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Rachel Griffin

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Rachel Griffin

Research Advisor: Martin S. Rice, Ph.D., OTR/L, FAOTA

Occupational Therapy Doctorate Program

Department of Rehabilitation Science

University of Toledo

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Abstract

This study explores compensatory movements of the upper extremity while wearing a static wrist splint. Through an 8 camera motion analysis, we were able to quantify the amount of shoulder range of motion used while opening a jar in two conditions: wearing a static wrist splint and not wearing a static wrist splint. Data from 32 healthy adult participants aged 19-58 years (10 male, 12 female) were included in the analyses. We found that the splinted condition had significantly more shoulder abduction than the non-splinted condition ($p=.0012$) and there was no significant difference between the two conditions for shoulder flexion/extension or shoulder rotation ($p > .05$). This research serves as an important reminder that splinting chronic conditions may not be the appropriate treatment since the degrees of freedom lost at the wrist must be compensated for in a proximal joint, in the case of this research, shoulder abduction while attempting to open a jar. Occupational therapists should adhere to proper follow up as well as provide education on how to reduce the risk of overuse injury in proximal, non-splinted joints.

Effects of Static Wrist Splinting on Compensatory Movements of the Upper Extremity

Introduction

Splinting can be dated back to the ancient Egyptians who used leaves, reeds, bamboo and bark padded with linen to treat fractures. Splints have since then evolved through the ages and have been made from a range of materials such as copper, wood, plaster, leather, and plastic (Collier & Thomas, 2002). Today, occupational therapists utilize splinting to protect structures from the risk of injury, facilitate proper positioning for functioning, immobilization for healing, to restrict undesired motion, correct or prevent deformity, or as a substitute for weak muscles. Additionally, splints are often used in conjunction with other treatment strategies to enhance occupational performance (M.V. Radomski & Trombly, 2007).

While it is not uncommon to hear the terms *splints*, *braces*, and *orthoses* used interchangeably, each are unique in their meaning. For instance, a splint is defined as “a rigid or flexible material used to protect, immobilize, or restrict motion in a part”. Similarly, a brace refers to “an appliance that gives support with movable parts to weak muscles, or to strained ligaments”. Finally, an orthosis is “designed for the support of weak or ineffective joints or muscles.”(Fess, 2002, p. 98)

Occupational therapists began working closely with hand surgeons in the 1960’s and developed effective techniques for rehabilitating through splinting. As their involvement in postoperative care grew, the role of the therapist became more defined and they separated themselves from the orthotist. The orthotist focused on braces for permanent loss while the therapist was an active part in the rehabilitation process. The development of hand therapy and low temperature thermoplastic splinting acted as a catalyst for occupational therapists working with hand and wrist splinting (M.V. Radomski & Trombly, 2007). As part of hand therapy, occupational therapists needed to account for the joints of the entire upper extremity.

Each joint is defined with a specific number of degrees of freedom. The glenohumeral joint has 3 degrees of freedom: abduction/adduction, flexion/extensions, and internal/external rotation. As the humerus moves, the scapula also needs to move in order to allow for range of movement. For example, when the humerus abducts the scapula upwardly rotates and retracts. This scapulohumeral rhythm makes functional range of motion possible. The elbow has one degree of freedom: flexion/extension. This joint is generally unaffected by the position of the glenohumeral joint. Alternatively, the “wrist joint” is actually several joints. The distal radioulnar joint has one degree of freedom and allows for pronation/supination. The radiocarpal joint has two degrees of freedom. Flexion/extension and radial/ulnar deviation can be seen at this joint. The remaining wrist joint is the midcarpal joint and accounts for the same actions as the radiocarpal joint with two degrees of freedom. So with these joints combined, the wrist can perform flexion/extension and radial/ulnar deviation in either pronated position or supinated motions. Degrees of freedom extend into the hand with varying degrees of freedom from one degree at each of the interphalangeal joints to two degrees of freedom at each of the metacarpophalangeal joints. With the culmination of the entire upper extremity, the resultant degrees of freedom at the hand and fingers provides substantial redundancy which in turn affords a plethora of potential motor control solutions for any given task required of the hand/fingers. For instance, when reaching for an object, such as an apple, there is a multitude of potential reach and grasp strategies available for the completion of retrieving the apple.

