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Towards an Objective Assessment of Comfort and Ergonomics during Surgery

A. Shafti¹, B. Urbistondo Lazpita¹, O. Elhage², H. A. Wurdemann³ and K. Althoefer⁴

¹*Dept. of Informatics, King's College London,*

²*Dept. of Urology, Guy's Hospital, King's College London,*

³*Dept. of Mechanical Engineering, University College London,*

⁴*School of Electrical Engineering & Computer Science, Queen Mary University of London.
ali.shafti@kcl.ac.uk*

INTRODUCTION

Comfort and ergonomics are familiar terms with typically subjective definitions. Each person has their own thoughts on what is comfort and ergonomics to them, making these parameters hard to assess and compare objectively. Work related musculoskeletal disorders (WMSDs) are the result of issues in these same parameters in the workplace left unnoticed and unattended, and this is particularly a big issue in clinical and surgical environments. It is therefore critical that an assessment scheme for comfort and ergonomics be in place for regular checks in the surgical environment. There are methods and techniques proposed and currently in use for this purpose. These range from subjective questionnaires to observation-based measurement and scoring of joint angles involved in a posture and task and are used regularly in clinical and industrial environments alike and are popular due to their ease of use and lack of a requirement for specific expertise. However, this simplicity has the downside of lack of objectivity and/or thoroughness. Questionnaires are based on the interviewee's subjective understanding of comfort whereas observational methods don't take into account specific muscle activation and load patterns or the potential effects of dynamic postures.

A more thorough and objective understanding of comfort and ergonomics can be achieved by relying on a person's biological signals rather than their subjective opinion. Biological signals can provide precious information about human behaviour and allow assessment of different activities in terms of health and comfort [1]. The acquisition of such data has traditionally been limited to laboratory environments due to the size and complexity of the equipment as well as the expertise required to conduct the tests and make sense of the data. That is why such signals are not typically a part of comfort and ergonomics assessments methods, as they are to be conducted regularly in workspaces at a low cost. The parameters of interest are effort, comfort and ergonomics. Such information can be applied when designing new tools in different fields to ensure comfort and ergonomics for the user. Furthermore, a real-time objective assessment of

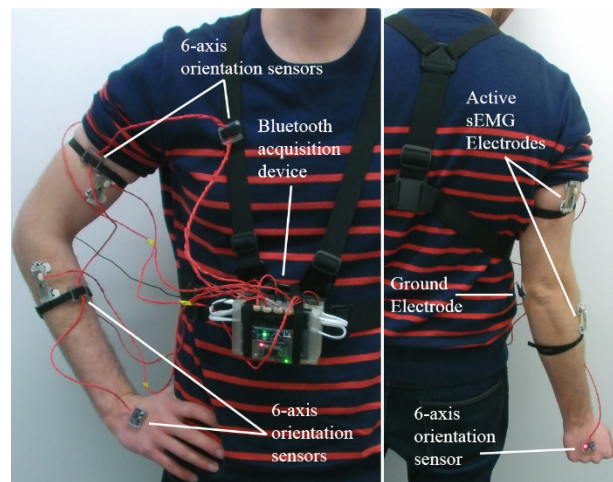


Figure 1. The wearable muscle activity and joint angle estimation device used in this work to study correlation of different comfort and ergonomics assessment techniques.

comfort will allow for better interaction between automated intelligent systems such as robots with humans.

This paper describes the use of low-cost, wearable sensors that bridge this gap, namely electromyography (EMG) and orientation sensors (accelerometer and gyroscope) to consider muscle activity and the kinematic behaviour of the body. Experiments are conducted to compare the results with those of already established subjective methods (Borg scale [2]) and observational tools (Rapid Upper Limb Assessment or RULA [3]).

MATERIALS AND METHODS

In order to compare the above mentioned methods, an experiment is designed to accommodate all techniques while subjecting the participants to tasks with different postures and varying levels of effort, comfort and ergonomics. The selected task is a buzz-wire test, i.e. a thick wire with random curves in different spatial planes that the participant needs to follow with a loop. The circuit connected to the buzz-wire will beep and record for every collision, called errors. Thus, performance can be rated as a mixture of time elapsed on each test and number of errors. The buzz-wire is set at three different height levels, depending on the participant's height. The participant is seated at a desk, in front of the buzz-wire, and asked to only rely on movements in their dominant arm to conclude the test. The task is repeated 3 times at each height, with the order randomised. Participants are

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fitted with a wearable sensing device consisting of orientation and EMG sensors that record the joint angles of the arm as well as muscle activity in the triceps brachii, biceps brachii, wrist extensor and wrist flexor muscles. The joint angles obtained through the orientation sensors are used to calculate an ergonomics score, using the RULA look-up table¹. The Borg scale is applied by asking the participants to describe the level of discomfort they felt during the task with a number between 0 and 10, once the task is completed. The EMG sensors are custom built for this experiment, following recommendations of “Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles” (SENIAM). The EMG signal was fed into a Bitalino® data acquisition device, which samples the data at 1 kHz, and transmits over Bluetooth. The orientation sensors are implemented with the InvenSense® MPU6050 breakout board and ‘MotionApps’ open source Arduino libraries developed by J. Rowberg. Ethical approval for these experiments was obtained previously, reference number: BDM/13/14-123.

