Effects of bimanual activity inclusion with treatment after distal radius fracture

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Effect of Bimanual Activity Inclusion with Treatment After Distal Radius Fractures

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Author Note

We have no known conflicts to disclose.

Jennifer Vasquez, OTR, CHT, assisted with data collection at the Conroe and Willis Select Physical Therapy clinic. Select Physical Therapy allowed clinicians to perform the study during work hours.
Abstract

Background: A distal radius fracture (DRF) requires immobilization, affecting functional skills, strength, and bimanual activities at one-to-two years post-injury. This research design added bimanual activity to a standard occupational therapy (OT) treatment protocol and home exercise program (HEP) to increase the speed of bimanual activity and improve functional skills for patients with open reduction with internal fixation (ORIF) after a DRF.

Methods: This quasi-experimental study used a single-group pretest-posttest design of individuals with DRF requiring ORIF. A HEP with 10 minutes of bimanual activity was added to a standard OT treatment protocol and performed twice daily. Primary outcome measures were the Michigan Hand Outcome Questionnaire (MHQ) and the Purdue Pegboard Test (PPT).

Results: The participants showed a statistically significant change in the overall MHQ ADL and total MHQ scores ($p < .001$) and all domains except for work performance and aesthetics. Based on the pre-established minimally clinically important difference of 13-point change, there was a clinically relevant change in the majority of the MHQ measurements. Participants showed statistically significant improvement ($p < .001$) with large effect size (1.50) for the PPT bimanual assembly peg placement.

Discussion: Participants demonstrated improvements in bimanual activities, pain, and functional skills as measured with the MHQ after adding bimanual activities to the OT treatment. The statistically significant changes in the PPT scores showed improved hand dexterity and bimanual skills with increased speed. Large effect size for bimanual assembly confirmed clinical improvement in bimanual tasks within a 4- to 5-week time frame after ORIF.

Keywords: bimanual test, bimanual assessments, fine motor coordination, upper extremity assessment, clinical assessment, function, avoidance.
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Effect of Bimanual Activity Inclusion with Treatment After Distal Radius Fractures

Bimanual hand function is a complex and highly coordinated skill requiring both hands in concert, with each hand performing a different motion, such as tying shoelaces (Cooper, 2014; Kantak et al., 2017; Kimmerle et al., 2003). Bimanual activities often require dexterity that involves the integration of visual feedback, proprioception, and equalization of force and pressure to control the smooth interaction of the hands when performing small, coordinated motions (Bobos et al., 2018a; Coats & Wann, 2012; Jaric et al., 2005; McPhee, 1987). The loss of routine, pain-free motion, and proprioception reduce the ability of the hands to move in separate and alternating movements during coordinated bimanual activities (Karagiannopoulos et al., 2013; Kimmerle et al., 2003; Krehbiel et al., 2017). These impairments limit the ability to perform daily self-care, household, and work-related activities required for individuals to maintain their functional independence and quality of life (Dekkers & Nielsen, 2011; Jaric et al., 2005; Karagiannopoulos et al., 2013; Kimmerle et al., 2003; Krehbiel et al., 2017).

A distal radius fracture (DRF) is the most commonly occurring upper extremity (UE) orthopedic injury, routinely requiring medical treatment with immobilization following closed reduction or open reduction with internal fixation (ORIF) (Cooper, 2014; Gogna et al., 2013; Karagiannopoulos et al., 2013; Meena et al., 2014; Smith et al., 2004; Valdes, 2009). This immobilization leads to subsequent weakness, stiffness, pain, and sensory loss in the wrist and hand (Dilek et al., 2018; Karagiannopoulos et al., 2013; Lövgren & Hellström, 2012; Nielsen & Dekkers, 2013). Several researchers have reported that individuals immobilized for DRF often avoided the use of the affected hand due to pain, stiffness, sensory loss, and fear of reinjury (Bobos et al., 2018a; Handoll & Elliott, 2015; Lövgren & Hellström, 2012; Nielsen & Dekkers, 2013). Yang et al. (2018) noted that limited range of motion (ROM) for wrist extension, full
finger flexion for composite fist, and thumb opposition had the strongest connection to changes in Disability of the Arm, Shoulder, and Hand (DASH) overall functional scores over time. The researchers expressed a concern that the loss of the combined wrist extension and ulnar deviation affected the individual’s occupational, household, and sporting activities (Yang et al., 2018).

To avoid using the affected hand, individuals shifted hand function to a unilateral motion using the unaffected hand, changing two-handed tasks to a single-handed activity (Dekkers & Nielsen, 2011; Lövgren & Hellström, 2012; Nielsen & Dekkers, 2013). Most daily tasks require bimanual hand function (Krehbiel et al., 2017), so when modifying a two-handed task to a one-handed form, other supports, and awkward manipulations are used instead to complete a task (Lövgren & Hellström, 2012; Nielsen & Dekkers, 2013). Moreover, researchers found that avoiding the use of the affected hand further limited bimanual activity due to diminished interaction, coordination, and dexterity in the performance of self-care and productivity tasks at one to two years post-injury (Bobos et al., 2018a, 2018b; Nielsen & Dekkers, 2013).

Decreased bimanual hand use in functional tasks supports the need for occupational therapy (OT) practitioners to assess the interaction of hands with bimanual activities during DRF rehabilitation. Currently, therapists use assessments of range of motion (ROM), edema, pain, and grip strength as their initial focus, with ROM and grip strength considered reliable predictors of function (Bobos et al., 2018a, 2018b; Bobos, Nazari, et al., 2018; Hardin, 2002). Numerous standardized assessments for measuring hand dexterity and coordination are available, but few incorporate bimanual activity (Causby et al., 2014; Hardin, 2002; Schoneveld et al., 2009). The Purdue Pegboard Test (PPT) is an established dexterity assessment tool that incorporates bilateral and bimanual tasks to determine dexterity skills (Alotaibi et al., 2009). Patient-reported outcome measures assessing functional skills have become more routinely used, with the Michigan Hand
Outcome Questionnaire (MHQ) becoming more popular with the inclusion of individual and bimanual activity sections for functional task levels (Kotsis et al., 2007).

According to surveyed therapists, increasing ROM while decreasing pain and edema was the primary focus of occupational and physical therapy treatment for patients with DRF (Ikpeze et al., 2016; Michlovitz et al., 2001). However, evidence supporting a standardized established treatment protocol with specific interventions for the management of a DRF is either limited and unclear or does not incorporate bimanual activities (Bobos et al., 2018a; Handoll & Elliott, 2015; Hardin, 2002; Kimmerle et al., 2003; Michlovitz et al., 2001; Quadlbauer et al., 2020; Valdes et al., 2014). The lack of standardized OT treatment for DRF with the inclusion of bimanual activity could diminish the potential for successful outcomes, limiting improvements in functional tasks and delaying the return to daily routine or work activities (Bobos et al., 2018a; Dekkers & Nielsen, 2011; Dekkers & Soballe, 2004; Kimmerle et al., 2003; Krehbiel et al., 2017).

