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RESEARCH ARTICLE

Surface electromyographic study of transplanting activity using hand hand-held seedling transplanter

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Abstract

A surface electromyographic study of transplanting activity using a handheld seedling transplanter was conducted to determine the extent of muscle involvement in this activity. Seven healthy subjects in the age range of 20 to 22 years were selected for the study. The following muscles namely right abductor (RA), right extensor (RE), right biceps (RB), right triceps (RT), right deltoid (RD) and right trapezius (RTZ), left abductor (LA) and left extensor (LE) were assessed in a simulated environment using surface electromyography (Biometrics Ltd, UK) with data logger. Task analysis of transplanting activity highlights the muscle involvement for each task. Lifting indicates that RB (30.2 %) has the highest involvement, while Piercing involves the RD (41.6 %) and dropping seedlings is carried out by RB (17.9 %) and pressing the lever and planting is done by RE (40.5 %). It can be observed that there is a significant difference between the subjects and their muscle activity. The extent of muscle activity in the RA indicates that its usage was highest during the initial phase, lasting 20 to 40 seconds. Among the four muscles, RD (46 % of MVC) was found to have the highest activity, followed by RB (40.3 %), RT (40.2 %) and RTZ (38. 2 %) during transplanting. The study's findings will help in designing ergonomically comfortable and user-friendly farm implements to minimise the occupational stress of women farmers. The extent of use of the various muscles will help designers develop ergonomically safe hand tools to increase productivity.

Keywords: hand held seedling transplanter; muscle activity; surface electromyography; transplanting; women workers

Introduction

Seedling transplanting operation is performed manually and accounts for 40 % of the total working hours of cultivation. The labour requirement in manual transplanting of vegetable seedlings varies from 120-420 man hr ha^{-1}. Since the majority of Indian farmers have small land holdings, they are unable to procure costly machinery for vegetable cultivation. The cheaper technologies, which can be beneficial over the traditional cultivation practices, are the current need of vegetable farming in general and seedling transplanting in particular. Thus, it is imperative to design region-specific agricultural tools that can be used by the women to perform the agricultural operations. Hence, a handheld seedling transplanter has been designed for use by agricultural workers for transplanting.

The extent of muscle activity involved in operating this handheld seedling transplanter has been studied using surface electromyography. Surface electromyography (sEMG) is frequently used to assess muscle activity, offers important insights into localized muscle fatigue through adjustments to signal parameters, including time domain, frequency domain, discrete wavelet transform and non-linear techniques (1). Surface electromyographic studies in ergonomics are concerned with fatigue analysis and are used to interpret the musculoskeletal disorders faced by the workers in different occupational settings (2-5).

The estimation of the forces of human muscles using SEMG has been studied extensively at the level of the wrists, elbows, and legs for many applications such as medical diagnosis and rehabilitation (6-11). Surface electromyographic studies in agricultural operations are essential to design simple hand-held farm equipment / implement for design engineers, which in turn helps the users to minimize occupational stress and increase comfort and productivity during agricultural operations. Very few studies have been carried out in agricultural activities using sEMG (12). The present study has been undertaken to evaluate the impact of using hand handheld seedling transplanter over the conventional transplanting on the muscle fatigue.

Materials and Methods

Selection of subjects

Seven healthy female subjects were selected for the study. The age range of the subjects was from 20 to 22 years and they had normal BMI. The details of the experiment were submitted to the Institutional Review Board and the same was explained in detail and their consent to participate in the study was obtained. All the subjects were compensated for their participation in the experiment. Since the participants were not familiar with the handling of the seedling transplanter, they were given training for about a week and once they were familiar with the operation and the speed at which they could handle the seedling transplanter, they were taken for the experiment.

