Effects of the Perdelle-Neo physical arm support assistance device for precision tasks and repetitive movements.

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This document is an English translation of the original French study report. It aims to faithfully preserve the structure and content of the source material without altering its tone. The original French report can be accessed on Perdelle's website perdelle.com.

Summary

Musculoskeletal disorders (MSDs) are the leading cause of occupational disease in France; exoskeletons are at the heart of innovations to prevent them. The present study aims to evaluate the effects of the Perdelle-Neo physical arm support device on five parameters: electromyographic activity (EMG), a scale of perceived pain, task duration, the Rapid Upper Limb Assessment (RULA) score and physiological recovery time. Fourteen volunteer participants performed five tasks without the device (SD condition) and with the device (AD condition); the order of performing tasks without or with the device was randomised. EMG activity was analysed on both left and right sides of the anterior deltoid, upper trapezius and lower trapezius muscles. The five tasks were always performed in the same order: performing a precision exercise with weight (1), handling light objects (2), handling heavy objects (3), sorting small parts (4) and assembling/mounting parts (5). The results show a significant reduction ($p < 0.05$) in EMG activity for five of the six muscles analysed and in the RULA score. On a visual analogue scale (VAS) from 0 to 10, perceived pain was halved. Use of the device had little effect on task duration. Post-activity physiological recovery time was reduced by 38 % with the Perdelle-Neo tool.

Keywords : MSDs, Exoskeleton, Physical assistance, EMG, Postural analysis, Perceived pain.

Introduction

Musculoskeletal disorders (MSDs), which involve muscles, nerves, ligaments and tendons, account for 87 % of occupational diseases. Prolonged postures, static work and repetitive gestures are the main factors leading to MSDs [1]. Since 1991, when 2 360 occupational diseases were recorded, a significant increase has been observed with 39 742 occupational diseases recorded in 2017, including 36 986 related to MSDs. The shoulder, elbow and carpal tunnel are respectively the three areas most affected [2]. According to the INRS, 14 359 occupational diseases are linked to shoulder joint pain. In addition to directly affecting workers' health, MSDs are also very costly to companies. According to a *Securex study* [3], in 2017 the total cost of absenteeism for a Belgian company with 100 employees amounts to more than €500 000 per year.

Attention paid by those involved in MSD prevention at work is increasingly important. Exoskeletons have recently found their place thanks to technical innovations by manufacturers. There are passive exoskeletons operating with springs that do not require a battery, as well as active exoskeletons equipped with motors and batteries; these can act on the trunk, lower limb and upper limb. Andrea B. et al. showed that an active exoskeleton considerably reduces muscle activity (triceps, biceps, rhomboid, pectoralis major) during an overhead drilling task [4, 5].

Furthermore, Håkan Sporrong et al. (1998) studied the impact of light manual precision work without an exoskeleton on the EMG activity of upper-limb muscles [6]. For the same arm position, adding light manual precision work increases EMG activity of shoulder muscles by 22 %. This demonstrates a strong need for a device that can compensate for increased EMG activity during precision work. That is why Perdelle-Neo proposes an upper-limb assistance device designed for precision and/or repetitive tasks (Figure 1).

The present study aims to evaluate the Perdelle-Neo device using objective data (EMG activity, upper-limb angulation, task completion time) and subjective data (VAS scale of perceived effort).

Methodology

Participants

Fourteen adult volunteers participated in this study: nine women (28 ± 6 years; 166 ± 9 cm; 63.9 ± 12.8 kg; nine right-handed) and five men (28 ± 9 years; 189 ± 6 cm; 76.4 ± 8.4 kg; one left-handed and four right-handed).

Assistance device

Perdelle-Neo is an upper-limb support device for workstations (Figure 1). It consists of two metal arcs attached to a support using a clamp. It allows the user's forearms to be supported by cuffs connected to the arcs via tensioned elastics.

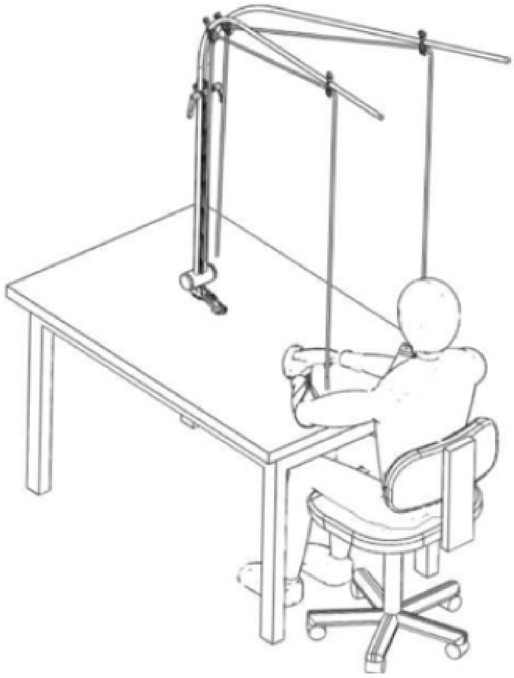

Figure 1 shows an illustration of the Perdelle-Neo physical arm support assistance device.

