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Preliminary results of a biomechanical risk assessment of an actual industrial use-case executed with and without a dual-arm CoBot

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Introduction

Industry 4.0 is the implementation of intelligent technologies to increase productivity and reduce the associated biomechanical risks [1]. From a general perspective, the integration of ergonomics and human factors requirements in human-robot collaborative (HRC) systems, such as collaborative robots (CoBots), represents a new option to reduce the physical effort of workers during the performance of manual material handling (MMH) activities and to introduce new ergonomic interventions for the prevention of work-related musculoskeletal disorders (WMDs). As the use of CoBots in manufacturing has recently increased significantly, all potential benefits need to be thoroughly investigated and proven, especially in the MMH activities where the physical interaction of the worker with the CoBot takes place. While the safety in this new hybrid scenario is widely studied, the effects on workers' health are still limited [2]. The present study aims to investigate the biomechanical parameters of workers performing an industrial use case with (wB) and without (woB) a dual-arm CoBot.

Methods

Four participants (all male; age: 27.8±7.4 years; height: 180.2±2.4 cm; weight: 78.4±10.7 kg; body mass index: 22.2±3.7 kg/m²) took part in the study. We reproduced in the laboratory an industrial application case. The apparatus consisted of the CoBot BAZAR, four tables, and one cylindrical load (5 kg) to be moved and cleaned. The task is to move the cylindrical load between the four tables in a predefined order and to clean it with a brush. The video (available at: <https://youtu.be/vul8iLO0Sdw>) shows the experiment. We carried out a task analysis with and without Bazar. We identified three main phases in which there were relevant differences in the performance of the task i) phase 1: an initial phase where the worker handled the cylinder; ii) phase 2: the principal phase where the worker holds the cylinder with one hand and brushes it with the other; phase 3: the final phase where the worker placed the brushed cylinder in the packaging area. For the assessment, we used the 3D Static Strength Prediction Program (3DSSPP), which reproduces the workers' posture by superimposing an avatar model on a selected frame. The software calculate various biomechanical parameters: percentage of maximum voluntary contraction (%MVC), static (continuous) allowed exertion time and low back spine compression force (L4Ort). The paired sample t-test (the data was normally distributed) was then used to evaluate whether the help of the CoBot had determined significant changes in each parameter. The significance level for all statistical analyses was set at p-value < 0.05.

Results

The results refer only for phase 2, which is the one that best fits the 3DSSPP because it's a static task. We didn't report values for the left upper arm because we didn't find significant %MVC values, which were all below 5% MVC. We didn't find unfavorable parameters when using a CoBot. We found several parameters that support the use of the CoBot. We found differences in orthogonal force at L4/L5 level (585.8N vs 1171.0N, $p \leq 0.01$). We found difference in %MVC of the right arm in favor of CoBot use for wrist flexion/extension (2.5% vs. 44.8%, $p \leq 0.01$), wrist rotation (0.0% vs. 22.5%, $p \leq 0.01$), shoulder humeral rotation (8.0% vs. 55.3%, $p = 0.03$) and trunk flexion (9.0% vs. 19.8%, $p = 0.02$). We found differences in maximum holding time for wrist flexion/extension (1200 s vs. 74.3 s, $p \leq 0.01$) and wrist uln/rad deviation (1200 s vs. 415.8 s, $p = 0.03$), elbow flexion/extension (1200 s vs. 531.5s, $p \leq 0.01$), shoulder humeral rotation (873 s vs. 125.2 s, $p \leq 0.01$) and shoulder back/forward (1200 s vs. 656.9 s, $p \leq 0.01$).

Discussion

Our results seem to support using CoBots in the industrial scenario analyzed. We find benefits for the right wrist, shoulder, and trunk flexion in phase 2. Moreover, it could be possible to automate phase 3. These preliminary positive results should be confirmed and strengthened with a larger sample.

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