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ScienceDirect

Procedia Manufacturing 3 (2015) 4260 – 4265

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

Applicability of affordable sEMG in ergonomics practice

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Abstract

This study was conducted in order to assess the potential of low-cost surface electromyography (sEMG) measurement systems to be applied in ergonomics practice on the example of provided relative grip force estimates. Two measurement configurations, with a total cost below $100, were compared with a commercially available electromyograph. It was hypothesized that Arduino based do-it-yourself measurement systems do not perform significantly worse than commercially available electromyograph. Ten participants' normalized sEMG activity of the m. flexor digitorum superficialis were compared in the case of three submaximal isometric hand grip force levels (25%, 50%, 75% of maximum voluntary contraction). Normalized sEMG activity, measured with different systems, was not statistically different. It was concluded that low-cost measurement systems have the potential to be used in order to detect muscle activation-deactivation patterns or at least the semi-quantitative assessment of grip force; however, the results of this study are limited to isometric contractions.

Peer-review under responsibility of AHFE Conference

Keywords: Low-cost EMG; Arduino in ergonomics; Isometric gripforce assessment

1. Introduction

Musculoskeletal disorders (MSD-s) have been a key topic in ergonomic research for decades. Putz-Anderson [1] listed the use of excessive force, highly repetitive work process, awkward postures and inadequate rest as the main causative factors for MSD-s, but more recent reviews have listed up to 70 [2] potential causative factors. Obviously it is impossible to consider such an amount of factors in experimental studies. Most of these factors can be assessed

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Peer-review under responsibility of AHFE Conference
doi:10.1016/j.promfg.2015.07.412

with self-administered questionnaires and the prevalence of some factors can be detected by observations but force evaluation still requires apparatus. Often Borg's perceived exertion scale [3] is used instead of an apparatus; however, some occupational studies report up to 50 % overestimation in self-reported force exertions [4].

The main challenge of force measurement in occupational settings is the representativeness of the results, thus the apparatus should not alter the task or require interference in the work process. Both force sensing resistors (FSR-s) [5] and surface electromyography (sEMG) [6] will satisfy such criteria.

In a review Hägg et al. [7] lists three major sEMG applications in ergonomics practice: 1) detecting activation patterns of muscles; 2) estimation of muscular force and 3) fatigue assessment. It is obvious that the second and third applications are impossible without the first. Muscular force and muscle fatigue assessments with sEMG do not necessary need to be performed simultaneously. Often the EMG power spectrum is used in fatigue analysis, where changes in median or mean frequency are used as fatigue indices [8–10]; however, critics of this approach suggest joint analysis of the EMG spectrum and amplitude, i.e. the JASA method [11, 12].

Several authors have explored the possibility of estimating grip force exertion via EMG amplitude [13–20]. However, applications of developed models are usually limited to the conditions they were developed for [21]. As the motion of the human hand has 27 degrees of freedom, a perfect model would not pass the cost-benefits analysis due to amount of calibration required. This would also require recording the signal from multiple muscles. Some grip force estimation models [19, 20] included six muscles (flexors and extensors), however, both of the studies report only minor error reduction if the models included more than three muscles.

Other disadvantages of EMG measurements include complex data processing and the cost of the apparatus. However, ongoing engineering progress permits concurrent attempts [22] to reduce the cost of the hardware. Recent examples of low-cost sEMG applications include rehabilitation exoskeletons [23] and hand prostheses [24, 25]. It is obvious that such solutions will require successful recognition of muscle activation and at least, to some extent, the estimation of strength exertion. The potential of the force exertion estimation still needs assessment.

It is possible to overcome the technological complexity by using modern day low-cost, easy-to-use prototyping platforms such as Arduino [26]. Also, the capability of Arduino microcontrollers to sample EMG signal has been proven [27] and it is possible to purchase commercially manufactured Arduino compatible sEMG measurement shields. A shield is a small electronic board which, if attached to a microcontroller, will add functionality and thus only minimal soldering, if any, is required, which reduces the practitioners' need for an engineering background. Only knowledge about functional anatomy and physiology is mandatory. As the access to sEMG measurements has been improved in the last few years, it is natural that the practitioners, specialized in the domain of physical ergonomics, are interested in the benchmarking of such do-it-yourself (DIY) measurement systems and the task for the scientific community is to provide the assessment.

The aim of this study was to assess the applicability of commercially available low-cost sEMG shields in ergonomics practice. It is hypothesized that Arduino based DIY measurement systems do not perform significantly ($\alpha = 0.05$) worse than commercially available electromyograph.

2. Methods

2.1. Test objects

In this study, low-cost measurement system is defined as fully operational sEMG measurement apparatus with a total cost below \$100. Initially four commercially available sEMG shields were considered – 'Muscle Sensor v3' (Advancer Technologies, Raleigh, USA); 'Olimex Shield EKG/EMG' (OLIMEX Ltd, Plovdiv, Bulgaria), 'Grove EMG Detector' (Seeed Technology Inc, Shenzhen, China) and 'BITalino' (PLUX wireless biosignals, Portugal). All the shields were tested prior to further assessment by recording the sEMG of maximum voluntary contraction from two subjects. Although BITalino showed promising results, it was excluded from further assessment because 1) it is not Arduino compatible; 2) the cost of a fully operational system exceeded the limit of \$100. The Grove EMG Detector was also excluded from further assessment because of low signal amplitude and it was impossible to adjust the level of gain.

Finally, Advancer Technologies' Muscle Sensor v3 (adjustable gain, input impedance 0.8 GΩ, CMRR = 90 dB, rectified EMG output) and Olimex Shield EKG/EMG (adjustable gain, input impedance 10 TΩ, CMRR = 80 dB,