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Do wrist orthoses cause compensatory elbow and shoulder movements when performing drinking and hammering tasks?

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Abstract

Purpose – Wrist orthoses are used by occupational therapists to decrease pain, support weak muscles and protect tissues during healing. However, use of wrist orthoses has been observed to produce compensatory movements in other upper extremity joints. This paper aims to determine whether wearing wrist orthoses produced compensatory movements of the elbow in addition to the shoulder when performing drinking and hammering tasks.

Design/methodology/approach – Two twin-axis electrogoniometers were positioned on the elbow and shoulder to track joint movement. The four conditions were drink with orthosis, hammer with orthosis, drink without orthosis and hammer without orthosis. Joint movement was defined as total angular excursion of the joint throughout the performance of the task. Separate 2×2 (joint $\times$ orthosis) repeated measures analyzes of variance (ANOVA) were used to evaluate differences in joint excursion of the elbow and shoulder joints between orthosis conditions for each task.

Findings – Wearing a wrist orthosis did not change the amount of joint excursion compared to not wearing an orthosis during the drinking and hammering tasks.

Originality/value – Findings suggest that wrist orthoses do not result in statistically significant changes in elbow and shoulder joint movements during simulated drinking and hammering tasks.

Keywords Electrogoniometer, Orthosis

Paper type Research paper

Introduction/background

Wrist orthoses are often provided by occupational therapists to decrease pain, support weak muscles and joints and protect tissues during healing. Because of the mobility of the wrist and its role in performing daily activities, restricting the mobility of the wrist with an orthosis may produce compensatory movements in other upper extremity joints during performance of daily tasks (Mell *et al.*, 2006; Yoo *et al.*, 2010). In general, studies report that wearing a wrist orthosis resulted in an increase in shoulder movements compared to not

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wearing an orthosis. King *et al.* (2003) found that more shoulder abduction occurred while wearing wrist orthoses during a stacking and pouring task compared to a no orthosis condition. Mell *et al.* (2005) found that wearing wrist orthoses resulted in increased humeral flexion when participants reached into a box, and they speculated that an increase in humeral elevation increases the risk of a shoulder disorder. An early study, by Chan and Chapparo (1999), was the only study to examine the effect of wrist orthoses on elbow motion. They found that wearing wrist orthoses resulted in an increase in the total shoulder motion and a decrease in the elbow motion compared to a no orthosis condition while grasping and moving different sized objects.

Furthermore, electromyographical activity of the shoulder muscles has also been shown to increase while wearing wrist orthoses during simulated work tasks (Mell *et al.*, 2006; Yoo *et al.*, 2010) and pouring motions (Bulthaup *et al.*, 1999). The latter study, the only study that assessed electromyography in the elbow muscles, also found increased muscle activity in the biceps and medial head of the triceps when participants wore orthoses compared to no orthoses.

While there is evidence that wearing wrist orthoses results in compensatory shoulder movements while performing upper extremity tasks, few studies have examined the effect of wrist orthoses on elbow motion. The combined effects of wrist orthosis use on both the shoulder and the elbow is important to understand, as compensatory movements may lead to cumulative strain and fatigue (Bulthaup *et al.*, 1999; Stern *et al.*, 1997). Therefore, the purpose of this study was to determine whether wrist orthoses produced compensatory movements of the elbow in addition to the shoulder when performing drinking and hammering tasks.

Methods

Participants

A convenience sample of 20 healthy adults (10 females and 10 males) was recruited to participate in this study. The participants were aged between 19 and 22 years ($M = 21.1 \pm 1.0$ years). Participants were right hand dominant without any self-reported history of upper extremity joint or nerve injury. All participants provided written informed consent prior to participation in this study. The study was approved by the University Institutional Review Board.

Procedure

Participants were seated at a standard height table in a chair adjusted such that their elbows were level with the surface of the table. A North Coast Liberty D-Ring static wrist splint, which positioned the wrist in 20° extension, was used for trials that required the use of an orthosis.

Two tasks which mimicked those of daily living were examined: drinking from a plastic cup and hammering a peg into a pegboard (Aizawa *et al.*, 2010; Leventhal *et al.*, 2010). Participants were given verbal instructions and a demonstration of how to perform each task. Participants then self-selected a pace of movement while performing each task with and without the wrist orthosis three times, with a minimum rest period of 30 s between trials. To ensure that the presentation of conditions was balanced between participants, a counterbalanced design was used (i.e. half of the participants completed the trials wearing an orthosis first, whereas the other half completed the trials without wearing the orthosis first).

Participants began the drinking movement seated at the table with their forearms resting on the table with the elbow flexed 90°. A plastic cup filled with 6 oz. water was held in the right hand (Figure 1). Participants were instructed to bring the cup to the mouth prior to drinking from the cup. When cued to begin, participants raised the cup to their mouths, took a sip and then returned the cup to its initial position on the table.

Participants began the hammering movement seated at the table with the left forearm resting on the table with the elbow flexed 90°. Participants held the hammer in the right hand, resting the head of the hammer on a peg (Figure 2). Participants were instructed to deliver a single forceful hammer stroke to the peg and then leave the hammer in contact with the peg until told to relax.