The concept of degrees of freedom was originally penned by Nikolai Bernstein (1967). Bernstein theorized that for any given task, such as the reaching for the apple example used above, the redundancy of having more degrees of freedom available to accomplish provides a variety of movement solutions for any given task. As such, the potential options for solving a movement challenge is potentially numerous. How then, is a particular movement strategy selected to accomplish a movement task? Newell (1991) theorized that the motor system relies on perceived constraints/information in the environment, the task at hand, and a knowledge of the integrity of one's own body (including the available degrees of freedom); all contribute to the selection and execution of motor tasks (Newell, 1991). These researchers theorized that this determination occurs in a hypothetical workspace that they termed the 'Perceptual Motor Workspace' (Newell, 1991, p. 218). Bass-Haugen, Mathiowetz and Flinn incorporated some of Newell and McDonald's concepts and applied them to the Task-Oriented Approach which includes additional concepts more applicable to the practice of occupational therapy (Bass-Haugen, Mathiowetz, & Flinn, 2008). Within this approach, the authors describe the compilation of influences from the environment (e.g., temperature, room conditions, etc.), from within the person (e.g., available degrees of freedom, memory, mood, etc.), and from the task at hand (e.g., rules of a game, size of an object used to accomplish the task, etc.). When challenged with a situation requiring a movement solution, the person's perceptual motor workspace considers all of these influences and builds a *movement solution*. This occurs by perceiving utility in the environmental and task influences along with a knowledge of the person's internal abilities (e.g., strength, range of motion, cognitive abilities). Perceiving items in the environment affords opportunity based upon the influences from the environment, task, and person which result in a preferred movement pattern. As the person's environment and task change, the movement patterns adapt accordingly to maintain the efficiency and effectiveness of the movements. Influences, particularly from the environment and from within the person vary between people and result in variations for movement solutions. For example, if a person injures their hand, he or she may change the way he or she reach for an object to avoid exacerbating his or her injury. Once the healing process has begun and the hand is no longer painful, the person will more than likely return to his or her previous pattern of movement (M.V. Radomski & Trombly, 2007). The body's ability to alter movement patters is due to the numerous redundancies that are "built" into our system. These redundancies allow us to have many options for how to complete a task. This idea also applies to constraints. When a person is placed in a constraint, such as a cockup splint, they must change their movement patterns to accommodate for the lost degrees of freedom. This change can place strain in other joints due to the increase demand on proximal joints. One study examined this idea and found that a simple feeding task, when performed in a wrist splint, increased the demand on the participants shoulder (May-Lisowski & King, 2008). Because the upper extremity has lost the degrees of freedom at the wrist, the motor system must find a way to accomodate this reduction in degrees of freedom through increasing range of motion in another joint, in this case, the glenohumeral joint takes on the additional degrees of freedom in order to complete the task.

Wrist and hand function has been a significant area of interest for occupational therapists since William Rush Dunton first coined the term "Occupational Therapy" in 1915. Dunton emphasized starting occupational therapy soon after the initial onset of the disorder or diagnosis. This central tenet influenced hand therapy in the 1960's when occupational therapist began working closely with surgeons during the rehabilitation process postoperatively (Dunton, 1915).

As occupational therapists began utilizing splinting in this process, the call for research on the effects of splinting became apparent. Researchers began exploring this subject and found that wrist immobilization affects the scores of the Jebsen Hand Function Test (Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969). Although not statistically significant, the time for completion of the full assessment was longer when wearing a static wrist splint. The study also indicated that wrist stability was enhanced. This began to show clinicians that although the splint is providing appropriate support, it may be adversely affecting the activities of daily living for the user (Carlson & Trombly, 1983).

In 1999, Chan and Chapparo also found that that static wrist splinting increased the time to completion of the Jebsen Hand Function Test. With a sample of nine elderly males, Chan et. al found that it took longer to complete the assessment when immobilized. They also utilized motion analysis and found that side flexion of the trunk, and shoulder showed an increase in the mean degrees of motion during flexion/extension and abduction/adduction when wearing the static wrist splint (Chan & Chapparo, 1999).

