How Do Orthoses Impact Ease of Donning, Handwriting, Typewriting, and Transmission of Manual Torque? A Study of Three Prefabricated Wrist-Hand Orthoses

Ana Lya M. Ferrari, MSc, Fausto O. Medola, PhD, Frode E. Sandnes, PhD

ABSTRACT

Introduction: Many upper-limb injuries have work-related causes such as continued use of computers, typing activities, mouse manipulation, and repetitive movements performed for long periods. This study evaluated the performance of wrist-hand orthoses in manual tasks and in transmission of torque measurement during canned glass opening.

Methods: Thirty healthy participants performed donning, typing, and handwriting tasks and transmission of manual torque. The procedures were performed in four conditions: with three different orthoses and with no orthosis as a control.

Results: The results showed a significant difference in the time of manual writing ($P < 0.001$) and in the number of words per minute ($P < 0.001$) in the typing task with and without orthoses. The perceived difficulty in performing typing ($P < 0.001$) and manual writing ($P < 0.001$) was lower with no orthoses and higher for canvas orthosis and the two neoprene orthoses. Transmission of manual torque also decreased with the orthoses compared with using no orthosis ($P < 0.001$). Among the orthoses, the canvas fabric orthosis yielded a lower performance compared with the two different neoprene fabric orthoses for all the tasks.

Conclusions: There are effects of the materials used and the orthosis design when performing handwriting typing tasks and twisting tasks (transmission of manual torque), as well as the correctness of how users donned the orthosis. (J Prosthet Orthot. 2020;00:00–00)

KEY INDEXING TERMS: orthotic devices, upper limb, wrist injuries

The wrist plays an important role in the upper-limb movement as a connection between the forearm and the hand. Because 90% of the upper-limb function is executed by the hands, the wrist functionality is highly important. Several pathologies can affect the functionality of the upper limbs such as carpal tunnel syndrome, subacromial bursitis, and articular dysfunctions such as osteoarthritis and rheumatoid arthritis.

Some of these medical conditions can result from work-related activities involving loads and repetitive movements over prolonged time intervals. Repetitive strain injuries (RSIs) are among the most frequent causes of work-related hand and wrist diseases. One relevant example would be the intensive use of computers that has been related to musculoskeletal disorders, especially when the duration of use exceeds 20 hrs per week. Extensive computer use is a common scenario for many people in modern life. Gerr et al. reported incidences of musculoskeletal disorders in the upper limbs after the first year of approximately 50% of employees that worked with computers.

Wrist-hand orthoses (WHO) are used in the treatment of carpal tunnel syndrome and other related inflammatory joint issues by providing stabilization to the wrist joint. The goals are to improve the functionality of the affected limb or reduce muscle fatigue in the upper limbs, and for this reason, orthoses are useful in treating injuries related to RSI in computer users. However, the use of these products may be limited due to factors such as forgetfulness, interference in routines, repetitive tasks, usage difficulty and discomfort, and pain when wearing the orthosis. These examples illustrate the importance of prescribing a suitable and easy-to-use device, which meets not only the biomechanical needs but also results in a pleasant and comfortable experience for the user.

The literature contains several evaluations of wrist orthoses under different situations. For instance, two such articles claimed that the orthosis has been evaluated according to motor performance and in efficiency to decrease pain and comfort of use in rehabilitation of chronic stoke patients. Other studies have focused on the biomechanics by exploring the influence of the orthoses on muscle activity.
From the perspective of product design, there are aspects of orthosis design that can influence the fit to the user, such as the flexibility and the rigidity of materials, the strip fastening system, and the design and position of the splint for wrist movement restriction. Commercially available models of prefabricated WHO differ in some of these features and therefore might lead to different outcomes in terms of the physical and thermal comfort and the performance of manual tasks.

However, although the available research on WHO provides important knowledge about clinical and biomechanical outcomes and problems related to use, the literature is limited on the impact of prefabricated WHO on addressing how different designs of these devices affect users and their perceptions of the use when performing common manual tasks.