RESULTS

Experiments are conducted on N=10 participants. A MATLAB script is created to analyse the EMG data. The signal for each muscle is normalised to the maximum voluntary contraction (MVC) of that muscle to allow for fair comparison. Each signal is then high-pass filtered with a 4th order Butterworth filter at 20 Hz, to remove motion artefacts before rectification. Once the signal is rectified, a sliding window (200ms) root mean square (rms) method is applied to acquire an envelope waveform. The average of this signal throughout the task is considered as the muscle effort score during that task. The RULA score obtained using the orientation sensors can vary in integer values between 1 and 9. The waveform resulting from the real-time variation in RULA score throughout the task is averaged to find a single measure of ergonomics for each task. The ANOVA statistical test is used to confirm or reject significant difference in mean values across the three different height levels of the buzz-wire test for the EMG, RULA and Borg scores. Performance score is obtained by using a time-penalty scheme where each error adds 10 seconds to the elapsed time. Therefore, a higher performance value means a longer time and more errors, i.e. worse performance. Table 1 summarises the results, averaged across all 10 participants. The values with significant mean difference within each column are highlighted.

CONCLUSION AND DISCUSSION

According to Table 1, a significant difference in EMG score is not witnessed across levels for the wrist extensor and flexor muscles. This makes sense as the force involved in holding the wrist steady does not change across different levels. There is however a significant difference across all levels when looking at the

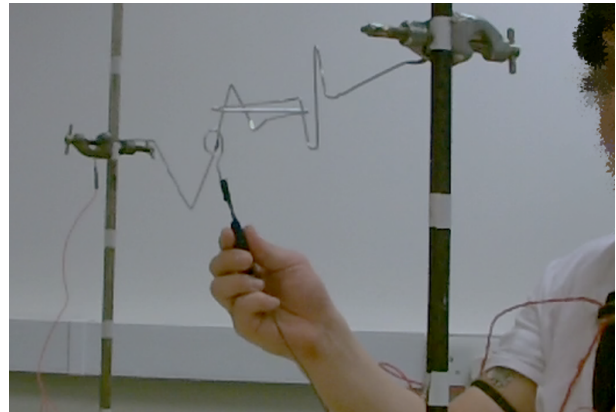


Figure 2. the buzz-wire test used during the experiments. triceps and when changing between levels 2 and 3 for the biceps. This also follows expected behaviour, as when the arm is lifted to different heights, the effort is being applied mainly by the triceps and biceps muscles. The RULA score shows significant difference across all levels which confirms its usefulness in detecting different ergonomic levels however small they might be. This is not the case however for the Borg scale which only detects large differences, i.e. from level 1 to level 3, based on Table 1. This means that the Borg scale cannot be relied on for minor changes in comfort and ergonomics. Furthermore, the subjectivity in the Borg scale was evident throughout the experiment, as participants answered the Borg scale question differently and some struggled to relate their discomfort to the given number scale. The result is a varying Borg score range across the participants which makes it difficult to compare the comfort of one participant with another and is the reason why Borg is mainly useful in large sample populations.

This is not the case with the RULA score or (normalised) EMG values however. These values can be compared across participants and are all within the same range and original bias. While the Borg scale is popular in clinical settings, the results of this preliminary study show that there is room for improvements. The RULA score presents a less subjective and more precise solution, but it does not take into account detailed muscle behaviour that can be obtained using low-cost, wearable EMG sensors. Thus, a combination of these two methods may be the best solution to move forward.

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Table 1. Average results for 10 participants.

	<i>Ext.</i>	<i>Flex.</i>	<i>Tri.</i>	<i>Bi.</i>	<i>Borg</i>	<i>RULA</i>	<i>Perf.</i>
1	0.08012	0.031	0.014	0.027	2.63	4.062	120.3
2	0.07610	0.033	0.017	0.028	2.90	4.176	129.7
3	0.07583	0.030	0.023	0.032	3.96	5.082	145.5

¹ <http://ergo-plus.com/wp-content/uploads/RULA.pdf>