In a slightly larger study of 17 participants, Bulthaup, Cipriani, and Thomas used electromyography and found that significantly more motor units were recruited during splinted conditions. Participants completed the task of picking up an object, pouring, and setting it down. Alignrite wrist splints with a tension strap were used and each participant completed the task in three separate conditions: unsplinted, in a long style splint, and in a short style splint. The participants were healthy woman between the ages of 22-40. All were right hand dominant. The researchers found that along with more recruitment of motor units during the two splinted conditions verus the unsplinted condition, more muscle activity for the wrist extensors was needed to complete the task when wearing the long splint verus the short or unsplinted condition. Bulthaup et. al furthermore investigated if the long style splint would evoke more proximal muscle activity then the short style splint. Their results indicated that both the long and short style splints recruited more motor units for the proximal muscles (Bulthaup, Cipriani, & Thomas, 1999).

This lead to a study in 2004 in which Clare, Haviland, and Belcher explored the efficacy of postoperative splinting in clients with digital nerve repairs. Clare et Al. reviewed 40 participants who underwent surgery for isolated sharp deep nerve division. Twenty of the participants were splinted beyond standard postoperative procedure (2 weeks) and 20 were splinted for the standard postoperative amount of time (2 days). Through questionnaires and an OT exam completed between 12 and 36 months postoperatively, the researchers found that the group who were splinted beyond standard protocol were delayed in returning to work, experienced increased stiffness, and decreased cold tolerance. This study suggests that splinting for extended periods of time may not be an effective therapeutic treatment (Clare, de Haviland Mee, & Belcher, 2004).

A small meta-analysis in 2007 examined four studies and found that for splinting to be therapeutic, it must be used with activity as well. The four main questions each study investigated included: Is splinting effective for patients recovering from a stroke? What is the crucial time for splinting? How many intervention sessions are ideal? Is there an understanding on the optimal duration of splint wearing? The authors found that the four studies indicated that by developing a 'rehabilitation protocol' that alternates between activity and immobility, as opposed to simply discontinuing splinting completely, the splinting has a more therapeutic benefit. They also discovered that intervention dosimetry pertaining to the time of initiation as well as the number of interventional sessions and duration of each session, should also be meticulously considered within a 'proposed protocol' developed by therapists using splinting for therapeutic purposes (Manigandan & Charles, 2007).

Therapists should not only be carefully tracking their clients' use of splints but should also consider the effect splinting has on the rest of the upper extremity. In 2005 Mell, Childress, and Hughes recruited 10 healthy adults and used a MotionStar electromagnetic tracking system to quantify how a Donjoy Orthopedics large wrist splint altered movement patterns when reaching into a box. Mell et. al found that when the subjects were wearing the wrist splint which limited wrist flexion/extension and deviation, they had significantly increased humeral elevation and humeral axial rotation (Mell, Childress, & Hughes, 2005). Several other studies explored the same idea with various activities. For instance, May-Lisowski and King also used a motion monitor during a splinted and unsplinted positions. In a sample size of 20 participants, there was a significant increase in shoulder flexion and shoulder abduction during a feeding occupation while wearing a prefabricated static wrist splint. They also found that shoulder internal rotation was unaffected during this occupation (May-Lisowski & King, 2008).

Gillen, Goldberg, Muller, and Straus investigated several tasks by using the Jebsen Taylor Test of Hand Function (Jebsen et al., 1969). This study was also unique because it not only compared splinted and unsplinted comparisons but various angles of splinting. The investigators randomly assigned participants to 0, 15, and 30 degrees of dosiflexion in a Rolyan® AlignRite™ Wrist Support and timed their completion on the assessment. These researchers found that there was a significant difference between splinted and unsplinted conditions when completing functional tasks but there was no difference between the three splinted positions (Gillen, Goldberg, Muller, & Straus, 2008).

In 2012, researchers examined pronation and supination motion while performing specific tasks. This study required participants wear one of two unique splints. One was a fixed neutral in which the participant’s forearm was immobilized into a neutral forearm and wrist position. The second splint was fixed supinated which similarly immobilized the participant into a supinated forearm and wrist position. The study involved 6 subjects who completed 5 ADL’s with typical movement patterns and in a randomly assigned splint. They quantified the movements with a motion capture system and found that significantly more range of motion was elicited in the splinted conditions versus the unsplinted condition. (Pereira, Thambyah, & Lee, 2012).

