Journal of Ergonomics and Advanced Researach
Volume 3 | Issue 1

Research Article Open Access

Joint Analysis of Spectrum and Amplitude (JASA) of Electromyograms Applied for The Indication of Muscular Fatigue in Carpet Weaving

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Citation: Narges Mortazavi, Teimour Allahyari, Hamid Reza Khalkhali, Mohammad Ali Sanjari (2023) Joint analysis of spectrum and amplitude (JASA) of electromyograms applied for the indication of muscular fatigue in carpet weaving. J Ergon Adv Res 3(1): 101

Abstract

Background

Hand carpet weaving requires prolonged static and repetitive tasks in a stationary and constrained postures, thus there is a high prevalence of muscle pain and fatigue and musculoskeletal disorders among carpet weavers.

Methods

This study aimed to determining the muscle fatigue in carpet weaving tasks by Joint Analysis of Spectral and amplitude (JASA (method. Two typical carpet weaving workstations were simulated in laboratory, and 12 female carpet weavers participated in this study. Electromyography (EMG) signals were recorded during work in bilateral upper trapezius and bilateral middle deltoid. The root mean square (RMS) and median frequency (MF) values were extracted from the raw EMG signal and used to estimate muscle load and fatigue. Joint analysis of spectral and amplitude (JASA (was performed for estimating the muscle fatigue.

Results

Result showed that in three out of four tested muscles, muscle fatigue and force decrease in workstation B were higher than those in workstation A.

Conclusion

In comparison to the separate analysis of spectral and amplitude parameters, the simultaneous analysis of amplitude and spectral parameters in JASA method, it seems provide more reliable results. However further studies on other involved muscles in carpet weaving tasks were recommended.

Keywords: JASA; Surface electromyography; Muscle fatigue; Carpet weaving

Introduction

Background

Normally increasing in the EMG amplitude or a shift in the EMG spectrum to lower frequencies suggested as an indicators of muscle fatigue. In order to determining muscle fatigue, first it must be to explore whether muscular fatigue or a change in the force production of the considered muscle is the cause of changes occurring in the EMG amplitude or spectrum. To deal with this problem, joint analysis of spectra and amplitude (JASA) method suggested to assess fatigue of muscular activity [1]. This method simultaneously deliberates the changes in the EMG amplitude and spectrum during the task [1]. Thus, the main advantage of JASA method is that participant do not have to interrupt the task intermittently to perform isometric contractions such as maximum voluntary contractions (MVC) test [2]. Some studies have examined the relationship between workstation, posture, muscle activity, and muscle fatigue. Seghers et al. showed that electrical activity was different in various workstations and postures; but, they found only rare occurrences of muscle fatigue, defined as a JASA method [3]. Straker also reported changes in EMG in two different workstations [4]. Luttman analyzed various tasks in an office environment and found muscular fatigue (time-related changes in the EMG amplitude and spectrum) among participants during some tasks [5]. This study therefore aimed to add to the existing literature by identifying muscular fatigue by JASA method in shoulder girdle muscles in two different carpet weaving workstations.

Methods

The data analysis method presented in this manuscript were applied by relying on a database of surface EMG recordings previously collected during evaluation of shoulder girdle muscle activity of carpet weavers [6]. This section provides a description of the method utilized to simultaneously analyzing of amplitude and spectrum of the EMG data.

Surface EMG Data

The data had been previously gathered using electromyography in two carpet weaving workstations to assess muscular activity and fatigue in shoulder girdle muscles [6]. The dataset included recordings from 12 female carpet weavers with mean age of the 32.5 ± 6.80 years old.

Two weaving workstations were simulated in the laboratory. The first one named as Traditional (A) was low-height vertical loom, weavers sat on the floor in a cross-legged position without any backrest. The second was ergonomic workstation (B): high-height vertical loom, in which weavers sat on an adjustable chair with backrest and armrest. For both workstation, surface EMG recordings were gathered bilaterally from the following muscles of the shoulder: upper trapezius and mid- deltoid. EMG recordings were collected during the same task of carpet weaving (knitting).