Measurements

Two twin-axis electrogoniometers (Biopac, Goleta, CA) were positioned on the elbow and shoulder to track joint movement. To measure elbow angular motion, the telescopic end block of a goniometer was attached to the center of the forearm. The participant then fully extended the elbow and the fixed end block was attached to the center of the upper arm. This aligned the goniometer to measure sagittal and frontal plane elbow motion of which only sagittal plan motion was analyzed. To measure shoulder angular motion, the telescopic end block of a goniometer was attached to the trunk along the superior aspect of the clavicle. The participant then flexed the shoulder to 90° and the fixed end block was attached to the lateral aspect of the upper arm. This aligned the goniometer to measure sagittal and frontal plane motion of the shoulder of which only sagittal plane movements of the shoulder were analyzed.

A synchronized video of the movement was used to identify the instant of first movement and completion of movement. Joint movement or excursion was then calculated

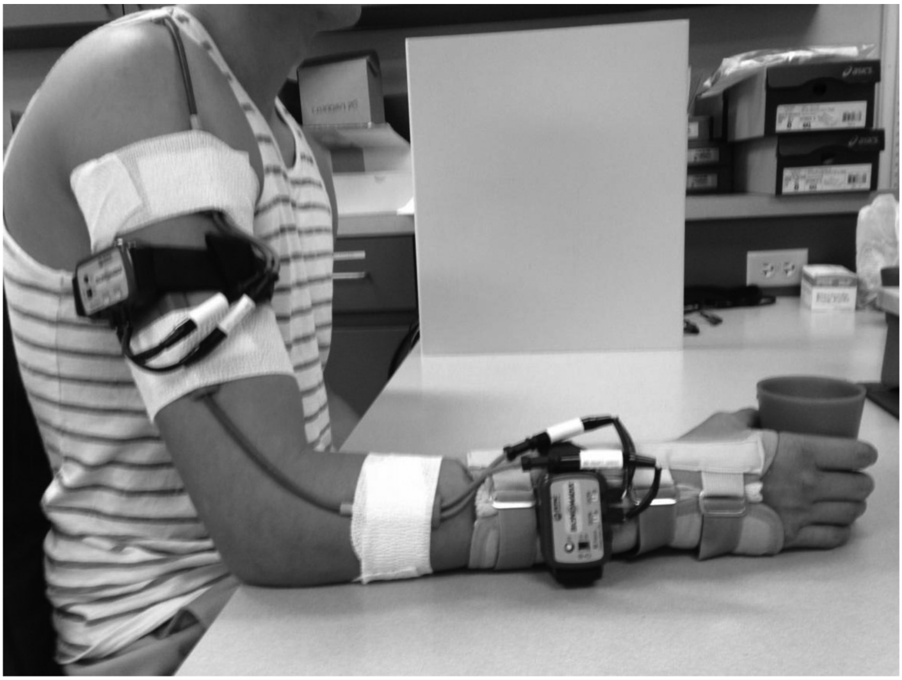

Figure 1.
The drinking task with participant wearing an orthosis

Figure 2.
The hammering task with the participant wearing the orthosis

as the total angular distance covered between the first movement and movement completion. For the drinking task, first movement was defined as the instant in which the participant began lifting the cup from the table. Movement completion was defined as the instant the participant began to lower the cup from their mouth. For the hammering task, first movement was defined as the instant in which the participant began to lift the hammer off the peg. Movement completion was defined as the frame after the hammer made contact with the peg and the peg had attained its maximum downward position.

Data analysis
Separate 2 × 2 (joint × orthosis) repeated measures analyzes of variance (ANOVA) were used to evaluate differences in joint excursion of the elbow and shoulder joints between orthosis conditions for each task.

Results
Joint excursion in the elbow (155 ± 47°) was similar to that of the shoulder (139 ± 33°) when performing the drinking task ($F(1,19) = 0.20$, $p = 0.66$, $\eta^2 = 0.01$). Furthermore, when performing the drinking task, wearing a wrist orthosis (148 ± 34°) did not alter the amount of joint excursion ($F(1,19) = 1.65$, $p = 0.22$, $\eta^2 = 0.08$) when compared to not wearing an orthosis (146 ± 31°) (Figure 3). Use of an orthosis accounted for only 8 per cent of the variance in joint movement. Thus, these changes were not indicative of a compensatory strategy to accommodate a wrist orthosis involving the shoulder and elbow, as the interaction between joint and wrist orthosis condition was not significant ($F(1,19) = 2.13$, $p = 0.16$, $\eta^2 = 0.10$).