Selection of muscles

Transplanting of seedlings using hand hand-held seedling transplanter involves muscles of the hand, neck and shoulder to a great extent. The operations include pushing, pulling, which require flexion and extension of the elbows. Activity analysis of the use of the seedling transplanter indicated that the seedling transplanter was operated by the dominant hand and the same hand is used to pick seedlings and drop the seedlings into the seedling transplanter. Similarly, the dominant hand is also used to operate the handle, which has a lever mechanism for opening and closing the seedling transplanter. The non-dominant hand is mainly used while lifting the seedling transplanter and moving to the next planting area. Hence, the following muscles, which are involved to a great extent, were selected. The muscles included the right abductor (RA), right extensor (RE), right biceps (RB), right triceps (RT), right deltoid (RD) and right trapezius (RTZ), as well as the left abductor (LA) and left extensor (LE).

Instrumentation

The bipolar electrodes (SX 230) with the data logger MWX8 (Biometrics Ltd, UK) were used for recording the muscle activity of all the selected muscles. Prior to placement of electrodes, the skin was prepared and the electrode was placed in the direction of the muscle as per SENIAM guidelines. A reference electrode was placed on the non-dominant clavicle. All the EMG signals were digitalized at 1000 Hz and recorded to flash memory for processing.

Conduct of the study

The MVC of all the selected eight muscles were assessed using the standard techniques. For the assessment of MVC of each muscle, three trials were conducted and the values were obtained. Suitable rest was provided to the subjects during the assessment of MVC and also between the MVC and the experimental study. Normalization of EMG data is necessary when electrodes are applied to different muscles and individuals because technical, anatomic and physiologic factors can affect EMG magnitude (1).

The experimental study was conducted in a simulated environment where the ridges and furrows technique was adopted. Ten-foot-long ridges were made and the subjects were asked to carry out the transplanting of vegetable seedlings for about 5 min continuously. The subjects were given a basket, which was hung from their left shoulder and housed the portrait seedlings. The entire activity was videographed and later synchronised to produce an analysis of the transplanting process. The raw EMG signals were processed using suitable filters and the Root Mean Square, one of the time-domain measures, was used to study the muscle activation levels. The experimental EMG was further analysed using SPSS 20.0 software. Analysis of variance, Duncan's post hoc test and multivariate analysis were carried out to determine the level of significance of the data.

Results

Table 1 and Fig. 1 present the tasks involved in transplanting seedlings using the handheld seedling transplanter. This activity involves four main tasks: lifting the transplanter (6 ms), piercing the soil (6 to 1.1 ms), dropping seedlings through the transplanter (1.1 to 2.2 ms) and pressing the lever and planting seedlings (2.2 to 3.0 ms). It is observed that approximately 3 seconds is the time taken to transplant a seedling using the seedling transplanter. Analysis of muscle involvement for lifting indicates that the right biceps (30.2) has the highest involvement. Piercing involves the right Deltoid (41.6) and dropping seedlings is carried out by the involvement of the right biceps (17.9). Pressing the lever and planting are done by the right extensor (40.5). The weight of the transplanter is around 1.5 kg and the present study highlights the involvement of the majority of right muscles during the use of the transplanter. Earlier studies on sEMG analysis of agricultural activities like raking and planting seedlings reported the involvement of biceps brachialis to a greater extent and the study also supports that right muscles were used more frequently than the left muscles (12).

The extent of muscle involvement during the piercing activity was mainly carried out by LE and RD. The provision of the handle on the left side of the transplanter enabled them to push the transplanter into the soil. RB, RE and RT were mostly involved in the elbow extension and flexion to complete the piercing task. Dropping of seedlings required less force and the most dominant hand (right hand) was used. During this activity RB muscle was used (17.9 %). The final task of pressing the lever in the handle and enabling planting of seedlings was done by the RE (40.5 %), RA (40.5 %). Pulling the transplanter after planting was mainly carried out by LE (43 %) and RB (34.0 %) and RT (30 %). Literatures cite the involvement of the muscles around the shoulder and elbow as being responsible for the pushing and pulling activities(13-15).

