Effects of Three Prefabricated Wrist Hand Orthoses on Ease of Donning, Handwriting and Typewriting, and Transmission of Manual Torque

Effects of wrist hand orthoses design on manual tasks

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Abstract

Introduction: Many upper limb injuries have work-related causes such as continued use of computers with typing activities and mouse manipulation.. This study evaluated the performance of wrist-hand orthoses in manual tasks and in transmission of torque measurement during canned glass opening. **Material and 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 ($p < .001$) and in the number of words per minute ($p < .001$) in the typing task with and without orthoses. The perceived difficulty in performing typing ($p < .001$) and manual writing ($p < .001$) 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 using no orthosis ($p < .001$). Among the orthoses, the canvas fabric orthosis yielded a lower performance compared to 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 donning the orthosis.

Keywords: Orthotic Devices, Upper Extremity, Wrist Injuries.

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1. INTRODUCTION

The wrist plays an important role in upper limb movement as a connection between the forearm and the hand. Since 90% of the upper limb function is executed by the hands, the wrist functionality is highly important.[1] Several factors can affect the functionality of the upper limbs such as carpal tunnel syndrome, subacromial bursitis, articular dysfunctions, for instance osteoarthritis and rheumatoid arthritis.[2] Some of these medical conditions are resulting from work related activities involving loads and repetititive movements over prolonged time intervals. Repetitive Strain Injuries (RSI) are among the most frequent causes of work-related hand and wrist diseases.[3]

One relevant example would be the intensive use of computers that has been related to musculoskeletal disorders, especially when the duration of use exceds 20 hours per week.[4] Extensive computer use is a common scenario for many people in modern life. Gerr et al.[5] reported incidences of musculoskeletal disorders in the upper limbs after the first year of around 50% of employees that worked with computers.

Wrist-hand orthoses are used in the treatment of carpal tunnel syndrome and other related inflamatory joint issuesby providing stabilization to the wrist joint.[6] The goals are to improve the functionality of affected limb[7,8] or reduce muscle fatigue in the upper limbs,[9] being also used by computer users.[10] 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.[11,12] 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[13] and in efficiency to decrease pain and comfort of use in rehabilitation of chronic stoke patients.[14] Other studies have focused on the biomechanics by exploring the influence of the orthosis on muscle activity. [15, 11]

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 wrist-hand orthoses 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, while the available research on wrist-hand orthosis provides important knowledge about clinical and biomechanical outcomes and problems related to the use, the literature is limited on the impact of Prefabricated WHOs on addressing how different designs of these devices affect users and their perceptions on the use when performing common manual tasks.

The purpose of this study was to evaluate the effect of three different prefabricated fabric style Wrist Hand Orthoses 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; secondly, these WHOs each have influence on the manual torque transmission as well.

2. METHOD

2.1 Experimental Design

Two controlled within-groups 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 orthosis #1, orthosis #2, orthosis #3 and no othrosis (as control).

Three dependent variables were measured for the first part of the experiment, namely task completion time, proper 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.

2.2 Participants

The sample comprised 30 healthy participants. The following inclusion criteria were used: a) the participants had no musculoskeletal disorders or injuries in the upper limb in the last year, and b) the participants had to be right-handed. Of the participants, 60% were female and 40% were male. All were over 18 years old (*M* = 22.6, *SD* = 3.1), with a height of (*M* = 1.68, *SD* = 0.09) in meters and a mass of (*M* = 66.9, *SD* = 13.5) in kg. None of the participants had used a wrist-hand orthosis before.

2.3 Materials

Three different prefabricated of the brand *Take Care* wrist-hand orthoses for wrist extension with a rigid stays within the fabric was used (see Fig. 1). The first orthosis was an adjustable one-size-fits-all design made of neoprene and the only orthosis with a different design. For a better understanding of the results, this adjustable orthosis will be named as orthosis #1. The follow orthoses had the same design, with three velcro straps for fit The only difference between them was the fabric used as orthosis #2 was made with neoprene and orthosis #3 was made with canvas. Orthosis #2 and #3 were available in the sizes small, medium and large, chosen according to users size..

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., UK) with 10 N·m and an Advanced Force Gauge AFG 500 digital dynamometer (Mecmesin Ltd., UK) with a maximum capacity of 500 N and an accuracy of 0.1%. An aluminum mock-up 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.

2.3 Tasks

The first part of the experiment was designed to include three tasks (see Fig. 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, since that the improper fit can affect negatively the function of the orthosis. The task started by giving the participants verbals 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 writing speed.