The purpose of this study was to determine if adding bimanual activity to a standard OT treatment protocol and HEP increased the speed of bimanual activity and functional skills for patients with DRF after surgery for ORIF. The following research question was explored: For individuals with DRF requiring ORIF, does participation in a four-week standard OT treatment protocol for DRF, with the addition of a bimanual activity routine, significantly improve bimanual hand function as measured with the PPT and self-rated MHQ?

**Literature Review**

**Bimanual Hand Function**

The principal function of both UEs is to hold and manipulate objects during one’s daily routine using bimanual interaction of the hands to complete the tasks (Bailey et al., 2016;
Kilbreath & Heard, 2005; Kimmerle et al., 2003). Bimanual hand function is defined as the use of both hands in a coordinated series of motions that requires the use of visual feedback, proprioception, and equalization of force and pressure to control the action (Bobos et al., 2018a; Coats & Wann, 2012; Jaric et al., 2005; McPhee, 1987). A bimanual activity requires coordination to ensure an accurate and efficient action, with each extremity contributing a skillful motion while interacting with the other extremity using a fine spatial and temporal manner (Franz, 2003; Kantak et al., 2017). Kilbreath and Heard (2005) noted in an observational study with healthy individuals that of those activities performed, 54% were bimanual hand function, and 29.4% were unilateral hand function. Bailey et al. (2016) demonstrated that 67% of healthy UE motion was bimanual interaction.

Numerous neurological theories are used to describe the bimanual activities of the hands, including the muscle synergy theory, the dynamic pattern theory, and the internal model theory (Kantak et al., 2017). In the muscle synergy theory, it is believed that a few set motion patterns combine to create multiple coordinated movement patterns for hand interaction to perform activities (d'Avella & Lacquaniti, 2013; Kantak et al., 2017). In the dynamic pattern theory, a synergistic pattern organization or motor pattern exists for specific extremity or hand movements, in which components of the motor pattern interact or cooperate to create complex behavioral patterns of motion for the extremity (Scholz, 1990). Scholz (1990) noted that coordinated hand function during an activity created transitions between observed spontaneous motion patterns due to a variable change in the speed or resistance in the interaction between the extremities. The performance of more complex patterns or learning new patterns required modifying the system's intrinsic synergistic patterns (Scholz, 1990). Kantak et al. (2017), Kelso (1983), and Scholz (1990) believed that changes in rhythmic movement from a stable to an
unstable pattern created stability or balance between spontaneous or changed movement patterns during the coordination of the hand activity. Lastly, the internal model proposes that modifying motor, cognitive, and perceptual constraints in the central cortical representation of bimanual activity helps determine the coordination between the extremities due to the task requirements and environment (Kantak et al., 2017; Yokoi et al., 2011). Sleimen-Malkoun et al. (2011) noted that the UEs develop bimanual synergy patterns that allow the limbs to act together for task-specific processes to act as a single unit. These motor patterns were either produced spontaneously or learned when the neuro-musculoskeletal system was intact (Sleimen-Malkoun et al., 2011). All theorists agreed that coordination between the UEs depended on the task performed and the use of the UE in either symmetrical or asymmetrical motions to coordinate the bimanual activities for UE function (Howard et al., 2009; Kantak et al., 2017; Sleimen-Malkoun et al., 2011).

Symmetrical bimanual actions involve simultaneous motion using homologous muscles to coordinate UE activity (Kantak et al., 2017; Sleimen-Malkoun et al., 2011). The symmetrical motions are faster than asymmetrical motions, using movements that are simpler and more stable (Howard et al., 2009; Kantak et al., 2017). Asymmetrical bimanual actions use non-homologous muscles in movement patterns (Kantak et al., 2017). Each extremity simultaneously moves the muscles in opposition, such as flexors versus extensors, to complete tasks such as screwing a nut on a bolt or applying different sequential patterns, such as tying a shoelace (Kantak et al., 2017). Asymmetrical bimanual movements are more complicated movement patterns and require more time to complete with extended preparation responses and active executions (Blinch et al., 2015; Kantak et al., 2017). The coordination between the UEs makes the motion functional and skillful, as each UE independently contributes to the action with spatial and speed adjustments through
sensorimotor integration to create a coordinated result (Bank et al., 2015; Franz, 2003; Kantak et al., 2017).

A DRF has the potential to create sensory and cortical changes along with producing pain, weakness, and fear in the use of the hand. The sensorimotor integration for movement of the UE could be affected by the change in the perception of sensory information for speed and placement (Franz, 2003; Karagiannopoulos et al., 2013). The immobilization of an extremity after a DRF could change proprioception and tactile acuity creating the potential for reducing fine motor coordination, dexterity, and bimanual activity (Dilek et al., 2018; Karagiannopoulos et al., 2013; Wollstein et al., 2019). Likewise, pain, fear of reinjury, or reduced sensation can affect the function and interaction between the hands, creating the potential to avoid the injured extremity and decreasing the bimanual interaction between the UEs (Lövgren & Hellström, 2012).

**Distal Radius Fractures**

**Description**

Distal radius fractures have been considered the second most common orthopedic injury and the most common UE orthopedic injury (Cooper, 2014; Corsino & Sieg, 2019; Driessens et al., 2013; Gogna et al., 2013; Karagiannopoulos et al., 2013; Meena et al., 2014; Smith et al., 2004; Valdes, 2009; Valdes et al., 2014) with the highest incidence presenting in children younger than 18 years and women 60 years and older (Gutierrez-Espinoza et al., 2017; Nielsen & Dekkers, 2013). DRFs represent 18% of fractures in individuals older than 65 years (Ikpeze et al., 2016), with most occurrences associated with a fall on an outstretched hand (Corsino & Sieg, 2019; Dewan et al., 2018; Ikpeze et al., 2016; Karagiannopoulos et al., 2013; Meena et al., 2014). Immobilization is often used during recovery, affecting long-term hand function.
Medical intervention