The purpose of this study was to evaluate the effect of three different prefabricated fabric-style WHO on the performance of manual tasks and torque transmission. We explored two hypotheses: first, different prefabricated fabric WHOs have influence on the time of execution of manual tasks and users’ perceived difficulties of these tasks; second, these WHOs each have influence on the manual torque transmission as well.

METHODS

EXPERIMENTAL DESIGN

Two controlled within-group experimental designs were chosen. The first part involved the evaluation of the performance in manual tasks, and the second part involved the measurement of transmission of manual torque. Device type was the independent variable with four levels, namely, universal orthosis, neoprene orthosis, canvas orthosis, and no orthosis (as control). Three dependent variables were measured for the first part of the experiment, namely, task completion time, correct donning, and perceived difficulty. The transmission of manual torque was the dependent variable for the second part of the experiment involving the opening of a canned glass.

PARTICIPANTS

The sample comprised 30 participants with no limb or wrist diagnoses of injuries or complaints. The following inclusion criteria were used: 1) the participants had no musculoskeletal disorders or injuries in the upper limb in the last year; and 2) the participants had to be right-handed. Of the participants, 60% were female and 40% were male. All were older than 18 years (M = 22.6, SD = 3.1), with a height (M = 1.68, SD = 0.09) in meters and a mass (M = 66.9, SD = 13.5) in kilograms. None of the participants had used a WHO orthosis before. This study was approved by the Ethical Research Committee of the School of Architecture, Arts, and Communication of São Paulo State University (UNESP), Bauru, Brazil (process number 71192117, 4.0000.5663). Before data collections, all participants read and signed an informed consent form and were ensured their rights of anonymity as well as their right to withdraw from the experiment at any time. No personal information was stored. The video recordings were deleted after data analysis.

MATERIALS

Three different prefabricated Take Care WHO for wrist extension with a rigid stay within the fabric were used (see Figure 1): universal orthosis, a one-size-fits-all model made of neoprene fabric with Velcro for adjustment according to users’ hand size, the only orthosis with a different design; neoprene orthosis, made with neoprene fabric and with three Velcro straps for fitting; and canvas orthosis, made with canvas fabric and with three Velcro straps for fitting. The neoprene and canvas orthoses had the same design, with the only difference between them being the type of fabric. Neoprene and canvas orthoses were available in the sizes small, medium, and large, chosen according to users’ hand size. The orthoses were chosen due to their same indication of use, for recovery from arthritis, tendonitis, tenosynovitis, and RSI or work-related musculoskeletal disorders (WMSDs).

The text input task was performed with an Acer Aspire V3-571 15.6” laptop with Microsoft Word, and the handwriting task was performed using a Bic Cristal pen and paper. An Olympus digital camera was used to record the orthosis donning task. The transmission of manual torque was evaluated with a ST10-871-101 STS Static Torque Screwdriver (Mecmesin Ltd., Horsham, United Kingdom) with 10 N-m and an Advanced Force Gauge AFG 500 digital dynamometer (Mecmesin Ltd., Horsham, United Kingdom) with a maximum capacity of 500 N and an accuracy of 0.1%. An aluminum mockup was made to simulate a canned glass with the torque screwdriver attached, allowing the participants to execute their maximum transmission of torque without any danger of physical harm.

TASKS

The first part of the experiment was designed to include three tasks (see Figure 2), namely, donning the orthosis, typing text on a computer, and handwriting with a pen on paper. The donning task consisted of the act of the user donning the orthosis, because the improper fit can affect negatively the function of the orthosis. The task started by giving the participants verbal instructions on how the participant should firmly position the orthosis with the rigid stay in the palmar region. The position of the orthosis was checked and adjusted by the researcher when needed before the other tasks. A text copying task was chosen for the typing task. The participant was given a short text comprising approximately 118 characters and verbally instructed to type the text in their regular typing speed using both hands. A different text was given for each of the conditions so that no participant wrote the same text more than once. Similarly, a copying task was also devised for the handwriting task using different texts from the typing task. Participants were instructed to write the text using the pen at their regular comfortable writing speed.