Further analysis indicates that in spite of the significant difference in the muscle activity between subjects, it could be observed that over a period of time, the muscle activity was found to increase with increasing time. The extent of the muscle activity of the RA indicates that its usage was highest during the initial phase of 20 to 40 sec (56 % of MVC) and lowered during the next 20 sec. This trend could be observed during the entire operation of seedling transplantation. This could be attributed to the involvement of the RA in pressing the lever to open up the transplanter to transplant the seedling in the ridges. However, the extent of usage of the LA was found to be significantly lower when compared to the RA. LE was mainly involved in lifting (37 % of MVC) the transplanter from one place to another after transplanting the seedling. However, the extent of usage of the RE (31 % of MVC) was comparatively lower than LE, which may be due to load sharing between the right and left hands. Analysis of the time series indicates that the usage was at its peak during

Table 1. Task analysis by their muscle involvement (%of MVC) during seedling transplanting

Task	Time (ms)	RA	RE	RB	RT	RD	RTZ	LA	LE
lifting	0.00 -.600	20.0	22.5	30.2	16.9	19.7	9.6	12.6	24.1
Piercing	.600-1.100	32.3	39.0	25.2	25.8	41.6	18.9	30.5	42.4
Dropping seedlings	1.100-2.250	0.30	0.19	17.9	0.36	7.6	0.32	0.25	0.27
Pressing the lever and planting	2.250-3.00	35.9	40.5	34.1	30.4	26.1	16.8	20.5	43.0

Right abductor (RA), Right extensor (RE), Right biceps (RB), Right triceps (RT), Right deltoid (RD), Right trapezius (RTZ), Left abductor (LA), Left extensor (LE)

A

B

C

D

Fig. 1. Different tasks involved in transplanting activity.

the first two minutes and then there was a reduction for the next minute and then it was found to increase. The four muscles, namely RB, RT, RD and RTZ, clearly indicate that with progressing time, the muscle activity also increases. This increase in the muscle activity could be observed after three minutes and then remained stable. Among the four muscles, RD (46 % of MVC) was found to have having highest activity, followed by RB (40.3 %), RT (40.2 %) and RTZ (38.2 %). Table 2 presents the statistical variation of different muscles during the transplanting activity. It could be observed that there is a significant difference in the subjects' muscle activity by their BMI. The F-values ranged from 27.857 (LE) to 169.210 (RB), indicating varying degrees of influence BMI had on each muscle. Following ANOVA, Duncan's Multiple Range Test (Table 3 and Fig. 2) revealed specific pairwise differences. Notably, Subject 6 exhibited the highest RB activity (0.36887, group *f*), while Subject 3 consistently showed the lowest activity across several muscles, including RE, RB and RTZ (group *a*), suggesting lower muscle activation in individuals with lower BMI. These results confirm that BMI significantly affects muscle activation patterns, with implications for designing personalized rehabilitation and training programs.

Table 4 and Fig. 3 show the results of an ANOVA examining changes in electromyographic (EMG) activity across time for eight muscles. No statistically significant differences were observed in any muscle ($p > 0.78$ for all comparisons), with F-values ranging from 0.086 to 0.682. These results suggest that muscle activation levels remained stable across the measured time intervals. The lack of temporal variation may be attributed to consistent task performance, short duration of measurement, or effective control of fatigue effects during the experiment.

Conclusion

Women generally perform transplanting activity in a bent posture and use of simple handheld devices to eliminate the bent posture during the transplanting activity enhances the comfort of the user. This study indicates the use of the various muscles involved in lifting operations, pressing and planting operations by use of hand held seedling transplanter. Further studies in this line will help in designing user-friendly and ergonomically designed farm implements to minimize the occupational stress of women farmers. The extent of use of the various muscles will help the designers to develop

