external moment provided by the forward reaction force, the biceps brachii and triceps brachii muscles co-contracted.

The additional load mainly facilitates the increased strength required from the muscles of the upper body. The larger force generated by static muscle contractions raises concerns about musculoskeletal problems. Despite numerous studies exploring the effect of load on pushing and pulling, fewer researchers have investigated increased muscle activity in the upper extremities. The results help us understand the risk of injury related to push and pull tasks.

Shoulder and elbow movements and surrounding muscle activities during pushing and pulling

Different pushing and pulling operations at different loads were captured in still images to analyze the postural discomfort. These images were employed to obtain the awkward posture adapted during push and pull operation. These angles include elbow and shoulder angles. The angles were computed using Kinovea software. The muscles around the shoulder and elbow are responsible for the flexor/extensor in the elbow and shoulder. The selected muscles were brachioradialis (elbow flexor), biceps brachii (elbow flexor), triceps brachii (elbow extensor), and middle deltoid (shoulder flexor).

During the pushing operation, in the initial phase elbow is maximally flexed, and the shoulder is extended and abducted (maximum for the operation). In the end phase, the elbow is extended maximally, and the shoulder is flexed maximally, with minimal abduction.

During the pulling operation, in the initial phase, elbow and shoulder joints are maximally extended and flexed, respectively. In the end phase, the elbow is flexed with a maximally extended and abducted shoulder joint. The use of heavier loads during the operation increases abduction at the shoulder joint.

Conclusions

The upper extremity muscle evaluation is essential in determining the risk of developing MSDs while performing pushing and pulling tasks. These tasks suggest a considerable probability of fatigue, leading to MSDs, whereas the task demands (manipulated through the load) significantly affected the upper body muscles. Results showed a more substantial effect on upper extremity muscles during increased push and pull demands, which is of concern as most of these muscles are involved in static contractions during these tasks. The activity of the middle deltoid and triceps brachii muscles was more during the pushing than the pulling task. However, muscle profiles are unique to each task, meaning that alternating push and pull tasks throughout the shift may be essential in reducing overexertion in specific muscles.

For all subjects, muscle activation increased by increasing the load for all selected muscles. The subjects’ evaluations showed more difficulty in controlling the 200 N load. As a result of the heavier load requiring a greater handling force from the subject, the outcome was consistent with Newton's laws of motion.

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