The transmission of manual torque evaluation (see Figure 3) in the second part of the experiment involved holding the mockup with the left hand and elbow bent at an angle of
approximately 90° and with the right hand using maximum strength to open the lid (anticlockwise).

**PROCEDURE**

All the data were collected during a single session. First, the performance in executing manual tasks were measured followed by the manual torque force measurements. The participants performed all procedures of both experiments under four conditions, wearing three different orthoses and wearing no orthosis. Participants were instructed to wash their hands if they were using any kind of skin cream and take off rings, bracelets, watches, or any adornments that could interfere with results before the procedures. The order of the four conditions was randomized to minimize learning effects. The three tasks were performed in a fixed order, namely, donning the orthosis, typing, and handwriting.

Time to complete the task was measured using a stopwatch from the time of the researcher’s verbal start signal to the time when the participant finished the task. The perceived task difficulty was measured using the visual analog scale (VAS).\(^{16,17}\) Forces were measured with the torque meter. The session was also video recorded.

All the study procedures were performed in a room with a controlled temperature of 24°C.

**DATA ANALYSIS**

Recorded videos were used to analyze the process of donning the orthosis and identify when orthoses were donned incorrectly. A numerical value of perceived difficulty (between 0 and 10) in the three procedures of performance (donning, typing, and handwriting) was obtained by measuring each marking on the VAS using a millimeter ruler. The task completion times in seconds were used for analyzing the donning and handwriting tasks. The typing task was analyzed using words per minute (wpm), which was calculated by dividing the number of characters typed (118) by 5 and dividing the resulting value by the task completion time in minutes. The manual torque value was obtained in Newton meter (N·m).

JASP version 0.9.2.0 was used to perform the repeated measures analysis of variance (ANOVA) with Bonferroni post hoc testing. Mauchly’s test was used to verify the assumption of sphericity. When data did not satisfy the assumption of sphericity, we used Greenhouse-Geisser corrections if the epsilon (ε) was below 0.75; otherwise, we use Huynh-Feldt corrections.

**RESULTS**

The four experimental conditions, namely, universal orthosis, neoprene orthosis, canvas orthosis, and no orthosis, were contrasted for both the tasks and the transmission of manual torque tests, except for the donning task, which only contrasted the three orthoses.

There was a significant effect of orthoses on task completion time \((F[2,58] = 4.491, P = 0.015, \eta^2 = 0.134)\). The mean time in seconds to don the neoprene orthosis \((M = 37.8, SD = 12.9)\) was longer than for the other two orthoses \((M = 31.5, SD = 11.9; M = 30.8, SD = 9.8)\). Post hoc tests revealed that there were statistically significant differences between universal orthosis and neoprene orthosis \((P = 0.043)\) and neoprene orthosis and canvas orthosis \((P = 0.023)\) (see Figure 4). There were no significant differences in the perceived difficulty of the donning task among the three orthoses \((F[5.070,243.057] = 0.605, P = 0.491)\).

Despite the shorter completion time in the donning the orthosis task, the universal orthosis was associated with the highest occurrences of incorrect fit \((N = 8)\). The neoprene orthosis yielded just a single inappropriate fit. All the participants donned the canvas orthosis correctly (see Figure 5).

Figure 6 shows the mean perceived difficulty of the typing task. There was a significant difference among the four conditions \((F[3,87] = 37.83, P \leq 0.001, \eta^2 = 0.566)\). The condition

![Figure 1. Universal orthosis (A), neoprene orthosis (B), and canvas orthosis (C) (front and back views).](image1)

![Figure 2. Participants performing the tasks: donning the orthosis (left), typing text (center), and handwriting (right).](image2)
with no orthosis was associated with the lowest perceived difficulty ($M = 0.26, SD = 0.56$). Post hoc tests revealed a significant difference between the no-orthosis condition and the three orthoses ($P < 0.001$). The canvas orthosis yielded the highest perceived difficulty ($M = 4.3, SD = 2.5$). There was also a significant difference between canvas orthosis and both neoprene fabric orthoses, universal ($P < 0.001$) and neoprene orthoses ($P = 0.001$). However, there was no significant difference between the two neoprene fabric orthoses (universal and neoprene).