The transmission of manual torque evaluation (see Fig. 3) in the second part of the experiment involved holding the mock-up with the left hand and elbow bent at an angle of approximately 90º and with the right hand use maximum strength to open the lid (anticlockwise).

2.4 Procedure

All the data was 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 wrist hand 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 Analogue 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.

2.5 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, type 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 ANOVA statistical analyses 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-Geisler corrections if the epsilon (ε) was below 0.75, otherwise we use Hyunh-Feldt corrections.

2.6 Ethics

This study was approved by the Ethical Research Committee of the Faculty of Architecture, Arts and Communication, of Sao Paulo State University (UNESP), Bauru (Process N. 71192117.4.0000.5663). Prior to data collections, all participants read and signed an informed concent 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.

3. RESULTS

The four experimental conditions, namely orthosis #1, orthosis #2, orthosis #3 and no orthosis, were contrasted for both the tasks and the transmission of manual torque tests, except for the wearing task which only contrated the three orthoses.

There was a significant effect of othoses on task completion time ($F(2, 58) = 4.491$, $p = .015$, $\eta^2 = 0.134$). The mean time in seconds to don the orthosis #2 ($M = 37.8$, $SD = 12.9$) was higher 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 orthosis #1 and orthosis #2 ($p = .043$) and orthosis #2 and orthosis #3 ($p = .023$) (see Fig. 4). There were no significant differences in the perceived difficulty of don 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 orthosis #1 was associated with the highest occurrences of incorrect orthosis adjustments ($N = 8$). The orthosis #2 yielded just a single inappropriate adjustment. All the participants doned the orthosis #3 correctly (see Fig. 5).

Figure 6 shows the mean perceived difficulty of the typing task. There was a significant difference among the four conditions ($F(3, 87) = 37.83$, $p = < .001$, $\eta^2 = 0.566$). The condition 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 ($p < .001$). The orthosis #3 yielded the highest perceived difficulty ($M = 4.3$, $SD = 2.5$). There was also a significant difference between orthosis #3 and both neoprene orthosis, orthosis #1 ($p < .001$) and orthosis #2 ($p = .001$). However, there was no significant difference between the two neoprene fabric orthoses (orthoses #1 and #2).

A significant difference in typing performance was observed ($F(3, 87) = 12.75$, $p < .001$, $\eta^2 = 0.305$). The typing speed (wpm) was the highest without the orthosis ($M = 39$, $SD = 9.1$) which was significantly different from the results obtained with the orthosis #1 ($p = .003$) and the orthoses #2 and #3 ($p < .001$) (see fig.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 ($W = 0.606$, $p = .016$). The Huynh-Feldt correction ($\varepsilon = 0.881$) was therefore applied. A significant differences in perceived difficulty was observed for handwriting ($F (2.643, 76.657) = 104.6$, $p = < .001$, $\eta^2 = 0.783$). Fig. 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 ($p < .001$). The orthosis #3 was perceived as the most difficult ($M = 7.42$, $SD = 2.07$), and it was significantly different to the two other orthoses ($p <.001$). There was no significant difference between the two neoprene fabric orthoses, #1 and #2.

The handwriting task time completion data did not satisfy the assumption of sphericity ($W = 0.311$, $p < .001$). The Greenhouse-Geisser correction ($\varepsilon = 0.561$) was therefore used. A significant difference in handwriting task completion times were found ($F(1.682, 48.767) = 21.0$, $p <.001$, $\eta^2 = 0.420$). The condition with no orthosis resulted in the shortest mean handwriting time in seconds ($M = 51.3$, $SD = 10.8$) and the orthosis #3 resulted in the longest mean time ($M = 68.1$, $SD = 14.6$). Post hoc tests revealed significant differences between using no orthosis and both the neoprene orthosis, #1 and #2 ($p < .001$), and the orthosis #3 ($p < .001$). A significant difference was also found between the orthoses #3 and #2 ($p < .001$) and between the orthosis #3 and #1 ($p = .007$) (see Fig. 9). There was no significant difference between no orthosis and using the orthosis #1 or between the two neoprene fabric orthoses, #1 and #2.