Medical interventions for DRF, including various types of immobilizations, continue to be controversial regarding the best approaches. The medical intervention for non-displaced or minimally displaced reducible fractures often includes closed reduction with the external support of either a cast or orthotic immobilization (Driessens et al., 2013; Ikpeze et al., 2016; Karagiannopoulos et al., 2013; Meena et al., 2014). However, difficulty maintaining the reduction in the cast complicates healing, resulting in re-displacement and malunions (Gutierrez-Espinoza et al., 2017; Karagiannopoulos et al., 2013; Meena et al., 2014; Sirniö et al., 2019). More severely displaced, intra-articular, or comminuted fractures often require surgical intervention with ORIF utilizing either dorsal or volar plating with or without percutaneous pinning and supportive orthosis (Driessens et al., 2013; Gogna et al., 2013; Meena et al., 2014; Smith et al., 2004; Valdes, 2009). Kirschner wire fixation and ORIF with volar plating are the two most often performed surgical approaches to restoring the anatomical position of the wrist and hand (Karagiannopoulos et al., 2013; Meena et al., 2014; Sirniö et al., 2019; Smith et al., 2004). The surgical procedure using a volar plate placement has been determined to reduce tendon irritation or rupture as the pronator quadratus is available to protect the flexor tendons (Sirniö et al., 2019; Smith et al., 2004).

Sirniö et al. (2019) compared two groups of patients who sustained a DRF. One group received closed reduction followed by cast immobilization, and the second group underwent ORIF with volar plating. Researchers assessed wrist function at the third, sixth, 12th, and 24th months using the DASH Questionnaire and a subjective assessment of wrist function, along with ROM, grip strength, radiology results, and any complications. Results showed that radiographic parameters were better in those who received early surgery, but ROM and grip strength had only
minor differences between the groups after six months (Sirniö et al., 2019). Results at 24 months showed that DASH scores had statistically significant differences for those greater than 65 years of age, who had surgery, and those placed in cast immobilization (Sirniö et al., 2019). Sirniö et al. (2019) noted deficits were still present in performing functional tasks for those with a cast immobilization or ORIF.

Martinez-Mendez et al. (2018) compared adults with intra-articular DRF treated with closed reduction and casting to participants with volar plating ORIF. Researchers assessed participants after two years using the Patient Rated Wrist Evaluation (PRWE), DASH, pain rating, wrist ROM, grip strength, and radiological parameters (Martinez-Mendez et al., 2018). Active range of motion (AROM) for the wrist was equal in both groups, but forearm pronation and supination ROM was greater for the surgical group (Martinez-Mendez et al., 2018). Functional outcomes measured by the PRWE and DASH showed better skills with the surgical group, even though functional difficulties and pain continued after two years (Martinez-Mendez et al., 2018). Heidgerd et al. (2019) similarly performed a one-year follow-up study comparing radiographic healing rates, pain, and ROM. They determined that patients who underwent surgery with ORIF with a volar plate had a higher percentage of healing or healed fractures than those who did not receive surgery (Heidgerd et al., 2019). The surgical patients also showed statistically significant ($p = .051$) improvements in wrist ROM (Heidgerd et al., 2019).

Mellstrand-Navarro et al. (2019) performed a systematic review regarding the treatment of DRF from 2005 to 2013. Researchers identified 19 articles that met the study criteria and performed a meta-analysis of clinical and health-economic studies on the effectiveness of DRF treatment (Mellstrand-Navarro et al., 2019). Treatment outcomes in older adults showed no differences between surgical and non-surgical approaches or the different surgical procedures
with percutaneous pinning or plating (Mellstrand-Navarro et al., 2019). Diaz-Garcia et al. (2011) and Martinez-Mendez et al. (2018) noted that the judgment for conservative or surgical intervention must be determined individually, balancing the risks and benefits and comparing the quality of life and the individuals’ activities, lifestyles, and preferences.

The debate regarding what type of medical intervention, when to begin mobilization, and what percentage of functional disability is acceptable long-term are still questions of concern (Koval et al., 2014). Dekkers and Nielsen (2011) found that one-year post-injury results from the DASH and Canadian Occupational Performance Measure (COPM) showed impairment in bimanual activities and tasks requiring a strong grip. Researchers need to continue to assess long-term functional outcomes for those with a DRF to determine appropriate OT intervention.

**Impact on Occupational Performance**

Changes in dexterity, sensation, and strength can affect the functional return of the injured hand. Dekkers and Nielsen (2011) performed an observational study using the COPM, DASH, and quality of life questionnaires to determine functional performance, pain, and quality of life of older women after sustaining an UE fracture. The participants reported impaired performance in self-care, productivity, and leisure activities due to diminished grip strength and coordination, which affected their ability to complete functional bilateral tasks such as opening containers, performing household activities, or gardening (Dekkers & Nielsen, 2011). The participants also had difficulty with tasks requiring two hands, such as lifting and carrying heavy items noting they replaced bimanual activities with one-handed techniques, resulting in diminished bimanual skills (Dekkers & Nielsen, 2011).

In a follow-up study, Nielsen and Dekkers (2013) compared outcome measures for 37 women with a DRF receiving internal fixation with casting or casting alone. They compared
DASH and COPM scores at cast removal to scores at three months, six months, and 12 months - post-injury (Nielsen & Dekkers, 2013). At 12 months, 78% of the participants noted performance problems with hygiene, dressing, and shopping (Nielsen & Dekkers, 2013). When performing productivity tasks at 12 months, 81% of the participants reported continued issues with tasks requiring greater resistance, such as household chores, gardening, and work activities (Nielsen & Dekkers, 2013). The DASH results showed that 92% of the participants had some disability 12 months after injury (Nielsen & Dekkers, 2013). Dekkers and Soballe (2004) also noted 12-month deficits in tasks requiring lifting and carrying due to pain and reduced grip strength. MacDermid et al. (2003) reported that one year after a DRF, 79% of participants had no or minimal pain or disability (n = 129). Still, 14% of the participants indicated that at one-year post-injury, mild to very severe pain and disability continued; they also reported deficits in the ability to carry weight at work and home and perform recreational activities (MacDermid et al., 2003).

Bobos et al. (2018b) conducted a study using the NK Hand Dexterity Test (NKHDT), gross grip, and AROM to determine the recovery of fine motor control and dexterity for individuals after DRF. At one-year post-injury, one-third of the participants considered pain, weak grip strength, and diminished basic self-care skills as their remaining functional problems (Bobos et al., 2018b; Bobos, Nazari, et al., 2018). Researchers also noted that dexterity improved within the first three to six months following DRF due to decreased pain and increased ROM but then declined from six months to 12 months, with the affected hand not returning to its previous level of functional dexterity after one year (Bobos et al., 2018b). After two years, dexterity skills measured with the NKHDT for single-hand performance showed an improvement with large peg items but decreased with medium and small peg items. Researchers were unsure why there was a decline but expected that a loss of learned skill with the NKHDT affected the performance rate.
with a decline in later studies (Bobos, Nazari, et al., 2018). Additionally, researchers discovered that grip strength had improved after two years with only a minimal difference between hands (Bobos, Nazari, et al., 2018).