A significant difference in typing performance was observed ($F[3,87] = 12.75, P < 0.001, \eta^2 = 0.305$). The typing speed (wpm) was the highest without the orthoses ($M = 39, SD = 9.1$), which was significantly different from the results obtained with the universal orthosis ($P = 0.003$) and the neoprene and canvas orthoses ($P < 0.001$) (see Figure 7). There was no significant difference in typing speed between the three orthoses.

The perceived difficulty of handwriting measurements did not satisfy the assumption of sphericity ($W = 0.606, P = 0.016$). The Huynh-Feldt correction ($\varepsilon = 0.881$) was therefore applied. A significant difference in perceived difficulty was observed for handwriting ($F[2.643, 76.657] = 104.6, P \leq 0.001, \eta^2 = 0.783$). Figure 8 shows that using no orthosis was perceived as least difficult ($M = 0.31, SD = 0.97$), and this difference was significantly different to the three orthoses ($P < 0.001$). The canvas orthosis was perceived as the most difficult ($M = 7.42, SD = 2.07$), and it was significantly different to the two other orthoses ($P < 0.001$). There was no significant difference between the two neoprene fabric orthoses (universal and neoprene).

The handwriting task time completion data did not satisfy the assumption of sphericity ($W = 0.311, P < 0.001$). The Greenhouse-Geisser correction ($\varepsilon = 0.561$) was therefore used. A significant difference in handwriting task completion times were found ($F[1.682, 48.767] = 21.0, P < 0.001, \eta^2 = 0.420$). The condition with no orthosis resulted in the shortest mean handwriting time in seconds ($M = 52.3, SD = 10.8$), and the canvas orthosis resulted in the longest mean time ($M = 68.1, SD = 14.6$). Post hoc tests revealed significant differences between using no orthosis and both orthoses with the same design, neoprene and canvas orthoses ($P < 0.001$). A significant difference was also found between the canvas and neoprene orthoses ($P < 0.001$) and between the canvas and universal orthoses ($P = 0.007$) (see Figure 9). There was no significant difference between no orthosis and using the universal orthosis or between the two neoprene fabric orthoses (universal and neoprene).

**TRANSMISSION OF MANUAL TORQUE EVALUATION**

The manual torque data did not meet the assumptions of sphericity ($W = 0.626, P = 0.024$), and Huynh-Feldt correction was therefore used ($\varepsilon = 0.820$). A significant difference
between the conditions in terms of manual torque was observed ($F(2.460,71.343) = 1.89, P < 0.001, \eta^2 = 0.324$). Transmission of torque in canned glass opening was 22.84% lower with using the canvas orthosis compared with the no orthoses situation, 17.17% lower using the universal orthosis compared with no-orthoses situation, and 13.82% lower with neoprene orthosis compared with no orthoses situation ($P < 0.001$). Significant differences were also observed between the orthoses neoprene and canvas ($P = 0.035$), where the canvas orthosis achieved the lowest transmission of torque ($M = 2.56, SD = 0.89$) and the neoprene orthosis the strongest transmission of torque ($M = 2.86, SD = 0.93$) among the orthoses (see Figure 10).

**DISCUSSION**

Although orthosis is an important part of the rehabilitation process, it should not become a hindrance to the user when performing manual tasks. From the perspective of product ergonomics, the performance and interference of orthoses in manual tasks and forces are important for the comprehension on how those devices can be adapted in order to cause less disturbance.