When performing the hammering task, elbow joint excursion (41 ± 18°) was similar ($F(1,19) = 0.59$, $p = 0.45$, $\eta^2 = 0.03$) to that observed in the shoulder (44 ± 13°). Joint excursion during the hammering task performed when wearing a wrist orthosis (44 ±13°) was no different ($F(1,19) = 1.12$, $p = 0.30$, $\eta^2 = 0.06$) than when not wearing an orthosis (41 ± 16°) (Figure 4). Use of an orthosis accounted for only 3 per cent of the variance in joint movement. Like the drinking task, these changes did not indicate the use of a movement strategy when performing a hammering task that involved compensatory movements in the elbow and shoulder because of the limited motion of the wrist, as the interaction between joint and wrist orthosis condition was not significant ($F(1,19) = 2.35$, $p = 0.14$, $\eta^2 = 0.11$).

Discussion

The observed trends in elbow movement are similar to those of Chan and Chapparo (1999) who found that wrist orthoses resulted in decreased elbow motion compared to no orthosis while performing tasks requiring grasping and moving. Similarly, the trends in shoulder movement from the present study were similar to several previous works that demonstrated increased shoulder movements (Chan and Chapparo, 1999; May-Lisowski and King, 2008; Mell *et al.*, 2005). However, the lack of statistical significance suggests that wrist orthoses neither altered elbow or shoulder movements nor produced an interactive effect between shoulder and elbow movements during a drinking or hammering task. Thus, use of wrist orthoses produced little compensatory joint movement.

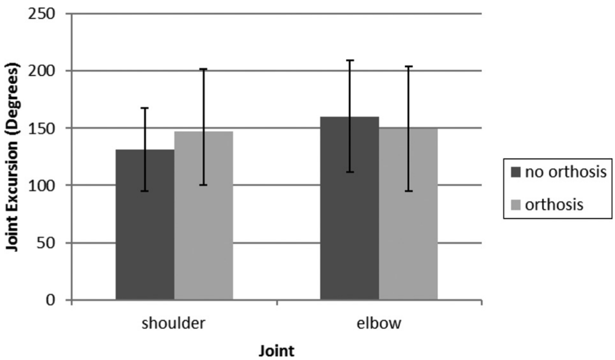

Figure 3.
The mean (SD) joint excursion for the elbow and shoulder, with and without an orthosis, for the drinking task

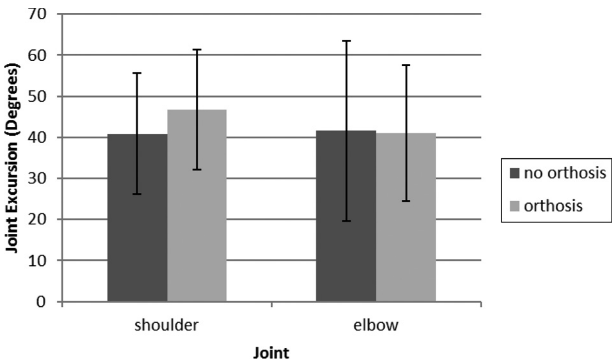

Figure 4.
The mean (SD) joint excursion for the elbow and shoulder, with and without an orthosis, for the hammering task

The placement of the twin-axis electrogoniometer used in the present study primarily allowed measurement of shoulder flexion. While it is possible that shoulder abduction could have contributed to increased joint excursion, other studies report more shoulder flexion than abduction motions are used during drinking and hammering (Aizawa *et al.*, 2010; Buckley *et al.*, 1996). For hammering, the number of repetitions may not have been sufficient to see increased shoulder motions. Côté *et al.* (2005) reported that repetitive hammering resulted in changes in elbow motion, perhaps because participants attempted to move at a constant speed to maintain normal hammering movement patterns. Leventhal *et al.* (2010) found minimal radiocarpal motion during simulated hammering and suggested that this was because of the wrist maintaining an extended position. If the wrist is already maintained in an extended position by wearing a wrist orthosis, there may not be much difference in other joint movements as found in the present study. Another explanation for the lack of significant changes in shoulder and elbow motion may be that the upper extremity uses different kinematic strategies to perform the same tasks (Buckley *et al.*, 1996). This adaptability could explain the results found in the present study, but more importantly, it provides some flexibility in designing any type of upper extremity orthosis. Start and end position of the hand and desired hand orientation during daily tasks should be taken into account by occupational therapists when fabricating orthoses.

In addition to the limitations of the electrogoniometer, other limitations were the small sample size and limited number of trials. While the sample size was small, it was similar in respect to number and age to the other studies on wrist orthoses (Bulthaup *et al.*, 1999; Mell *et al.*, 2005; Yoo *et al.*, 2010). Second, participants only completed three trials of each task; however, other studies also used three to five trials (King *et al.*, 2003; Yoo *et al.*, 2010). Slower movement times for performance of the drinking task were observed when participants wore the wrist orthosis. However, this factor was not controlled for, as participants were told to perform the tasks at their own pace and time was not a factor focused on in this study similar to King *et al.* (2003).

The results of this study suggest that wrist orthoses do not result in additional increases in elbow and shoulder joint movements during simulated drinking and hammering tasks. Therefore, the use of wrist orthoses may not increase the susceptibility of other upper extremity joints to aggravation or injury. Future studies may want to examine longer-term use of orthoses, as there may be cumulative effects of even small changes in joint motion over time as suggested by Bulthaup *et al.* (1999).

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