Protocol

Participants performed five tasks under two conditions: with the assistance device (AD) and without the device (SD). The order of tasks and conditions varied between subjects, but within a subject the order of tasks was the same in both AD and SD conditions. Fifteen minutes of rest were allowed between conditions. At the end of each condition, subjects completed a VAS (Figure 2) concerning their perception of muscle pain after the five tasks. Tasks 2, 3 and 4 were performed seated and tasks 1 and 5 standing.

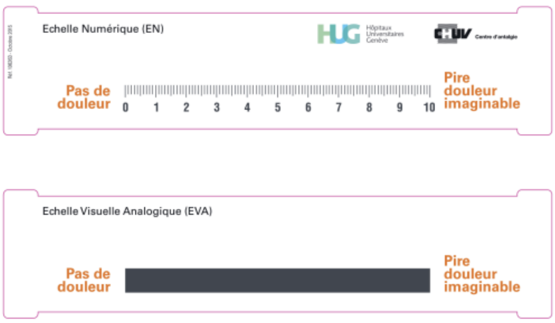

Figure 2 shows the VAS scale.

The five tasks were as follows:

1. **Performing a precision exercise with weight.** As cited previously, *Håkan Sporrong and al*. [6] showed that light manual precision work affected shoulder muscles. The work consisted of guiding a pointer through a drawn labyrinth. Knowing that this task affected EMG activity of shoulder muscles, subjects were asked to follow the path of four labyrinths. A board on which labyrinths were drawn was placed in front of participants; the labyrinths were identical for all subjects and they had to be traced in the same order.

2. **Handling light objects.** *J.P. De Groot* [7] showed that repeatedly placing light objects such as letters in pigeonholes induced high strain on the trapezius, anterior and lateral deltoids. Pigeonholes located at or above eye level produce the greatest muscle strain. Accordingly, subjects were asked to place small light parts of three different sizes on an elevated support; they had to form three stacks to sort the parts by size.

3. **Handling heavy objects.** Continuing from task 2, participants were asked to lift and lower heavy objects (1 kg ± 0.1 kg) on the same support used in task 2. Three objects of the same format were placed on the table in front of them; participants had to manipulate the left object with the left hand, the right object with the right hand, and the middle object with both hands【904972778954034†L193-L197】. Lifting and lowering the objects constituted one repetition; subjects performed fifteen repetitions.

4. **Sorting small parts.** Sorting small objects is a common task in industry. Subjects were asked to sort parts of different colours, sizes and shapes. They had to place the parts into eight boxes, each corresponding to a colour. The boxes were placed on the table in an arc around the participant; the two central boxes were raised using a crate. Participants could adopt their own strategy except that they were not allowed to grasp multiple parts at once, as they had to place them one by one.

5. **Assembling/mounting parts.** Subjects had to stack pieces to build a tower in the shape of a helix. They used large pieces and tried to make the tallest possible

tower within a two-minute time limit. If they knocked the tower over, they had to rebuild it until the end of the allocated time.

EMG measurement

The left and right anterior deltoids, upper and lower trapezius muscles were analysed during this study. Electrodes were placed according to SENIAM recommendations [8]. The EMG signals were collected using the E.M.I.L sensors and mobile application from the company Optimergo. Signals were measured at a frequency of 1 000 Hz and filtered with a high-pass at 6 Hz and a low-pass at 240 Hz. For each subject, the RMS value was calculated in both conditions; values were then normalised (nRMS) via a relative maximum voluntary contraction (MVC) corresponding to the maximum RMS value for the subject across all acquisitions. EMG values (nRMS) for the fourteen subjects were then averaged for each condition.

Video capture

Two cameras were used to film the subjects' posture during the study. One camera was placed to the left of the subjects to see them in profile; the other provided a bird's-eye view from the front.

Data analysis

Temporal analysis of task duration within subjects and analysis of the VAS scale were performed with Excel. EMG data and recovery time analysis were performed with Matlab. Postural analysis to obtain the RULA score was performed using Python software.