Overuse injuries are also commonly treated through splinting and are prevalent in today's working society. According to a recent meta-analysis on carpal tunnel syndrome, which is commonly attributed to overuse, 2.3 out of every 100 people are diagnosed with carpal tunnel syndrome (Dale et al., 2013). Two common treatments for repetitive strain injury are surgery and splinting. Thirty seven percent of people being treated non-surgically for carpal tunnel syndrome report adequate symptom control through splinting and although surgery is a more effective treatment, splinting is often used along with the surgical process (Bland, 2007). This poses an interesting question for treatment. If the overuse injury is being treated with splinting, this potentially transfers the reduction in degrees of freedom to the proximal joints. Does this transfer of movement then cause the proximal joints to become irritated from the altered movement patterns and additional demand placed on them? Is it possible that this strategy results in creating musculoskeletal problems elsewhere as the body attempts to compensate for the loss of mobility?

The purpose of this study is to determine whether wrist/hand orthoses elicit compensatory motions while performing a common upper extremity bilateral task; namely, opening a screw-top container. Specifically, we hypothesis that in a population of healthy adults, there will be measureable compensatory movement (range of motion) in the upper extremity when opening a jar while wearing a prefabricated wrist orthosis versus opening a jar while not wearing a wrist orthosis.

Methods

Variables

The independent variable in this study involved the splint versus no splint conditions. The immobilized condition was accomplished by using a Rolyan Alignrite static wrist splint. The dependent variable was range of motion in degrees at the shoulder, elbow, wrist, and trunk.

Apparatus

The Motor Control Laboratory of the Occupational Therapy program at The University of Toledo served as the setting for the experiment. Initial laboratory setup consisted of standard counter height table (80 cm x 62 cm x 91.44 cm), a plastic jar (7 cm x 12.5 cm) which was secured to the table via bolts and epoxy. The lid was secured by a torque-clutch electric drill standardized to a standard peanut butter jar.

Eight Owl Motion Analysis cameras (Motion Analysis Corporation, 3617 Westwind Blvd. Santa Rosa, CA 95403) recorded data from 7 motion sensors using Cortex (version 6403.4.1.1301) data acquisition software. Reflective markers were placed on the upper extremity and upper body. Specifically, markers were affixed to the thumb, index finger, wrist and the lower and upper arm. For the upper body, markers were placed on the abdomen, trunk, and neck.

Each participant was fitted with an appropriately sized (extra-small, small, medium, large, or extra-large) long style Rolyan Alignrite splint with tension strap.

Participants

Based on the performance of the participants in Mell et. al, we assumed that in shoulder range of motion with a standard deviation of approximately 8.65 degrees, a mean difference of approximately 6.5 degrees, a β of .8, an α of .05 we expected a statistical significant difference from a sample size of 38 participants (Mell et al., 2005).

Thirty-eight participants for this study were recruited from a Midwestern university setting. Participants included both men and women between the ages of 18 and 65. Inclusion criteria for participation included being right-handed (by self-report) adults and having no orthopedic or neurological condition that would adversely affect his or her ability to open a common type of food container having a screw-top lid.

Procedure

This study was approved by sponsoring institution's Biomedical Institutional Review board. Data were collected from September, 2013 through February, 2014. Upon entering the motion analysis lab, participants were briefed on the study protocol and inform consent was obtained prior to any data collection. Each participant was then fitted for a wrist orthosis.

Participants were instructed that they would complete the task twice and would be randomly assigned to an order of presentation. Randomization occurred using permutated blocks determined by the randomization software, RAPB, specifically, the order of presentation would be: splint then no-splint or no-splint then splint. For the permutated blocks, there were 5 blocks of 2 participants, two blocks of 4 participants, one block of 6 participants, and one block of 8 participants. The investigator was aware of the randomization assignment once the participant's research ID number was inputted into a custom computer program that would subsequently show the participant's order of presentation assignment (e.g., Splint, No-Splint or No-Splint, Splint). The motion analysis lab was set up such that there was a jar secured to a standard-height (36 inches) counter top. The lid of the jar was screwed on using a drill outfitted with a torque-sensitive clutch that standardized the amount of torque used to tighten the lid to 7 pounds. The participants were asked to stand at the table and open the lid of the jar with their right hand. This was then repeated according to their randomly assigned condition.