![Figure 7. Mean typing speed (wpm). Error bars show standard deviation.](image1)

![Figure 8. Mean perceived difficulty. Error bars show standard deviation.](image2)

![Figure 9. Mean handwriting completion time. Error bars show standard deviation.](image3)

![Figure 10. Mean torque. Error bars show standard deviation.](image4)
when using the canvas orthosis while performing these two tasks may suggest a better stabilization provided by this orthosis in comparison to the other two neoprene fabric orthoses, universal and neoprene. In both cases, the conditions with no orthoses exhibited lower perceived difficulty compared with using an orthosis. The purpose of these orthoses is to stabilize the wrist. Thus, the greatest difficulty in performing tasks requiring wrist movement was expected. It is possible that the fabric material of the orthoses had more influence than design on stabilization as there was no difference in perceived difficulty between the two neoprene fabric orthoses (universal and neoprene).

The lower typing speeds exhibited with the conditions of using the orthoses compared with free hand indicate that the performance in typing text was negatively affected by the orthoses. However, no significant differences in task completion times were observed for the handwriting task when comparing using no orthosis and the universal orthosis. The canvas orthosis exhibited the longest completion times of the three orthoses. The neoprene fabric may give the best performance with tasks that require wrist movement. These findings agree with those of Stern et al. They compared different models of commercial orthoses and did not find significant differences in handwriting times when using elastic orthoses and no orthosis. They only found significant differences in handwriting times with canvas fabric orthosis and no orthosis. Other studies have also reported differences in handwriting time between custom-made orthoses of thermoplastic and semirigid material compared with handwriting without orthoses.

The wrist position is essential for manual prehension and manual torque transmission, where the maximum transmission of torque is obtained with flexed wrists, and lower transmission of torque in neutral wrist positions obtained with stabilization and extension orthoses. Because of movement restrictions, the torque evaluation showed significant differences between all the orthoses and using no orthosis. Among the orthoses, the only difference was observed between the canvas orthosis and neoprene orthosis, with the first showing the lowest transmission of torque. It is likely that factors such as difficulty of grasping caused by the orthoses have contributed to reduced task performance.

A decrease in hand power grip and pinch grip (tip pinch, pinch side, and palmar pinch) with a thermoplastic wrist orthosis has been reported. Van Petten et al. also found a reduction in grip strength comparing conditions with and without a WHO orthoses. However, they found no significant difference between a thermoplastic and a nonrigid orthosis.

Recruiting non-WHO users allowed a large sample. However, this cohort may result in biased findings. Future work should therefore investigate manual task performance and torque transmission in experienced users of WHO. Another weakness of this study was that the bimanual typing task was performed using orthoses on one hand only. Hence, the performance of this bimanual task was not symmetric. Future work should therefore introduce orthoses on both hands or measure the keystroke dynamics independently for both hands.

CONCLUSIONS

This study evaluated the performance of three commercially available wrist-hand orthoses in perceived difficulty, manual tasks, and manual torque transmission. The results show that, compared with not using an orthosis, the use of orthoses affect the performance in most of the conditions, except the use of the universal orthosis in the handwriting task. In addition, we found differences in performance among the evaluated orthoses. The canvas orthosis, made with canvas fabric, was more restrictive, with higher levels of perceived difficulty requiring the longest time to complete the tasks. It also exhibited a lower measure of torque transmission compared with the two other neoprene fabric orthoses, universal and neoprene. Although the major goal of these orthoses is to stabilize the wrist joint, the results show that the use affects performance, and that this impact depends on the orthosis design and manufacturing materials used. Similarly, this also affected the process of donning and fitting the orthosis. The lack of visual clues expressed by the device design, which could guide the procedures to don the orthosis, and the difficulty for the users to adjust the orthosis by themselves may have impaired the performance in the tasks. In conclusion, prefabricated wrist-hand orthoses made of different materials and with different designs exhibit different performance in manual tasks such as handwriting, typing, and transmission of manual torque. Although some characteristics of the orthosis depend on the goals of the patient’s rehabilitation, some aspects of their design can be considered for the development and prescription of these devices in order to minimize their influence in the performance of manual tasks and to benefit the user’s satisfaction.

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