Table 2. Analysis of variance between subjects (BMI) and muscle activity

Muscles		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	.777	6	.129		
RA	Within Groups	.334	98	.003	38.027	.000
	Total	1.110	104			
	Between Groups	.573	6	.095		
RE	Within Groups	.076	98	.001	122.365	.000
	Total	.649	104			
	Between Groups	1.321	6	.220		
RB	Within Groups	.128	98	.001	169.210	.000
	Total	1.449	104			
	Between Groups	.309	6	.052		
RT	Within Groups	.166	98	.002	30.489	.000
	Total	.475	104			
	Between Groups	1.458	6	.243		
RD	Within Groups	.198	98	.002	120.236	.000
	Total	1.656	104			
	Between Groups	.244	6	.041		
RTZ	Within Groups	.069	98	.001	57.980	.000
	Total	.313	104			
	Between Groups	1.383	6	.230		
LA	Within Groups	.466	98	.005	48.512	.000
	Total	1.848	104			
	Between Groups	.747	6	.125		
LE	Within Groups	.438	98	.004	27.857	.000
	Total	1.185	104			

Right abductor (RA), Right extensor (RE), Right biceps (RB), Right triceps (RT), Right deltoid (RD), Right trapezius (RTZ), Left abductor (LA), Left extensor (LE)

Table 3. Electromyographic data of different muscles by the study participants (i)

Subjects	RA	RE	RB	RT	RD	RTZ	LA	LE
1	0.21547^{b}	0.14691^{c}	0.17588^{d}	0.12668^{d}	0.34422^{f}	0.10867^{d}	0.02352^{a}	0.2673^{d}
2	0.21532^{b}	0.12227^{b}	0.22043^{e}	0.13807^{d}	0.29276^{e}	0.15072^{f}	0.14658^{c}	0.12583^{b}
3	0.26226^{c}	0.01873^{a}	0.01048^{a}	0.00936^{a}	0.02476^{a}	0.01602^{a}	0.01257^{a}	0.01865^{a}
4	0.25257^{bc}	0.24402^{c}	0.08513^{c}	0.07292^{bc}	0.24507^{c}	0.07347^{c}	0.21234^{d}	0.10072^{b}
5	0.37676^{d}	0.16168^{c}	0.04692^{b}	0.09448^{c}	0.02476^{a}	0.04247^{b}	0.19167^{cd}	0.26696^{d}
6	0.10972^{a}	0.16192^{c}	0.36887^{f}	0.05098^{b}	0.11582^{b}	0.03317^{ab}	0.08648^{b}	0.14358^{b}
7	0.10972^{a}	0.027413^{a}	0.16908^{d}	0.18462^{e}	0.13803^{b}	0.13231^{f}	0.368273e	0.20398^{c}

Right abductor (RA), Right extensor (RE), Right biceps (RB), Right triceps (RT), Right deltoid (RD), Right trapezius (RTZ), Left abductor (LA), Left extensor (LE)

When the analysis of variance results were statistically significant, Duncan's multiple range test was conducted to determine the differences between the means of muscle activity at $p<0.05$