Data Analysis

Motion was captured at 120Hz, using the Owl Digital RealTime motion capture system from Motion Analysis. The system was calibrated and checked for accuracy prior to each data collection session in accordance with the manufacturer's guidelines. A custom routine designed using Visual3D software version 4.96.10 (C-Motion, Inc., 20030 Century Blvd, Suite 104A, Germantown, MD 20874) filtered the data using a low-pass filter with dual passes at a low-pass cutoff frequency of 6Hz. Shoulder angle data were calculated using a custom angle projection routines within Visual3D software. The reduced data were analyzed Graphpad Prism statistical software version 4.02 (GraphPad Software, Inc. La Jolla, CA, 92037).

Results

Data from 6 participants were not included in the analysis due to a lack of marker data leaving data from 32 participants aged 19 to 58 years (10 male, 12 female) that were included in the statistical analyses. The abduction data resembled a Gaussian distribution but the flexion/extension and rotation data did not, hence we used a one-tailed *t*-test for abduction, and a Wilcoxon Signed Rank test for the flexion/extension and rotation results (Table 1, Table 2). The splinted condition, had significantly more shoulder abduction than the non-splinted condition, $t(31)=3.298$, $p= 0.0012$ (Figure 1). There was no significant difference between the two conditions for shoulder flexion/extension, $Z= 6.000$, $p= 0.4795$ (Figure 2), or shoulder rotation, $Z= 4.000$, $p= 0.4870$ (Figure 3).

Discussion

This study examined the difference in upper extremity joint movements while opening a standard jar with and without a wrist cock-up splint. Several significant points are suggested from this study. With the addition of a splint to the standardized movement, there was a statistically significant difference in the amount of shoulder abduction that required to complete the task. This suggests that by reducing the available degrees of freedom in the wrist, the upper extremity compensated by increasing the range of motion in the shoulder. Additional findings suggest that the use of static wrist orthoses does not affect the amount of rotation or flexion/extenstion required by the upper extremity. Although the wrist conditions were not statically significant for the rotational or flexion/extension plane of motion, slight differences were seen in their respective means.

These findings suggest that a static wrist orthoses does affect the typical movement pattern for opening a standard jar. Limiting the available degrees of freedom at the wrist forces the upper extremity to compensate at the glenohumeral joint by increasing the amount of shoulder abduction required for the task. This may not appear like a stressful compensation, however for a person who is chronically splinted, this additional movement may create wear and tear on the shoulder.

These results are similar to the study by May-Lisowski & King (2008) in which 20 right hand dominant participants were asked to complete a feeding task with and without a static wrist orthosis. Using 7 magnetic sensors, May-Lisowski & King found that the splinted condition required a significant increase in shoulder flexion and abduction (May-Lisowski & King, 2008). Similarly, a study by Bulthaup et.al found that splinted condition required more proximal muscle activity than the non-splinted condition when picking up an object. This study had participants simulate picking up, pouring, and setting down an object while wearing short, long, or no split.

Researchers used electromyography to quantify the difference in motor units recruited during each of the three conditions. Limiting the degrees of freedom in the distal joints required significantly more motor unit recruitment of the proximal joints (Bulthaup et al., 1999).

This concept is also supported by Chan & Chapparo (1999) who studied the effects of wrist immobilization on upper limb function of elderly males. Participants were asked to complete the Jebsen Hand Function Test while wearing a fitted wrist orthosis. Through the use of a motion analysis system, these researchers found that not only does a splint increase the time for test completion, but also creates additional movement in trunk rotation, side flexion, and all movement planes of the shoulder. The current study did not find additional movement in all planes of the shoulder which may be attributed the different movements required in the studies. The Jebsen Hand Function Test requires significantly more motions and varied tasks in comparison to the current study, which required the exclusive to complete than opening a jar (Chan & Chapparo, 1999).

Mell et. al published a similar study in 2005 in which they investigated the effects of wearing a wrist splint on shoulder kinematics during object manipulation. Participants were asked to reach into a box with and without a splint. Their movements were recorded using MotionStar technology. Results showed a statistically significant increase in humeral elevation and humeral axial rotation. Although the outcomes of this study differed from the current study in that Mell et. al reported a wrist orthosis significantly increased humeral elevation and humeral axial rotation, the results indicate that performing an occupationally relevant task while wearing a static wrist splint increases risk factors for shoulder disorders (Mell et al., 2005).