These long-term cohort studies provide valuable information on hand function after DRF, but most used performance tests that only measured unilateral speed of motion and did not include functional skills (Bobos et al., 2018b; Schoneveld et al., 2009). They also did not include bilateral or bimanual activities (Bobos et al., 2018b; Schoneveld et al., 2009).

Immobilization often creates sensory changes, weakness, stiffness, and pain, which can contribute to the avoidance of the injured hand during functional activities with an overall decrease in function (Dekkers & Nielsen, 2011). Researchers continue to address treatment approaches, including the timing of beginning mobilization after a DRF, who should be involved, and the required treatment (Koval et al., 2014). Arora et al. (2011) acknowledged that early mobilization resulted in a faster return of function, which could be an advantage for older adults as it helped to maintain an individual's independence. Volar plate fixation allowed earlier motion starting as soon as two weeks post-injury, with participants showing a faster recovery speed and improved DASH scores (Diaz-Garcia et al., 2011; Koval et al., 2014). Researchers noted no differences in ROM, pain, PRWE, or DASH after one year (Arora et al., 2011). However, Sirniö et al. (2019) noted that early mobilization could create a risk for fracture collapse or malunions.

During the medical intervention for DRF with either ORIF or casting immobilization, some time is spent with the wrist immobilized, reducing the individual's ability to use the affected hand and increasing the potential for long-term sensory changes (Boersma et al., 2018; Hagert, 2010; Weibull et al., 2011). Additionally, immobilization of the wrist can reduce fine
motor coordination, dexterity, and bimanual interaction due to changes in proprioception and tactile acuity (Dilek et al., 2018; Karagiannopoulos et al., 2013).

**Consequences of Immobilization**

**Sensory responses.** Proprioception is a vital aspect of self-awareness and positioning of the hand and arm, allowing for the functional use of the hand and recognition of the physical body (Hagert, 2010). It uses mechanoreceptors in the ligaments that react to joint pressure, speed, and motion, along with cutaneous afferent receptors in the skin and soft tissues to facilitate sensorimotor control (Hagert, 2010; Karagiannopoulos et al., 2013). The sensory information received through the hands helps one to interpret the objects used within the environment through afferent skin receptors and proprioceptive signals (Hagert, 2010; Squeri et al., 2012). The combined information from the sensory system gives a clearer picture of the location, texture, and temperature of the objects used (Hagert, 2010).

In studies regarding immobilization, healthy volunteers showed changes in skin temperature, mechanosensitivity, and thermosensitivity after four weeks of immobilization in a cast (Boersma et al., 2018; Terkelsen et al., 2008). The subjects noted pain with movement at cast removal and increased skin folding pain that lasted up to two weeks (Terkelsen et al., 2008). The sensitivity to cold and changes in skin temperature was noted to resolve after three days of mobilization following the removal of the cast (Terkelsen et al., 2008). These changes were considered inconclusive but did demonstrate a possible response for changes in blood flow in deeper structures due to the release of substance P (Terkelsen et al., 2008). Substance P is a neuropeptide that binds to the endothelium of deep blood vessels, causing vasodilation and specific changes to peripheral nociceptors during immobilization (Terkelsen et al., 2008).
Wollstein et al. (2019) noted a significant initial sensorimotor change in patients immobilized with splints for six weeks following ORIF. Their goal was to improve proprioceptive sensation in the wrist with sensory stimulation to the affected extremity utilizing activities of daily living (ADL) and proprioception activities with and without vision (Wollstein et al., 2019). At six weeks, they reported the sensory loss persisted, and the researchers believed this was due to the continued use of an immobilizing orthosis (Wollstein et al., 2019). The researchers did note a return of sensation after three months (Wollstein et al., 2019). They also reported a significant \( p = .001 \) improvement in DASH scores at three months for those receiving proprioception exercises versus those treated in the control group (Wollstein et al., 2019).

Karagiannopoulos et al. (2013) assessed light touch sensation and proprioception by comparing three groups of individuals with DRF. Researchers compared participants’ changes in sensation, proprioception, grip strength, and self-reported function after immobilization (Karagiannopoulos et al., 2013). Results showed that those immobilized for four to six weeks, with or without surgery, due to a DRF had a significant decrease in moving light touch sensation \( p = .009 \) and proprioception of the wrist and hand \( p < .001 \) compared to the control group (Karagiannopoulos et al., 2013). The researchers also noted a significant correlation \( p = .01 \) between light touch sensation, proprioception, and PRWE scores at eight weeks (Karagiannopoulos et al., 2013). Joint proprioception and grip force were determined as clinically relevant indicators for determining functional levels (Karagiannopoulos et al., 2013). According to Squeri et al. (2012), the loss of feedback for proprioception, light touch, and force decreased the interaction between the hands with increased pain, fear of reinjury, and avoidance. The change in proprioception and tactile acuity created the potential for decreased fine motor
coordination, dexterity, and bimanual interaction after immobilization for DRF (Dilek et al., 2018, Karagiannopoulos et al., 2013).

**Changes in Cortical Responses.** There is a commonality between changes in sensory feedback and the interpretation of sensory information with changes in cortical processing when completing a functional motion (Weibull et al., 2011). Functional magnetic resonance imaging (fMRI) studies have shown that immobilization for as few as 72 hours can create cortical and clinical effects on hand function in healthy individuals (Weibull et al., 2011). Pretest-posttest fMRI comparisons during dominant hand immobilization showed a significant cortical effect ($p = .05$) with a change in the interpretation of sensory information (Weibull et al., 2011). The fMRI showed increased activity in the ipsilateral somatosensory cortex area during movement with the non-dominant hand (Weibull et al., 2011). Researchers found an increase in the hemispheric cortical activity for the non-immobilized hand, noting a dominance change, as the individual used the non-dominant hand to perform all daily tasks due to the immobilization of the dominant hand (Weibull et al., 2011). Weibull et al. (2011) also found that fMRI results showed that the immobilized hand had decreased cortical motor and sensory activity compared with a pretest to posttest data. Active motion using finger tapping and the application of tactile stimulation using a pneumatically driven and electronically controlled system during fMRI provided the cortical stimulation (Weibull et al., 2011). Researchers noted an association between changes in cortical activity for motor and sensory processing with reduced grip strength, dexterity, and tactile discrimination in the immobilized hand (Weibull et al., 2011).