Statistical analyses

Statistical analyses were performed with JASP software. For perceived effort tests, as samples followed normality, a paired Student's t-test was performed. The significance threshold was set at 5 % ($p < 0.05$).

Results

Muscle activity - EMG

Muscle activity for the muscles analysed was systematically lower with the device. The reduction with the device was respectively −21.3 % for the left anterior deltoid, −28.2 % for the right anterior deltoid, −11.6 % for the left lower trapezius, −21.7 % for the right lower trapezius, −13.6 % for the left upper trapezius and −13.8 % for the right upper trapezius. The results (Figure 3) are significant ($p < 0.05$) for all muscles analysed except for the right upper trapezius.

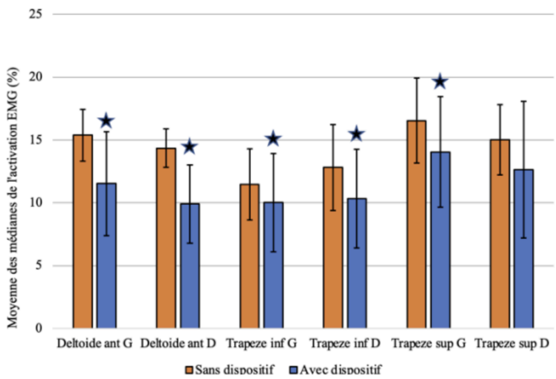

Figure 3 : Mean of the normalized median EMG values across all subjects relative to the MVC, without and with the device. The star indicates a significant difference (p < 0.05) compared with the reference condition (SD).

Perceived pain

The results (Figure 4) show an average score of 2.85 on a VAS from 0 to 10 after the five tasks performed without the device; after performing the same five tasks with the device, subjects gave an average subjective score of 1.60.

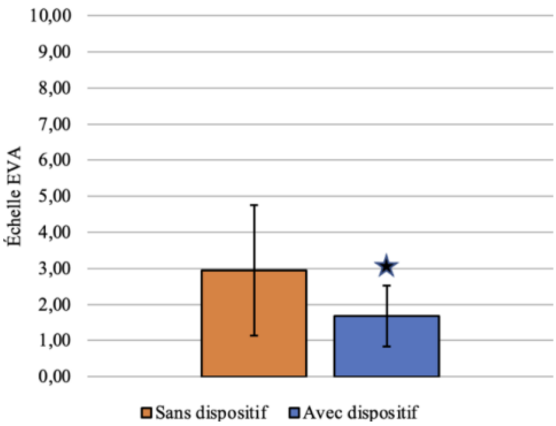

Figure 4 : Mean VAS score at the end of the conditions with and without the device. The star indicates a significant difference (p < 0.05) compared with the reference condition (SD).

Task duration

To complete all five tasks, subjects took on average 741.71 s (± 90.43) with the device versus 713.43 s (± 61.95) without it, i.e. an increase of 3.8 % in the condition with the device.

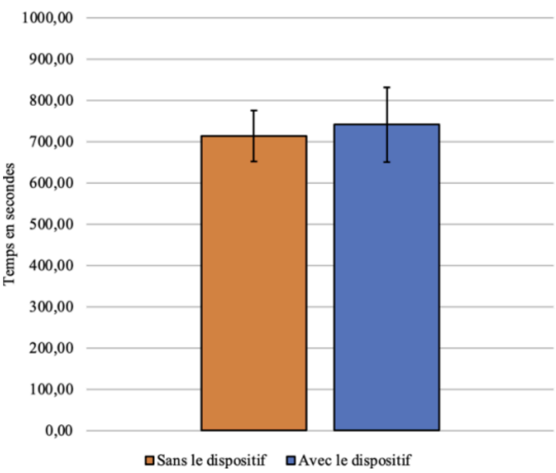

Figure 5 : Total duration of the tasks performed in each condition.

RULA score

The score obtained for each task performed is significantly lower (p < 0.05) except for task 5 (Figure 6). The reduction in score is −19.2 % for task 1, −13.2 % for task 2, −14.2 % for task 3, −6 % for task 4 and −2.7 % for task 5.