Root mean square (RMS) is the applied integrative measure of the EMG amplitude and its dependence on muscular force and fatigue. Analysis of root mean square (RMS) of EMG signal was done for raw data. To normalize raw data, the MVC data for each muscle was used. Median frequency (MF) as a measure of EMG spectrum calculated by Fast Fourier Transformation (FFT).

Joint Analysis of Spectra and Amplitudes (JASA)

JASA method was applied in order to identify muscular fatigue. In this procedure, changes in amplitude and spectrum were simultaneously analyzed. Temporal pattern of the EMG activities of the tested muscles was characterized for three hours of working. RMS and median frequency were used as a measurement of the EMG amplitude and an indicator of the spectral distribution, respectively. In the comparison between mean power frequency (MPF) and median frequency (MF), Luttmann suggested using MF in JASA method (1). JASA method is schematically shown in Figure. 1 and expressed as follows:

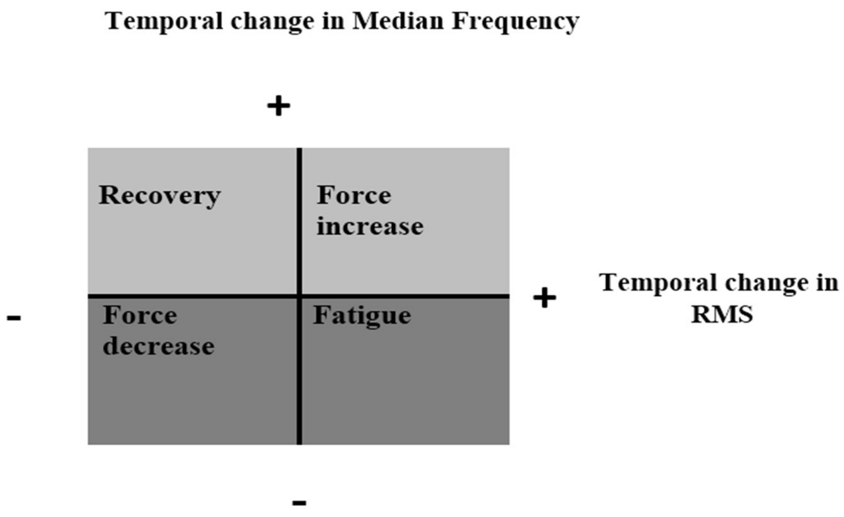

Figure 1: the schematic figure for representing the “joint analysis of EMG spectrum and amplitude (JASA)” methods

- Increase in both RMS and MF over time indicates an increase in muscle force (upper-right quadrant in JASA diagram).
- Increase in RMS and decrease in MF indicate muscle fatigue (lower-right quadrant).
- Decrease in RMS and increase in MF indicate muscle recovery (upper-left quadrant).
- Decrease in RMS accompanied by a decrease in MF indicates decline of the force produced by the muscle (lower-left quadrant).
- RMS and MF time series were figured by regression lines and slope of regression lines was summarized using negative and positive values and shown as a symbol in each quadrant in the diagram.

Results

Muscular Activity in Relation to Workstations, Muscle Type, Side and Time

Normalized RMS was averaged for four muscles and two workstations during 3 h (Table 1).