Lissek et al. (2009) also noted that fMRI data showed hand immobilization created perceptual and cortical changes with reduced tactile acuity, but this returned to normal two to three weeks after cast removal and with the return of the immobilized hand’s activity. Even so,
the tactile improvement on the healthy non-immobilized side remained superior to the formerly injured, immobilized side (Lissek et al., 2009). The fMRI studies also showed that immobilization of a hand might result in impaired tactile acuity and reduced activation of the corresponding finger representation in the sensory area of the cortex (Lissek et al., 2009).

Changes in sensory information, cortical representation, and hand dominance could affect the recovery of bimanual skills, as diminished grip strength and lack of hand awareness may reduce the use of the hand in functional tasks. Therefore, it stands to reason that including targeted bimanual activities in rehabilitation after a DRF can improve sensory processing, reduce pain, and decrease hand avoidance.

**Occupational Therapy Assessment for DRF**

To promote the return of functional skills with an increase in the use of the injured hand, OT practitioners need to have a clear understanding of the injury and limitations of the client. Establishing a complete understanding of the deficits requires including measurements for pain, bimanual skills, and functional limitations. This inclusion would clarify avoidance behaviors that limit the incorporation of motion for bimanual activities and dexterity skills.

Ziebart et al. (2021) identified the core measurements following a DRF as grip strength, pinch strength, and wrist ROM for the physical impairments; and functional levels with the Patient Rated Wrist and Hand Evaluation and MHQ for activity limitations. Following a systematic review, they noted that ROM for forearm supination and pronation, along with grip strength, had good reliability, validity, and responsiveness (Ziebart et al., 2021). Wrist ROM measurements showed acceptable patient responsiveness but poor reliability (Ziebart et al., 2021). The Jebsen-Taylor Hand Function Test had good responsiveness if performed in the first three months but decreased after three months (Ziebart et al., 2021). Correlations were
significant ($p < .01$) for grip strength, ROM, dexterity, client pain levels, and disability ratings but showed poor responsiveness if the reassessment interval was less than three months (Ziebart et al., 2021).

Grice (2015) surveyed 594 occupational and physical therapists specializing in hand therapy regarding the use of occupation-based and impairment-based assessments following injuries to the hand and arm. They determined which assessments were most frequently used in their evaluations (Grice, 2015). Grice (2015) found the most commonly used occupation-based assessments included informal ADL interviews (52% with all patients), the Quick DASH (27% with all patients), and the DASH (18% with all patients). The impairment-based assessments, ranked in order of their frequency of use, were goniometry, pain, grip strength, pinch strength, edema (using circumferential measures), manual muscle testing, sensation, edema (using volumetric principles), and fine motor skills by using the PPT and Nine-Hole Peg Test (Grice, 2015).

Alotaibi et al. (2009) surveyed OTs, noting that the most frequently used performance assessments in hand therapy rehabilitation were dynamometer, goniometry, pinch strength, Nine-Hole Peg Test, Semmes-Weinstein Monofilaments, and the PPT (with 32% of patients). Dexterity assessments ranked in order of frequency of use were: PPT, Nine-Hole Peg Test, Moberg Pick-up Test, Minnesota Rate of Manipulation Test (MRM), Crawford Small Parts Dexterity Test, Bennett Hand Tool Test, and the Box and Block Test (Alotaibi et al., 2009). Of those dexterity tools used, only three contained a bimanual activity component: the PPT (Lindstrom-Hazel & Veenstra, 2015), the Crawford Small Parts Dexterity Test (Osborne & Sanders, 1956), and the Bennett Hand Tool Test (Lafayette Instrument, 2011). A dexterity test was infrequent and routinely only used in a unilateral approach measuring the speed to complete
the task, removing the bimanual component with no interplay between the hands (Alotaibi et al., 2009; Bobos et al., 2018b; Schoneveld et al., 2009).

Bobos et al. (2018a) reported that "most of the literature has focused on physical impairments in hand ROM or hand grip strength as functional outcome measures after a DRF" (p. 441). Researchers found that therapists refrained from using occupation or impairment-based assessments due to time constraints, unfamiliarity with these evaluations, the evaluation's lack of availability within the clinic, and lack of reimbursement (Alotaibi et al., 2009; Grice, 2015). The therapists' refrainment included the limited use of dexterity assessments and even fewer bimanual activity assessments (Alotaibi et al., 2009; Bobos et al., 2018b; Schoneveld et al., 2009). Despite the relevance to function, it was rare to quantify bimanual activity deficits during standardized clinical assessments (Slutsky & Herman, 2005; Valdes et al., 2014).

**Occupational Therapy Interventions for DRF**

Researchers of previous studies regarding the treatment of DRF did not establish a standard OT treatment protocol for intervention, often explaining that their selection of treatment activities was determined by the patient's unique needs or the facility's standard treatment processes. Several research studies concerning available treatments after DRF showed commonalities to include pain management with modalities, manual therapy, passive range of motion (PROM), AROM/exercise, edema control, wound/scar management, joint mobilization, a home exercise program (HEP) and eventually strengthening (Brodeur-Lyons & Oakes, 2009; Bruder et al., 2012; Cooper, 2014; Handoll & Elliott, 2015; Michlovitz et al., 2001; Saunders et al., 2016; Valdes et al., 2014). Initial treatment routinely focused on edema control, protective splinting, scar management, and AROM of the digits and adjacent structures (Brodeur-Lyons & Oakes, 2009; Dilek et al., 2018; Saunders et al., 2016; Waterbury et al., 2016). As fractures
healed, therapy progressed to PROM of the wrist and fingers, strengthening, unilateral dexterity exercises, tendon gliding, and soft tissue mobilization (Brodeur-Lyons & Oakes, 2009; Dilek et al., 2018; Michlovitz et al., 2001; Saunders et al., 2016; Slutsky & Herman, 2005; Waterbury et al., 2016). The American Academy of Orthopaedic Surgeons (AAOS) (2019) recommended the early establishment of finger mobility using dexterity activities. Still, hand therapists did not routinely include these activities in the initial treatment protocols (AAOS, 2019). The mention of hand dexterity exercises for unilateral action in intervention research studies is present, but the identification of specific activities for bimanual treatment was not determined (AAOS, 2019; Bobos et al., 2018a, 2018b; Bruder et al., 2012; Handoll & Elliott, 2015).

Avoidance in the use of the affected hand in functional activities and exercises that require bimanual interaction has the potential to cause a decline in functional activities for self-care, productivity, and leisure tasks (Bobos et al., 2018b; Lövgren & Hellström, 2012). Unclear guidelines for assessing and managing hand dexterity with a lack of inclusion of bimanual activity after a DRF could contribute to the lack of recovery of two-handed skills (Bobos, Nazari, et al., 2018; Kimmerle et al., 2003).