Zinck further supported this idea through his study of compensatory movements in participants wearing a splint. Participants completed activities of daily living while wearing a wrist splint. Their movements were captured with an eight camera VICON M-cam system. Zinck found that increased motion and angles were most noticeable over several joints and these compensatory movements may lead to an increased risk for repetitive strain injuries (Zinck, 2009).

The general findings of this study are supported by Bernstein's theory of degrees of freedom. Bernstein stated that for any given task, the redundancy of having more degrees of freedom available to accomplish the task provides the potential for a variety of movement solutions. For people who are required to change their movement patterns to compensate for a loss in degrees of freedom, the strain of the additional movement in a different joint could lead to overuse injuries. The joint is now expected to provide the degrees of freedom it had been previously using as well as the new ones that have been moved proximally. This consequence may leads clinicians to critically evaluate the benefits versus the risks in their clinical decision making process. If a person is prone to overuse injuries, by splinting the agitated joint, the person increases their risk of irritating the proximal joints which now have additional degrees of freedom they are responsible for.

According to Peimer (1996), immobilization splints, such as those used in this study, are used to "immobilize and rest healing tissue." Commonly splinted conditions include trauma, arthritis, and control of pain, provision of external support, and substitute for absent, weak or imbalanced muscles. Conditions that would be included in these categories are spinal cord injuries, rheumatoid arthritis, De Quervain's tenosynovitis, carpal tunnel, and nerve injuries (Peirmer, 1996, p. 2391-2392). Some if these disorders would not be at risk for an over use injury however, arthritic conditions, DeQuervain's tenosynovitis, and carpal tunnel would all be at risk for overuse injury. Conditions that cause inflammation of the tendons and joints rarely stay in just one joint. For example, according to the Mayo Clinic, rheumatoid arthritis initially affects the joint in the hands, wrist, feet, and ankles but larger joints, such as elbows, shoulders, and knees are affected later in the course of the disease (Chang-Miller, 2014).

Limitations of this study include an unnatural data collection laboratory environment and only having participants from the healthy population, therefore, generalization to other patient populations should be done cautiously. The motion capture equipment along with the laboratory setting for the conduction of this study may have intimidated participants, thus influencing typical movement. Participants were also asked to open a jar that was bolted to a table. Several participants commented that they generally open a jar by holding it in two hands. Finally, despite following a standardized protocol, investigator bias may have influenced the data collection process.

There is a need for continued research in the comparison of movement patterns for tasks while splinted and unsplinted. Future research should include tasks other than opening a jar such as common house hold tasks that a person is apt to do multiple times a day. For example, motion analysis of stirring a bowl, washing dishes, and lifting dishes into cabinets. Future research should also include special populations who are prescribed splints such as carpal tunnel syndrome. A comparison of the two conditions relative to specific diseases or disorders that affect upper extremity range of motion, such as arthritis, also would be beneficial to determine the clinical significance of prescribing static wrist orthoses to clients

Conclusion

The purpose of this study was to determine whether wearing a wrist orthoses elicits compensatory motions while performing a common upper extremity bilateral task: namely, opening a screw-top container. The results revealed that wearing a static wrist orthosis increased the amount of shoulder abduction required to complete the task. Other differences were noted in the results, however the only statistically significant result was the increase in shoulder abduction. The results of this study were based on performance of a normal population, and therefore generalization of the results is limited. However these results do suggest that within a normal population, wearing a static wrist orthoses while opening a jar does increase the amount of abduction required at the glenohumeral joint.

Implications include employing adequate supervision of clients who are chronically splinted. For example, occupational therapists should be aware of the increased strain on proximal joints when they prescribe a wrist orthosis for their clients. A follow up evaluation should be carefully considered to ensure that clients are not developing repetitive strain injuries or overuse injuries in their proximal joints. Additionally, education should be provided to clients receiving orthoses on how it could affect their movement patterns such as practicing common movement patterns the client uses for activities of daily living so therapists can assist clients in becoming aware of the change that is required for their movement patterns. Future research should evaluate special populations who historically have used chronic splinting for treatment such as arthritis and how it affects the typical movement patterns as well as the incidence in overuse injuries of proximal joints.

