Review of EMG indexes for quantifying the total muscle activity

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ABSTRACT

Objective: The aim of this study is to review the existing indexes for quantifying the total muscle activity for muscle groups. **Background:** EMG has been used in ergonomics for many years with many approaches and techniques employed to solve different problems. Most previous studies used to detect surface EMG signals from several specific muscles, and present the electrical activity levels of muscles one by one. However, there are relatively few attempted to account the "total" muscular load of overall muscle groups. **Method:** Google scholar, ScienceDirect, Pubmed, and Springerlink were searched for studies describing total muscle activity. The methods of the existing research papers (subjects, measuring equipment, measurement position, measurement methods) and the research purposes (clinical, physical exercise, workplace design, health assessment etc.) were analyzed and summarized. **Results:** A total of 27 papers were eligible for this review study and the methods to quantity the "total EMG index" can be divided into 4, such as: (1) average method (10 studies), (2) summation method (8 studies), (3) magnitude method (7 studies), and (4) weighting method (2 studies). **Conclusion:** According to this review study, each of the indexes all has pros and cons, the research purpose and application field were different between each other, so a comparison would be needed to find the best index for quantifying the “total muscle activity” in the future. **Application:** The results of this review study might help to determine the method for quantifying the total muscle activity of muscle groups.

Keywords: Surface electromyography, Total EMG index, Total muscle activity, Global muscular activity,

1. Introduction

Electromyography (EMG) is the study of muscle function by means of the investigation of the electrical signals that the muscles exude, which has been used in ergonomics for several decades with many approaches and techniques employed to solve different problems (Soderherg, 1992). It seems that almost previous studies of muscle activity have one thing in common: despite the different parameters used, they had detected surface EMG signals from several specific muscles, and the electrical activity levels of muscles were presented one by one (Hansson et al., 2000; Juul-Kristensen et al., 2002).

Although the previous studies involved a great deal of data of sEMG of individual muscles, a kind of index for quantitative analysis was not published. Until recently, a few studies attempted to actually account the "total" muscular load of overall muscles to provide a "total EMG index".

A common scaling method is to express the overall sEMG activity as an average value of the electrical activity produced by the individual muscles (Burnely et al., 2002). Comparatively, some studies used the summation of EMG values of several muscles (Kohyama et al., 1998). In the studies of "voluntary response index (VRI)" for quantitative analysis of motor control using signal amplitude, they used the magnitude of sEMG to quantify the total EMG activity (Lee et al., 2004). In a few studies, the weighting of each muscle was considered (Katayama and Hassura, 2003; Serrador et al., 1999).

Quantifying the total muscle activity continues to develop and expend. Future studies will be performed to compare the different indexes. Therefore, this review study aimed to discuss the existing indexes of the total EMG for overall muscles. By analyzing the pros and cons of the indexes, this study tried to identify factors could influence the total muscle activity. Finally, based on the observations, we propose recommendation for future studies.

2. Method

The articles were searched by Google scholar, ScienceDirect, Pubmed, and Springerlink. Keywords were used as “index for the activation level”, “muscle activation index”, “Global muscular activity”, “total muscle activity”, “total amount of sEMG”, and “total EMG of muscles”.

Based on the collected papers, the methods of the existing research papers (subjects, measurement muscles, measurement parameters, measurement tasks) and the research purposes (clinical, physical exercise, workplace design etc.) were analyzed and summarized.

3. Results

A total of 27 papers were identified for this review study. According to the methods, we divided them into four: (1) average method (10 studies), (2) summation method (8 studies), (3) magnitude method (7 studies), and (4) weighting method (2 studies).