3.4 Transmission of Manual Torque evaluation

Manual torque data did not meet the assumptions of sphericity ($W = 0.626$, $p = .024$) and Huynh-Feldt correction was therefore used ($\varepsilon = 0.820$). A significant difference between the conditions in terms of manual torque was observed ($F(2.460, 71.343) = 1.89$, $p < .001$, $\eta^2 = 0.324$). Transmission of Torque in canned glass opening was 22.84% lower without an orthosis compared to using the orthosis #3, 17.17% lower strength using no orthosis compared to using the orthosis #1 and a 13.82% lower strength without an orthosis compared to the orthosis #2 ($p < .001$). Significant differences were also observed between the orthosis #2 and #3 ($p = .035$), where the orthosis #3 achieved the lowest transmission of torque ($M = 2.56$, $SD = 0.89$) and orthosis #2 the strongest transmission of torque ($M = 2.86$, $SD = 0.93$) (see Fig. 10). There was no significant difference between the two neoprene fabric orthoses, orthoses #1 and #2.

4. DISCUSSION

Although orthoses are 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 wrist-hand orthoses in manual tasks and forces are important for the comprehension on how those devices can be adapted in order to cause less disturbance.

Task execution times with the orthosis #2 were shorter than with the other two orthoses. The orthosis #1, although yielding low task completion times, was the model fitted incorrectly most frequently by the users. Although the orthosis #3 resulted in similar task completion times for donnig the orthosis to the orthosis #1, none of the participants donned the orthosis #3 incorrectly.

The results suggest that the fabric material may be a factor influencing task performance, as the main difference between the canvas and the neoprene orthoses is the fabric. The neoprene fabric is more elastic and conformable than the canvas fabric, which may have prevented participants from adjusting the orthoses by themselves. The stiff fabric of the orthosis #3 may have provided more rigid in nature. The high occurrence of participants donning the orthosis incorrectly suggests that the orthosis #1 is less intuitive than the other two, or, in other words, it's design does not communicate properly how it should be donn.

The performance in manual tasks showed significant differences in the perceived difficulty of both typing and handwriting tasks. The higher levels of difficulty reported by the participants when using orthosis #3 while performing these two tasks may suggest a better stabilization provided by this orthosis in comparison to the other two neoprene orthoses, #1 and #2. In both cases, the conditions with no orthoses exhibited lower perceived difficulty compared to using an orthosis. The purpose of these orthoses is to stabilize the wrist in extension. 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, #1 and #2.

The lower typing speeds exhibited with the conditions of using the orthoses compared to 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 and the orthosis #1. The orthosis #3 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.[18] 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[19] and semi-rigid material[20] compared to handwriting without orthoses.

The wrist position it is essencial for manual prehension[21] and manual torque transmisison, 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 wrist-hand orthoses.[21, 22] Due to 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 orthosis #3 and orthosis #2, with the first showing the least 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.[11] Van Petten et al.,[20] also found a reduction in grip strength comparing conditions with and without a wrist-hand orthoses. However, they found no significant difference between a thermoplastic orthosis and a non-rigid orthosis.

Recruiting non wrist hand orthosis 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 wrist hand orthoses. Another weakness of this study was that the bimanual typing task was performed using orthoses on one hand only. Hence the performanceof this bimanual task was not symmetric. Future work should therefore introduce orthoses on both hands or measure the keystroke dynamics independently for both hands.

5. 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 to not using an orthrosis, the use of orthoses affect the performance in most of the conditions, except the use of the orthosis #1 in the handwriting task. Additionally, we found differences in performance among the evaluated orthoses. The orthosis #3, made with canvas fabric, was more restrictive, with higher levels of perceived difficulty requiring longer time to complete the tasks. It also exhibitet a lower measure of torque transmission compared to the two other neoprene fabric orthoses, orthosis #1 and #2. Although the major goal of these orthoses is to stabilize the wrist joint, the results shows 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 adjusting the orthosis.

The lack of visual clues expressed by the device design, that 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 benefit user's satisfaction.

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Figure Legends

Figure 1. (a) Orthosis #1, (b) Orthosis #2 and (c) Orthosis #3 (front and back views).

Figure 2. Participants performing the tasks: donning the orthosis (left), typing text (center) and handwriting (right).

Figure 3. A participant holding the mock-up with the torquemeter inside for the manual torque evaluation.

Figure 4. Mean completion times for the three conditions. Error bars show standard deviation.

Figure 5. Number of participants (N) who donning the orthosis improperly for the three orthoses.

Figure 6. Mean perceived difficulty. Error bars show standard deviation.

Figure 7. Mean typing speed (wpm). Error bars show standard deviation.

Figure 8. Mean perceived difficulty. Error bars show standard deviation.

Figure 9. Mean handwriting completion time. Error bars show standard deviation.

Figure 10. Mean torque. Error bars show standard deviation.