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Assessment of muscular effort in workers performing an actual use-case manual material handling with and without the assistance of Bazar robot

T. Varrecchia¹, G. Chini¹, S. Tarbouriech², B. Navarro², A. Cherubini², F. Draicchio¹, M. Serrao³, A. Ranavolo¹

¹INAIL, Rome, Italy, ²LIRMM, Univ Montpellier, Montpellier, France, ³Sapienza University of Rome, Rome, Italy

INTRODUCTION

Human-robot collaboration (HRC) technologies represent one of the new options for the prevention of work-related musculoskeletal disorders (WMDs) [1]. They share the workspace with workers, communicate with them, manage the human partner's flexibility and ergonomics and physically interact, to work together on a common goal [2]. Reconfigurable collaborative robots adapt to the workers' intentions and task variations, offloading them from external loads and keeping them in ergonomic working circumstances, to improve efficiency and quality of the task execution. Although collaborative work is a widespread method for lowering WMDs, the scientific literature reveals conflicting findings on its efficacy, due to factors affecting team capacity, autonomy, and coordination [3]. To measure motor coordination during dynamic tasks, a common approach is muscle co-activation that may become functionally unfavorable [3]. Therefore, this research aims to evaluate upper limb muscle coactivation in workers performing an industrial use case manual material handling (MMH), proposed by the SME HANKAMP (Netherlands), by comparing a scenario where the workers are helped by a dual-arm cobot BAZAR [4] with a scenario without BAZAR. This cobot BAZAR is being assessed in the context of SOPHIA (<http://www.project-sophia.eu>) project funded by the European Union's Horizon 2020 (grant agreement No. 871237).

METHODS

Eleven participants (5 females and 6 males; 27.73 ± 5.99 years; BMI: 23.06 ± 3.93 kg/m²) took part in the study carried out at the University of Montpellier in accordance with the Helsinki Declaration and authorized by the local Ethics Committee (Protocol number IRB-EM 2103A). Six bipolar electrodes (FreeEMG300 System, BTS, Italy, sampling rate at 1000 Hz) were placed on the flexors and extensors muscles of the shoulder (anterior and posterior deltoideus), elbow (biceps and triceps brachii caput longum) and wrist (flexor and extensor carpi radialis) joints. The experiments are shown in the video available at: <https://youtu.be/vul8iLO0Sdw>. Each participant, after being instructed, completed the task 3 times without BAZAR and 3 with BAZAR (Figure 1A). We randomly ordered the 2 conditions for each subject. Furthermore, participants performed a specific exercise twice with each muscle to obtain the isometric maximal voluntary contractions (iMVCs) [1,3]. The envelope of each task's sEMG signals was then extracted, normalized respect to the average iMVC peak value for each muscle, time-normalized and then interpolated according to the brushing sub-task duration (400 samples) [1,3]. The time-varying multi-muscle coactivation function (TMCf) [3] was estimated and the mean and maximum values were calculated. A statistical analysis was carried out to evaluate whether the help of the cobot had determined significant changes in each parameter (p -value < 0.05).

RESULTS

Figure 1B show the mean and standard deviation of mean and max values of evaluated TMCf for each condition. Significant effects of the presence of BAZAR were found for mean ($p < 0.001$) and max ($p = 0.001$) values of TMCf: the values significantly decrease when the task is performed with BAZAR.

Figure 1. Task with and without BAZAR for a representative participant (A). Means, standard deviations and statistical results (*) of mean and max values of time-varying multi-muscle coactivation function (TMCf) in the two tasks (B).



DISCUSSION

The results showed a reduction in upper limb co-activation when the specific MMH was performed with BAZAR. Therefore, HRC technologies, which share the workspace with workers, not only offload workers from external loads and improve the task execution efficiency and quality. They also allow a better coordination and reduce the worker's physical effort while she/he physically interacts with the robot, and positively affect her/his physiological motor strategy.

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