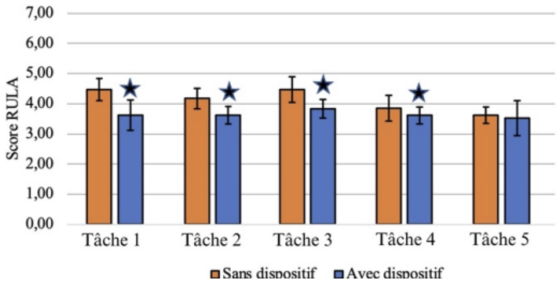

Figure 6 : RULA score of the postures for each task performed without and with the device. The star indicates a significant difference (p < 0.05) compared with the reference condition (SD).

Physiological recovery time

The results obtained (Figure 7) show a decrease in all physiological recovery times required after the tasks. The reduction in time is −55.2 % for the left anterior deltoid, −69.5 % for the right anterior deltoid, −23.1 % for the left lower trapezius, −25.4 % for the right lower trapezius, −27.3 % for the left upper trapezius and −27.2 % for the right upper trapezius. These data are significant (p < 0.05) for the left anterior deltoid and the right lower trapezius.

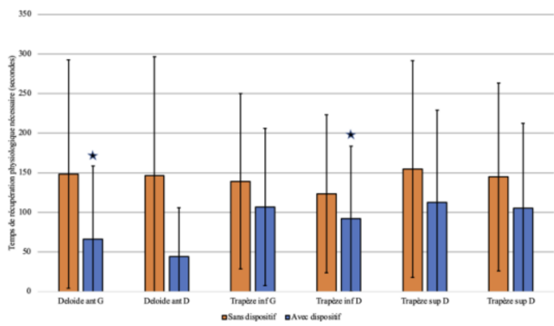

Figure 7 : Time required for physiological recovery after each condition. The star indicates a significant difference (p < 0.05) compared with the reference condition (SD).

Discussion

The aim of the study was to evaluate the effects of the Perdelle-Neo physical arm support device on EMG activity, perceived pain, task duration, posture and physiological recovery time. Concerning muscle activity measured by EMG, the results show a significant decrease ($p < 0.05$) when using the Perdelle-Neo device. However, the protocol did not include a training phase that could influence task performance with the device. An identical study conducted with a group of subjects already accustomed to using the device would yield more significant results. In addition, the tasks in the protocol were performed in a third-party location not representative of a company's challenges and constraints. A study in an appropriate environment could show greater differences.

Regarding perceived pain measured using a universal scale, the results show a halving when using the device. The significant results from the VAS confirm the subjects' perceptions. The results of the analysis of the total time to complete the tasks show that with the device there is a slight increase of 3.8 %; this value is not significant. It would be interesting to carry out another study with a group of subjects who use the device daily. Indeed, the phenomenon of habituation could reduce this time difference or even decrease the total time required to perform tasks thanks to the device. Perceived pain and muscle activity being lower with the device, task duration could become an indicator of productivity linked to workstation comfort.

The average RULA score is decreased by 11.1 % with the use of the Perdelle-Neo device. Since arm support is taken into account in the RULA scoring grid, this reduction results from the calculation of the score according to different criteria [10]. The improvement in posture felt by operators is confirmed by this statistic.

Permanent muscle activation causes ischemia and an inability to eliminate waste products, which increases contraction and pain, provoking a vicious circle that leads to self-activation (auto-ignition) [9]. Muscle activity being lower with the device, muscles therefore need less rest after activity. Muscle fibres are regenerated when they are relaxed; it is therefore important to respect physiological rest to avoid the appearance of pain due to their wear. In this study, the necessary physiological recovery time is on average reduced by 38 % with the device, corresponding to 55 second

Limitations

The study lasted about one hour per subject; certain discomforts could appear over longer periods of use, and the effect of the exoskeleton during long-term use would require more in-depth study in a real environment. A second limitation relates mainly to the sample: fourteen participants (young and in good health) may not represent the overall population of workers found in active life (older or injured). Consequently the results should be interpreted with caution before being generalised.

Conclusion

The mean decrease of around 18.4 % in EMG activity observed on the anterior deltoids, upper and lower trapezius shows that the Perdelle-Neo device helps relieve effort on the upper limb. Using the system seems to provide assistance in preventing MSDs on the biomechanical aspect. In this study, perceived pain is halved when the device is used, highlighting its contribution to improving comfort and working conditions. Task completion time varies little with the device, allowing a workstation equipped with the device to maintain an imposed rhythm. The RULA score is improved by the arm support, enabling a better rating of a workstation equipped with the device. Finally, the recovery time required after completing tasks is reduced with the device, confirming the interest of its regular use.

Conflict of Interest

The study was conducted by an independent company not linked to the company Perdelle that manufactures and sells the device. There is no conflict of interest.

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