3.1 Average method

Many literatures regarding average method assessed total muscle activity in the sports field. In order to quantify the relation between the changes in oxygen uptake (VO_2) and changes in muscle activity, 6 studies were conducted to examine either leg (Burnely et al., 2002; Hughson et al., 2003; vercruyseen et al., 2009; DiMenna et al., 2009) or shoulder (Bernasconi et al., 2006; Bernasconi et al., 2007) muscles in cycling exercise using a index of “total” muscle activity. Clarys et al. (2001) conducted a study to examine the influence of geographic variations on the muscular activity in ski and cycle sports. Both frequency (mean power frequency) and amplitude (root mean square (RMS), and the integrated EMG) parameters were used o estimate the total muscle activity. Other studies also calculated the average value of EMG from selected leg muscles (Besier et al., 2003; Ricamato et al., 2005; Boyas et al., 2009) in the studies of running, gait and hiking posture, respectively.

3.2 Summation method

Studies of dentistry appeared to use the sum of rectified amplitude and/or RMS as the total EMG index for the muscular effort (Kohyama et al., 1998; Caloss et al., 2010). In sports field, muscular strength and stiffness were estimated by summation of normalized RMS or iEMG values (Shima et al., 2002; Duc et al., 2008; Ocarino et al., 2008). In ergonomics studies, the sum of EMG responses of RMS and linear envelop for all recorded muscles was also useful for determining the muscular strain of specific work tasks (Kothiyal and Kayis, 2001; Dickerson et al., 2007; Chopp et al., 2010).

3.3 Magnitude method

In the studies of using sEMG recordings for the central dysfunction, a series of work was carried out for quantification of the amount of activity in multiple recording channels. Lee et al. (2004) conducted a study where they proposed an “voluntary response index (VRI)". The first element of VRI is the magnitude of response vector (RV), which is a measure of the total amount of sEMG activity. The magnitude is computed as the square root of the sum of the squares of the individual muscle amplitudes. After that, the VRI has been used to distinguish patients from control subjects in several studies, (Lim et al., 2004; McKay et al., 2004; Lim et al., 2005; Lin et al., 2006; Cheng et al., 2010; Yang et al., 2010), all these studies showed sensitive to detect the altered patterns of muscle activation in subjects with disorders.

3.4 Weighting method

The total muscle index would be improved if the differential weights in accordance to muscle function were used. However, there are few studies considered the contribution of each muscle to force generation.

In the study of Serrador et al. (1999), the total EMG activity was obtained by summing the normalized values from the four muscles according to the weighting of the total mass of each muscle. In a study of development of "Performance Indexes" for arm posture selection, from the view of optimization principle, they proposed the "Minimum muscle activation density index", representing the activation index divided by a cross section (PCSA) of each muscle.

4. Conclusion

This review study aimed to summarize the available literature of the different methods to quantify the Total EMG index. Only 27 papers that were eligible for reviewing were identified to calculate the total muscle activity. Average method and summation method was described in 10 (37.0%) and 8 (29.6%) papers, respectively. In 7 papers (25.9%) magnitude method was investigated, in 2 of the papers (7.4%) weighting method was described.

The papers used average method all showed valuable results, but this treatment seemed to be arbitrary because the contribution of each muscle to force generation and oxygen uptake was not considered (Burnley et al., 2002). Also, the average of EMG data may overlook important information (Nussbaum and Chaffin, 1997).

Studies of clinical, sports and ergonomics all seemed like to use the sum of rectified amplitude and/or RMS as the total EMG index for the muscular effort, but it would be difficult to use in studies which different number of muscles were measured as the values get bigger.

Despite the excellent reliability, the "voluntary response index (VRI)" did not consider the temporal elements of motor control. It may need to add contributions to this method's sensitivity that might be brought by detailed features of the sEMG patterns (Lim et al., 2005).

Even though it is not detailed, contribution of each muscle was considered in the weighting method. However, other factors like muscle direction, volume, length, fiber types may influence the value of total muscle activity of different muscle groups (Wood et al., 1989).

Our observation indicate that there is no clear guidance on how to sum the activity of different muscle groups (Serrador et al., 1999), a comparison would be needed to find the results obtained by different quantification methods. In future studies, both subjective discomfort rating and heart rate are need to measure simultaneously with muscle activity, and the sensitivity of these indexes would be identified using the correlation analyses between the EMG indexes, subjective discomfort rating and heart rate. Moreover, differential weights in accordance to the muscle function are needed to consider for the quantification of total EMG index in the future.

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