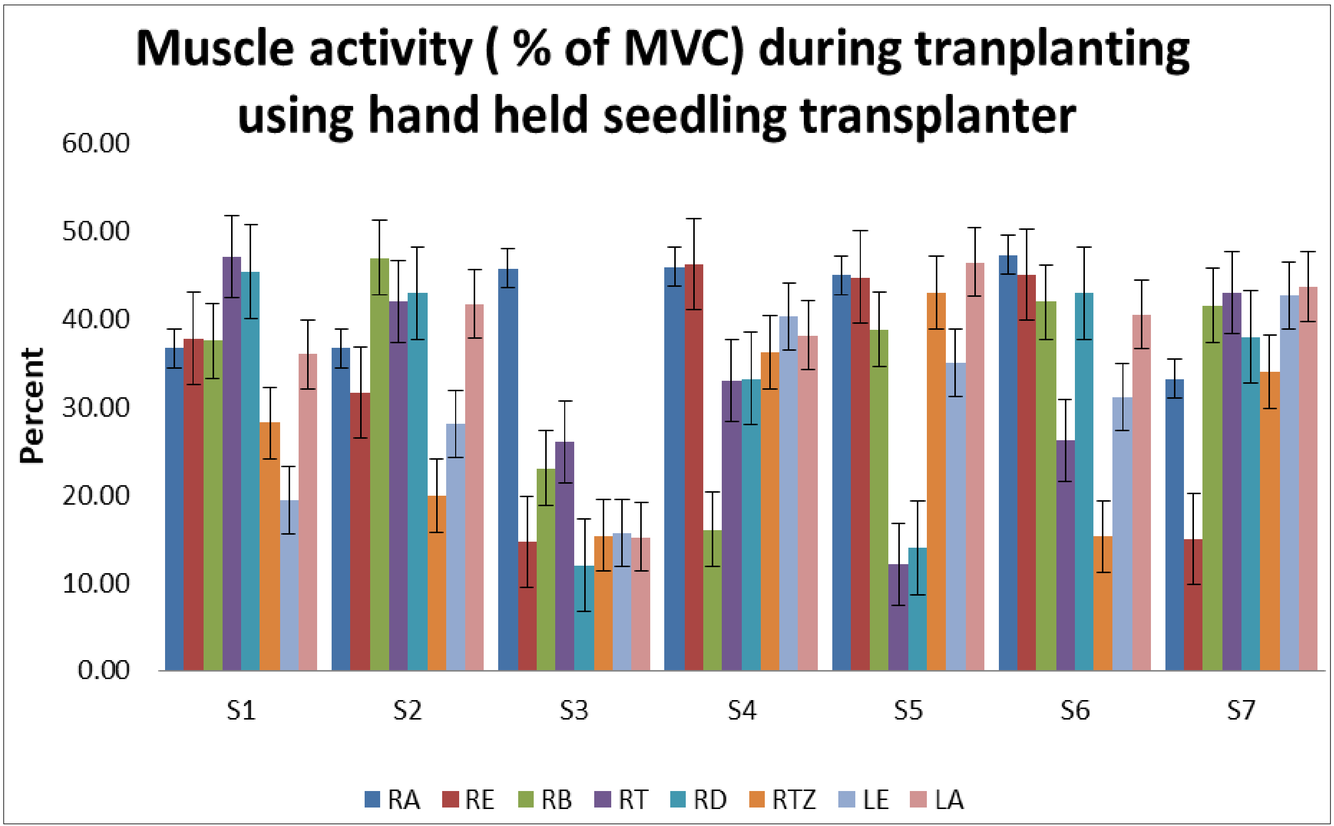

Fig. 2. Muscle activity during transplanting using hand held seedling transplanter.

Table 4. Analysis of variance between muscles and time

		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	.050	14	.004		
RA	Within Groups	1.060	90	.012	.304	.992
	Total	1.110	104			
	Between Groups	.012	14	.001		
RE	Within Groups	.637	90	.007	.123	1.000
	Total	.649	104			
	Between Groups	.019	14	.001		
RB	Within Groups	1.430	90	.016	.087	1.000
	Total	1.449	104			
	Between Groups	.046	14	.003		
RT	Within Groups	.430	90	.005	.682	.786
	Total	.475	104			
	Between Groups	.022	14	.002		
RD	Within Groups	1.634	90	.018	.086	1.000
	Total	1.656	104			
	Between Groups	.012	14	.001		
RTZ	Within Groups	.301	90	.003	.261	.996
	Total	.313	104			
	Between Groups	.042	14	.003		
LA	Within Groups	1.807	90	.020	.148	1.000
	Total	1.848	104			
	Between Groups	.108	14	.008		
LE	Within Groups	1.077	90	.012	.643	.822
	Total	1.185	104			

Right abductor (RA), Right extensor (RE), Right biceps (RB), Right triceps (RT), Right deltoid (RD), Right trapezius (RTZ), Left abductor (LA), Left extensor (LE)