**Purpose of the Study**

The slow return of bimanual hand function after a DRF due to pain, stiffness, and diminished sensation delays the return of functional activities and patient independence. The current research does not present the use of two-handed activities in the standard OT treatment protocol for individuals with DRF. By adding bimanual activity, the participant would increase their functional outcomes or improve the inclusion of the affected hand. Therefore, the purpose of this study was to determine if the addition of bimanual activity to a standard OT treatment protocol and HEP increased the speed of bimanual action and functional skills for patients with
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DRF after surgery for ORIF. The research question addressed was: For individuals with DRF requiring ORIF, does participation in a 4-week standard OT treatment protocol for DRF, with the addition of a bimanual activity routine, significantly improve bimanual hand function as measured with the self-rated MHQ and the PPT?

Method

Study Design

The focus of this study was on the addition of bimanual activity to a standard OT treatment protocol and HEP to increase the speed of bimanual activity and functional skills for patients with DRF after surgery for ORIF. A quasi-experimental study approach with a single-group pretest-posttest design was used. Participants were individuals who sustained a DRF requiring ORIF and were referred to outpatient therapy for OT rehabilitation. During the treatment sessions, pretest/posttest measurement data for functional and skilled tasks allowed for a more objective improvement analysis.

Participants

After a referral for OT, convenience sampling was used to recruit participants from one of three free-standing outpatient clinics in The Woodlands, Willis, and Conroe, Texas. Participants met the following inclusion criteria:

1. Sustained a DRF requiring surgery for ORIF.
2. 18 to 85 years of age.
3. DRF with or without accompanying hand or wrist ligament tear, metacarpal fracture, or ulna styloid fracture.
4. Ability to speak and understand English unless an interpreter who speaks and reads English is present.
Exclusion criteria applied included:

1. Injury or surgical complications with peripheral nerve injury due to laceration or compression.
2. A concomitant elbow fracture or rotator cuff injury.
3. Central nervous system disorder that included residual impairments to the fracture side.
4. Cognitive disorders that affected the individual’s ability to understand HEP or instructions per initial medical history screen or caregiver report.

**Sample Size**

An a priori sample size estimation was conducted using the G*Power 3.1 (Faul et al., 2007). The calculation was based on measuring a change in MHQ scores using a two-tailed paired $t$-test at an alpha of .05, a power of .80, and an effect size (ES) of 0.50. Based on the calculation, a minimum sample size of 34 participants was required. The sample size was increased by 20% for a final minimum sample size of 40 participants to account for possible attrition.

**Instruments**

**Michigan Hand Outcomes Questionnaire**

The MHQ is a hand-specific outcome instrument in which individuals self-report their hand function following hand trauma, DRF, burns, hand disease, systemic illness, nerve compression, arthritis, and inflammatory conditions (Nolte et al., 2017; Shauver & Chung, 2013). The MHQ comprises six domains: overall hand function, ADL, pain, work performance, aesthetics, and patient satisfaction, with two combined calculations for overall MHQ ADL and total MHQ scores (Nolte et al., 2017; Shauver & Chung, 2013). Each domain has calculations for
functional levels with statistically significant correlations, ranging from 0.25 to 0.43, between self-assessment and score changes for all domains (Chung et al., 1999). The MHQ has normative values for healthy individuals for age and gender-adjusted populations, with scores determined for each domain, overall MHQ ADL scores, and total MHQ scores for the right upper extremity (RUE), left upper extremity (LUE) and bimanual upper extremities (BUE) (Chung et al., 1999, Nolte et al., 2017). Researchers found no differences in normative values based on age, gender, and race (Nolte et al., 2017). Nolte et al. (2017) noted that education levels for individuals who completed a college degree correlated with higher scores than those without a college degree for the total MHQ score, overall hand function, ADL, satisfaction, and work performance domains, respectively, along with a decrease in the pain domain.

Functional scores for the MHQ are calculated for unilateral and bilateral activities (Shauver & Chung, 2013), with the bimanual interaction of the hands incorporated into the ADL domain. Established mathematical calculations produce scores for each domain, and combined overall MHQ ADL, and total MHQ scores for the BUE, RUE, and LUE, ranging from 0 to 100, with 100 corresponding to greater function (McMillan & Binhammer, 2009; Nolte et al., 2017).

London et al. (2014) used three analysis methods to establish a minimally clinically important difference (MCID) of 13 for the total MHQ score in a study of participants with atraumatic hand conditions. The researchers noted that with hand/forearm conditions, the MCID ranged from eight to 13 for the total MHQ score (London et al., 2014). The MCID for the MHQ subscales put the range at 10.9 - 14.4 for all domains, using triangulation of three analysis methods (London et al., 2014). In more recent research, Koopman et al. (2021) determined a minimally important change (MIC) for the total MHQ score of 9.3 in patients following trigger finger release. The MIC for the MHQ domains ranged from 7.7 to 20.0, except for the aesthetics
domain (Koopman et al., 2021). Koopman et al. (2021) noted they could not determine a MIC range for aesthetics due to a low correlation with the anchor question. Due to a high ceiling effect, no discriminative ability was present for any domains on the MHQ in individuals with a DRF (Shauver & Chung, 2013).

The MHQ form is available in electronic and paper formats (Nolte et al., 2017; Shauver & Chung, 2013). Each participant in this study used the paper format. License approval to use the MHQ was attained before initiating the current research. During the study, the questionnaire required approximately 15 minutes to complete.

**Reliability and Validity.** The MHQ has good content validity and internal consistency (Schoneveld et al., 2009). Chung et al. (1998) noted the MHQ intra-class correlation coefficient (ICC) for individual domains for test-retest ranged from .81 to .97 in individuals with hand injuries or disease. Shauver and Chung (2013) noted an ICC range of .85 to .96. A calculation for internal consistency of each of the six individual domains for the bilateral and unilateral function was determined using a Cronbach’s alpha, resulting in a range of .86 for the pain domain to a .97 with the ADL domain (Chung et al., 1998; Shauver & Chung, 2013).

**Purdue Pegboard Test**

The PPT (Appendix A) has four subtests and assesses unilateral, bilateral, and bimanual hand use and dexterity. Unilateral hand use is based on single-hand performance, with the client placing one peg into a column of holes at a time. The bilateral hand performance requires the patient to use both hands simultaneously to place pegs in a column without interaction between the two hands. The bimanual activity requires the interaction of both hands to perform an assembly task requiring the manipulation of four objects. To complete the unilateral and bilateral subtests, the client must place as many pegs as possible in 30 seconds for each subtest. To
complete the bimanual assembly subtest, the client must complete as many assemblies as possible in 60 seconds. Normative values for each subtest (Appendix B) have been established for individuals aged five to 89 years, stratified by age and gender (Agnew et al., 1988; Desrosiers et al., 1995; Lafayette Instrument, 2015; Lindstrom-Hazel & Veenstra, 2015).