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Table 1

Wilcoxon and t-test results for comparison of splint versus no splint

Source	Test statistic	*p* value
Abduction	t = 3.30	0.002
Flexion/extension	Z = 267	0.480
Rotation	Z = 262	0.487

Table 2

Mean, and standard deviation, for the splinted and unsplinted conditions

Motion	Mean (degrees)	Standard Deviation (degrees)
Abduction		
Splinted	72.28	24.39
Unsplinted	60.97	18.89
Flexion		
Splinted	132.40	91.39
Unsplinted	138.20	100.80
Rotation		
Splinted	45.74	22.65
Unsplinted	46.63	26.32

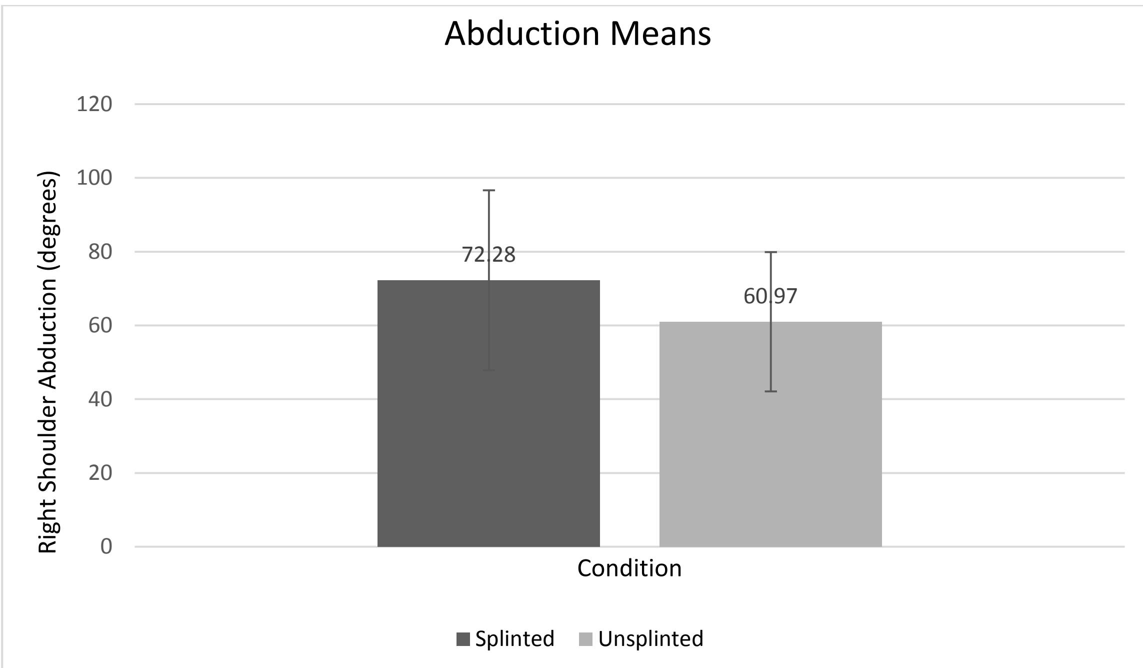

Figure 1 Abduction mean for splinted and unsplinted conditions with standard deviation.