Workstation A				
Time	Left trapezius	Right trapezius	Left deltoid	Right deltoid
1	35.841±7.330	31.744±5.237	17.343±2.826	14.661±2.107
2	38.283±7.027	32.403±7.649	21.106±4.019	16.764±2.096
3	35.273±5.832	32.616±6.400	17.181±3.070	16.178±1.819
4	36.987±7.196	36.501±8.765	16.331±2.374	15.022±1.414
Workstation B				
1	27.682±4.328	30.901±4.620	11.050±1.447	18.494±4.210
2	30.990±4.647	24.457±3.873	11.150±1.756	16.848±4.945
3	25.170±3.834	26.554±6.328	10.499±1.447	13.464±2.751
4	31.160±4.060	28.616±6.528	12.043±1.547	14.496±2.593

Table 1: Mean ± Standard Deviation of normalized muscle activity (% RMS) in four muscles at two different workstations during three hours (divided into four times)

Median Frequency in Relation to Workstations, Muscle Type, Side and Time

The median frequency was averaged for four muscles and two workstations during 3 h (Table 2).

Workstation A				
Time	Left trapezius	Right trapezius	Left deltoid	Right deltoid
1	57.790±2.788	54.763±4.369	52.755±4.505	51.562±4.329
2	59.896±2.221	60.872±2.781	53.711±1.190	58.594±2.452
3	5.943±2.491	61.98±3.609	56.688±1.666	56.966±2.175
4	58.594±2.544	65.00±3.994	57.943±3.872	57.292±2.420
Workstation B				
1	57.292±3.343	55.664±2.103	65.966±1.697	56.966±2.066
2	57.943±3.183	56.641±3.279	58.268±2.743	58.594±2.634
3	55.339±3.255	55.664±2.312	61.198±3.946	54.036±2.247
4	55.664±3.336	56.316±2.473	60.221±.920	52.083±3.273

Table 2: Mean ± Standard Deviation of median frequency (MF) in four muscles at two different workstations during three hours (divided into four times)

Mean and standard deviation of median frequency can be found in Table 2. The results of the repeated ANOVA show no significant difference between the 2 workstations.

In JASA plot, localization of each symbol in one of the four quadrants showed the state of each muscle in every workstation: "fatigue", "recovery", "force increase", or "force decrease". Steps of the above descriptions are shown in Table 3 and Fig. 2 for one participant.

Slope of regression line for EMG measurement		
Studied muscle	**Normalized RMS**	**Median frequency**
UTL	+	-
MDL	+	-
UTR	_	+
MDR	+	+

Table 3: Slope of EMG parameters with regression line for 3 hours working, example of one subject

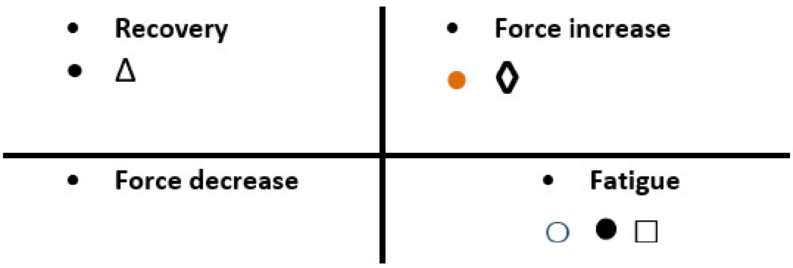

Figure 2: JASA plot for a subject, each figure refers to one muscle under test: Δ: MDL, ◊: MDR, ●: UTL, □: UTR

Results of all the participants and muscles showed that muscle fatigue occurred with a force decrease in left upper trapezius in the participants from both workstations; but, the left mid-deltoid in most of the participants was in force increase and recovery state. Right trapezius and deltoid in workstation A were in force increase and recovery state in several participants; but, in workstation B, these muscles were in fatigue and force decrease status. Therefore, force decrease and muscle fatigue occurred more in workstation B than A (Figure.3).