In this study, researchers used the PPT to complete one trial of each subtest, following the standardized instruction for procedures (Buddenberg & Davis, 2000; Gallus & Mathiowetz, 2003; Lafayette Instrument, 2015). The PPT subtest required an average of five to ten minutes to complete. Prior to the initiation of our study, the primary researcher and second certified hand therapist (CHT) determined that if the participants could not complete the unilateral subtest with the affected hand, the bilateral and bimanual assembly subtests would not be performed. Due to time constraints at the initial visit, the primary researcher and second CHT completed each PPT subtest only once, pretest and posttest.

**Reliability and Validity.** The PPT is a well-known hand dexterity assessment used by health professionals with a high validity and reliability rating compared to other dexterity assessments (Causby et al., 2014; Lafayette Instrument, 2015; Lindstrom-Hazel & Veenstra, 2015). Lindstrom-Hazel & Veenstra (2015) noted the assembly subtest of the PPT had the potential to be a brief clinical assessment for BUE dexterity showing good reliability and a good correlation to daily living, vocational, and avocational tasks. The PPT showed good validity and reliability results for healthy individuals of varying ages and sex assigned at birth (Causby et al., 2014; Lindstrom-Hazel & Veenstra, 2015). The PPT test-retest reliability scores demonstrated differences between a single-trial assessment with an ICC range of .37 - .71 (Buddenberg & Davis, 2000; Lindstrom-Hazel & Veenstra, 2015) and a three-trial test with a test-retest reliability ICC of .81 - .97 (Buddenberg & Davis, 2000; Gallus & Mathiowetz, 2003; Lindstrom-
Hazel & Veenstra, 2015). Subtests of the PPT showed no consistent practice effect (Gallus & Mathiowetz, 2003). The PPT is a publicly available assessment with no license requirements for use in research.

**Procedure**

**Institutional Review Board**

Approval was obtained from the University of Indianapolis Human Research Protections Program before participant recruitment began. A reliance agreement was established with the primary researcher’s work clinics on June 29, 2021, with an Institutional Review Board (IRB) identification number 01276. Approval was also obtained for managing Coronavirus Disease 2019 (COVID-19) procedures during the study through the University of Indianapolis committee in June 2021. The study was initiated in October 2021 and continued through October 2022.

Adding a third clinic became necessary as the second CHT changed her schedule, which required her to split her time between the two clinics in her area. Additionally, after the volunteer session to establish interrater reliability, we believed the initial OT session would take too much time using three PPT trials. Reducing the PPT to one trial would reduce the clinic administration time and still follow the standard protocols for the assessment. On October 25, 2021, a request for modifications was submitted and approved by the University of Indianapolis IRB to include a third clinic with a change in the flier and a reduction of the PPT from three trials to one trial.

**Researcher Training**

The primary researcher and the second CHT assisting with data collection reviewed the assessment administration and scoring procedures for the MHQ and PPT. To ensure consistency, the researchers reviewed the standardized protocol for completing initial assessments, the standard OT treatment protocol, and bimanual activities for DRF.
Establishing Interrater Reliability. Two volunteer training sessions were conducted to establish the ICC for reliability between the primary researcher and the second CHT for administering the MHQ and PPT. Healthy volunteers were recruited using convenience sampling through direct contact with individuals known by the primary researcher to practice the procedures used with the study participants. The study procedures and written consent forms were reviewed with each volunteer, each volunteer signed a consent form, and the witness signed the document before initiating training activities. The researchers issued an identification number to each volunteer to protect participant identification for documenting testing scores. Practice testing was performed in the gym area of the work clinic using the clinic's standard COVID-19 precautions. Each participant answered required questions regarding potential COVID-19 exposure, which was recorded upon entering the building. All participants were required to wear a mask throughout the procedure and wash their hands before performing any tasks. The primary researcher and second CHT disinfected all equipment following each use.

In the first session, both researchers administered the MHQ and three trials of all four subtests of the PPT to the same individuals at separate times. It was determined for this study that an ICC ≥ .75 would be considered an acceptable level of interrater reliability. In the initial group, the MHQ met the ICC criteria for the ADL RUE and the total MHQ score for the RUE but not for the ADL LUE or the total MHQ score of the LUE. More details provided on Table 1. ICC scores on the PPT did not meet the criteria for the RUE but did for all other subtests. More details provided on Table 2 for ICC scores.

As the ICC criteria were not fully met, the primary researcher and second CHT met for a second time to review measurement procedures and administration of the tests. The primary researcher and second CHT discussed possible changes with the committee. They determined
that changes in the initial placement of the volunteer subject’s hands, the start of the timers, and the need for new timers would improve consistency between the researchers. Also, there was a need to reduce interaction among the volunteers, as talking during the tests could have affected score outcomes. Due to time restraints, the PPT administration was reduced from three trials to one. The IRB approved all modifications before the initiation of the study with participants.

A second practice session to establish inter-rater reliability was completed using four volunteers. Each volunteer completed one trial of each subtest on the PPT and the MHQ questionnaire with the primary researcher and second CHT. Bimanual activities and HEP log sheets were reviewed for scoring to ensure consistency in instruction for bimanual HEP activities and documentation. The ICC for the PPT test was > .75 for all subtests except for the unilateral RUE. See Table 2. The data analysis determined that an ICC > .75 was attained at both trials for the bimanual subtest. As the bimanual hand function was the priority focus, the committee approved the initiation of recruitment of participants for the primary researcher and the second CHT.

**Intervention**

**Standard of Care.** Researchers have not established a single standardized OT treatment protocol regarding the general treatment after a DRF, however, authors have described common elements in their interventions for this population (Brodeur-Lyons & Oakes, 2009; Bruder et al., 2012; Cooper, 2014; Handoll & Elliott, 2015; Michlovitz et al., 2001; Saunders et al., 2016; Valdes et al., 2014). Due to the lack of a standardized treatment protocol for DRF, the primary researcher consolidated three descriptions of interventions (Brodeur-Lyons & Oakes, 2009; Cooper, 2014; Saunders et al., 2016) into a standard OT treatment protocol for the study. The protocol was then reviewed and approved by four CHTs for use in the study (Appendix C).
During the study, the approved standard OT treatment protocol was performed within the OT sessions one to three times per week, depending on the participant's referral. The primary researcher and the second CHT determined the initial treatment level during the OT sessions according to the participant’s level of edema, AROM measurements, and post-operative time frames using industry standards with the application of the therapeutic activities. A HEP for edema control with elevation and AROM for the fingers, wrist, and elbow was started on the first day of OT treatment (Appendix D). At six weeks post-operative, strengthening activities began with the referring provider’s consent.