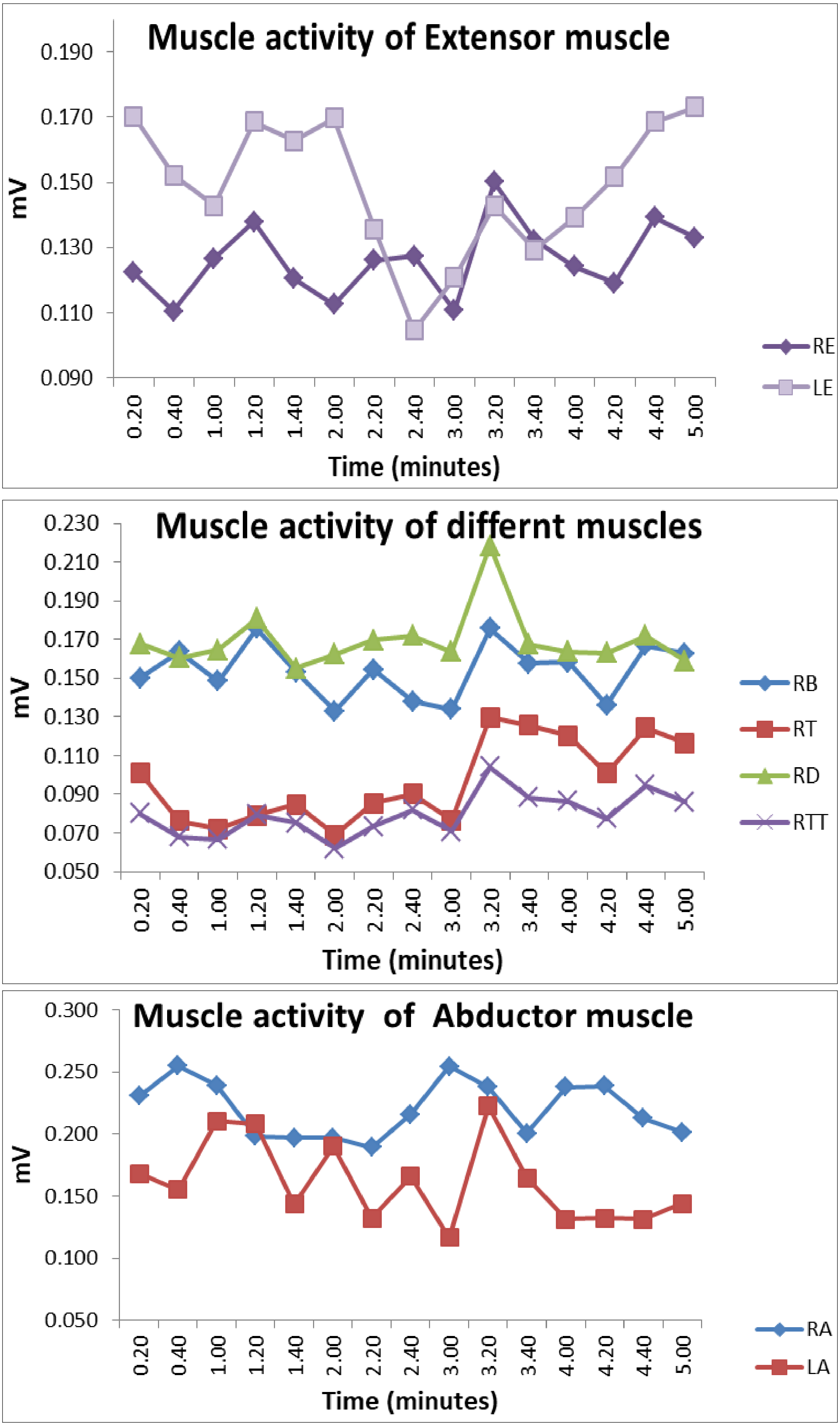

Fig. 3. a. Muscle activity of Extensor muscle by time; **b.** Muscle activity of right biceps, right triceps, right deltoid and right trapezius by time; **c.** Muscle activity of Abductor muscle by time.

ergonomically safe and appropriate hand tools to increase productivity.

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Authors' contributions

PP carried out the research and data collection. PK was involved in designing the protocol for the study. NB and AR were involved in editing the manuscript. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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