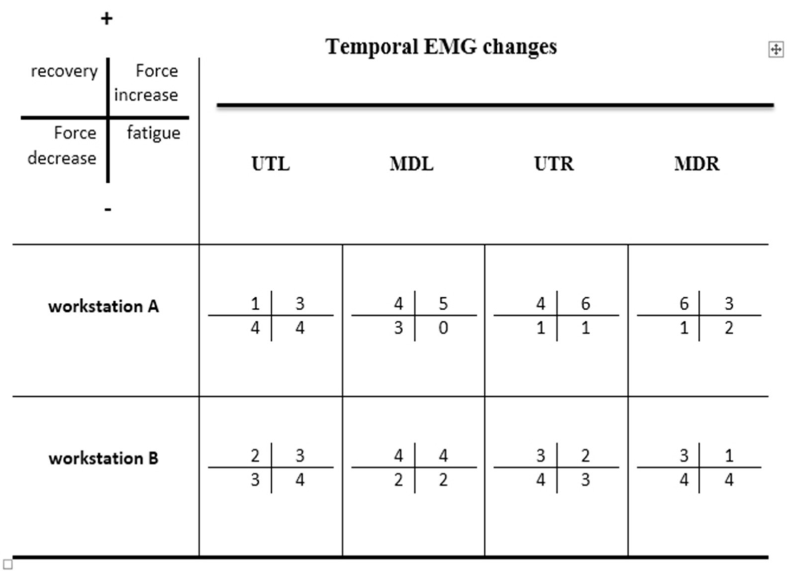

Figure 3: Application of JASA plot, for 4 muscles and 2 workstations of 12 subjects, using the scheme represented in Fig. 1; the digits in each quadrant show the number of subjects in each status (recovery, force increase, force decrease and fatigue) in 3 hours working.

Discussion

Joint analysis of EMG spectrum and amplitude (JASA) showed the relationship, on the one hand, between EMG amplitude and spectrum, and on the other hand, between force and fatigue. As mentioned in the result section, in three out of the four tested muscles, muscle fatigue and force decrease in workstation B were higher than those in workstation A; however, the result of muscular activity was in conflict with JASA results (Fig. 3). In some studies, this point have been implied that increased EMG amplitude may indicate muscle fatigue (9) and decreased spectral values also may reflect fatigue state. JASA method assesses these two parameters simultaneously and provides more accurate results. Therefore, in comparison between RMS values and JASA results, JASA results can be more trusted and it can be concluded that fatigue occurrence in workstation B is more than that in workstation A. Several factors might cause these results and habitual workstation would be the factor affecting fatigue. Furthermore, in workstation A, the participants had more space to move and change their postures during work, which might cause reduced fatigue.

Although the whole shift studies would be more accurate, in the current study, there were different limitations for recruiting carpet weavers for 8 h. Therefore, the test period was set to 3 h. As can be seen in JASA plot, muscular fatigue was evident in almost all muscles in both workstations, but this point is noticeable that in the whole shift test we reach to accurate results. Therefore, based on JASA method, shoulder region's muscle fatigue occurred more in workstation B than workstation A.

Conclusions

We would like to emphasize the importance of considering both EMG amplitude and spectrum data in identifying muscular fatigue that could be help in developing musculoskeletal disorders prevention programs. Failure to identification or misidentification of fatigue can lead to inappropriate preventive measures and can have musculoskeletal disorders as a consequence.

Declarations

Authors' contributions

Conceived and designed the experiments: TA and NM. Performed the experiments: NM. Analyzed the data: HRKH, MAS and NM. Wrote the paper: TA and NM. All authors read and approved the final manuscript.

Acknowledgments

Not Applicable

Competing Interests

The authors declare that they have no competing interests.

Availability of Data and Material

Data supporting of this article are included within the article and additional file.

Funding

This study was fully supported by Urmia University of Medical Sciences with project No. 91-03-34-760. Funding body has not any role in the design, collection, analysis, and interpretation of data or writing the manuscript while they provide the fund for this

study as MSc project.

Ethics Approval and Consent to Participate

This study was approved by the Medical Ethics Committee, Urmia University of Medical Sciences with code of IR.UMSU.REC.1391.113 (decision No. 91, of July 23, 2012). All the participants were apprised of the procedure, purpose, and risk of the research and written informed consent was obtained from each of them prior to the participation.

Consent for Publication

Not applicable.

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