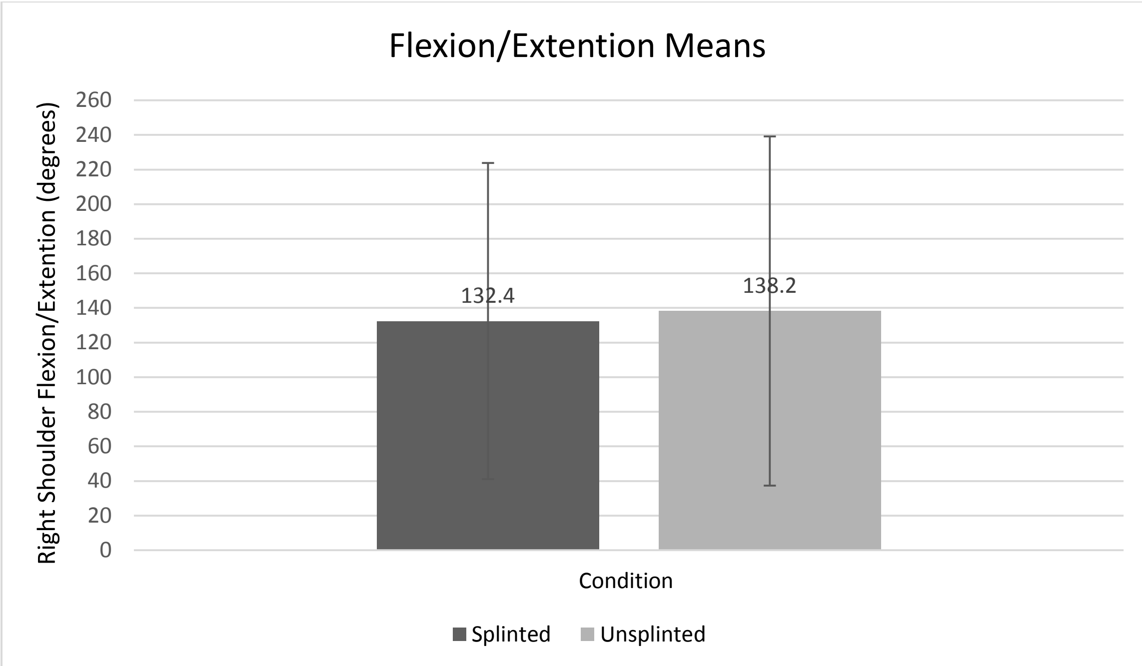

Figure 2 Flexion/extension mean for splinted and unsplinted conditions with standard deviation.

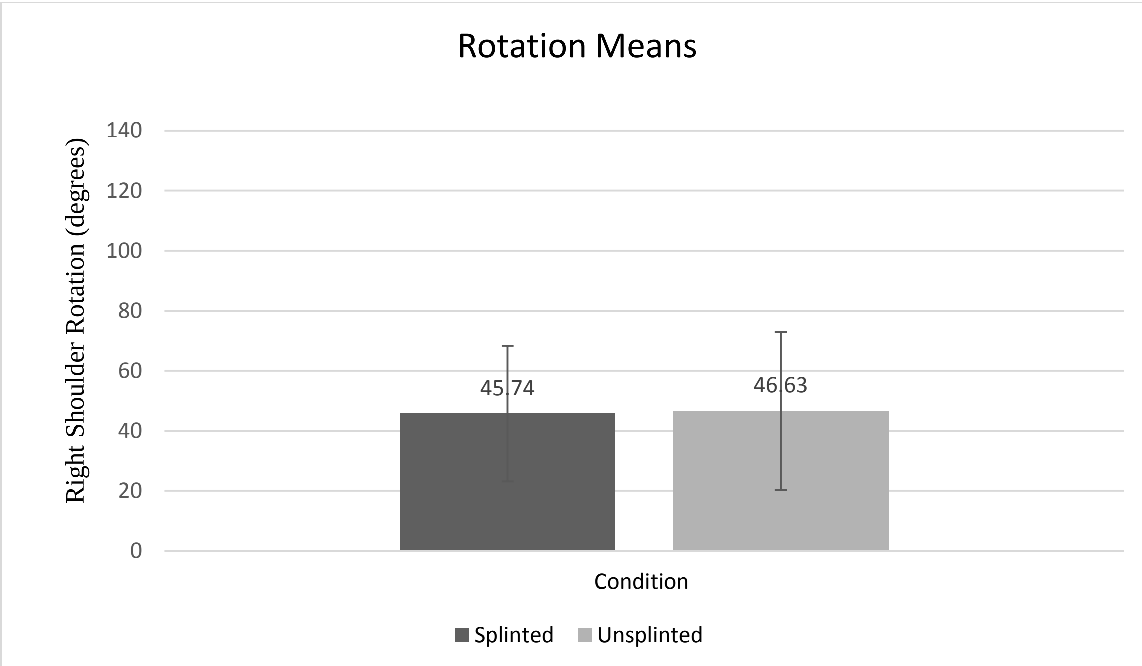

Figure 3 Rotation mean for splinted and unsplinted conditions with standard deviation.