**Bimanual Activity.** This study added 10 minutes of unbilled bimanual activities from a predetermined activity list to the participant’s OT intervention (Appendix E & Appendix F). The primary researcher developed the bimanual activity list using OT practitioner experience and consolidated standard treatment protocols. It was then reviewed and revised by the second CHT. The primary researcher or second CHT assigned the bimanual tasks. The 10 minutes of bimanual activities were initiated following the initial assessment, including the MHQ and PPT assessments, and performed after completing the standard OT treatment protocol at each OT session. This was to encourage performance accuracy, the progression of skill level, and understanding of the activities for the interaction between the two hands. The primary researcher and second CHT varied the bimanual activity between sessions to avoid a learned effect and encourage bimanual interaction of the hands. The primary researcher and second CHT used a predetermined level of progression to grade the bimanual activity as participants improved to facilitate the participant skill with bimanual activities. A HEP for bimanual activity was issued, at the initial visit, to the participant with instructions for assigned activity levels for completing bimanual activities twice daily. Participants completed a daily log of HEP performed, with the
logs reviewed and updated at weeks two and four. At the end of the four weeks, patients were requested to return the HEP log. Tracking participant attendance of scheduled appointments and completion of HEP sessions determined individual compliance within the program.

**Recruitment.** Individuals with a diagnosis of DRF were identified through referrals sent by providers to three outpatient clinics. Once the patient’s initial assessment scheduling was completed, the front office staff emailed pre-registration forms for medical history and DASH outcome measures as a standard clinic procedure. At the individual’s initial visit, the primary researcher or second CHT at the clinic reviewed the referral and medical history form to determine if the patient met the study inclusion criteria. A more in-depth explanation of the study and a study flier (Appendix G) were given to the patient with a verbal request to participate in the study by the assessing therapist.

**Informed Consent**

Participants who agreed to be involved in the study were given more specific explanations of its benefits and purpose at the initial session with instructions that a bimanual activity program would be added to their standard OT treatment protocol and HEP without cost. Within their assigned clinics, the primary researcher and the second CHT reviewed the informed consent document before initiating the assessment, including the study's purpose, potential risks, potential benefits, study procedures, and bimanual activity. The primary researcher and second CHT then obtained written consent from the participants with a witness signature.

**Data Collection**

The primary researcher and second CHT collected data and provided OT services for enrolled participants. Demographic information and individual characteristic data were collected during the pre-intervention to determine participant eligibility based on inclusion and exclusion
criteria. The standard initial assessment was completed on the first visit for those who were eligible and consented to be in the study. The participants also completed the MHQ and PPT assessments. Data collection for the MHQ and PPT was performed at the initial assessment and then at a session four-to-five weeks post-treatment. Participants were instructed in the bimanual activities they were to perform with their HEP after completion of the initial assessment and the MHQ and PPT. They were issued an exercise tool box with objects needed for the bimanual activities and exercises. Participants received written and pictorial instructions for the bimanual exercises and HEP log sheet (Appendix E & Appendix F). The return of the HEP log was requested for collection at weeks four to five to determine the completion of daily exercises.

**Data Management**

Each participant was assigned a unique study identification number before data collection that included “C,” “Ws,” or “Wd” to denote the clinic site. The study identification number was used in all electronic data files to avoid the use of identifiable data. The MHQ and PPT results, the prescription, the medical history document, and the consent forms were scanned and saved in the EMR attachment file in each patient’s account. We stored the hard copy of consent forms, PPT scores (Appendix B), and MHQ scores in a locked file cabinet and later shredded following data analysis. The scores on the PPT score sheet and MHQ were calculated on separate Excel scoring spreadsheets, and then the scores were documented in the EMR. The HEP log sheets (Appendix H) were requested and reviewed after four weeks, with the percentage of completed sessions determined by the number of sessions performed divided by the number of sessions requested. The rate of completed HEP sessions was documented in the final Excel spreadsheet.

The primary researcher extracted MHQ and PPT results from the EMR and entered the results into three Excel spreadsheets. The first Excel spreadsheet was a scoring program that
automatically calculated the MHQ score issued to the primary researcher by the University of Michigan. The second Excel spreadsheet was a data scoring program developed for this study using the PPT score sheet by the primary researcher. The third Excel spreadsheet was a consolidation sheet for all final data. At the end of four weeks, all data were transferred to the final Excel spreadsheet. Data included MHQ and PPT scores; demographic information; days post-operative treatment initiated; days post-operative AROM and PROM started; the self-reported number of HEP sessions completed; and the number of sessions scheduled and attended.

**Data Analysis**

The IBM SPSS Statistics for Windows Version 26.0 (IBM Corp., Armonk, NY) was used for all analysis. All tests were two-tailed, and a significance level of less than .05 was considered statistically significant. The normality of data was determined using the Shapiro-Wilk test and visual inspection of histograms, box plots, and Q-Q plots. Nominal data are presented as frequencies and percentages, with normally distributed interval and ratio data reported as means and standard deviations. Results that were normally distributed were compared using a paired- \( t \) test to determine if they were statistically significant for the MHQ and PPT data. The results that had non-normally distributed interval and ratio data are reported as medians and interquartile ranges and analyzed using the nonparametric Wilcoxon signed-ranks test.

ICCs were conducted to determine the interrater reliability between the primary researcher and second CHT for assessments using the MHQ and PPT. Two training sessions were performed with data from six volunteers in the first session and four volunteers in the second. An ICC ≥ .75 was considered an acceptable level of interrater reliability.

The MHQ scores for the combined overall MHQ ADL and total MHQ scores were analyzed for each participant with the change in pretest-posttest scores (posttest scores minus
pretest scores) calculated and compared to London et al. (2014) 13-point established MCID. The percentage of participants who met the 13-point MCID for combined scores was determined. The six domains of the MHQ were analyzed for each participant, with the change in pretest/posttest scores calculated and compared to the London et al. (2014) established range (10.9 to 14.4). The percentage of those who met the range for each domain was also determined.

Effect sizes were calculated from the PPT scores for each subtest. The calculations were conducted based on the recommendations of Cohen (1992). Effect sizes were interpreted as follows: 0.20 = small effect, 0.50 = medium effect, and 0.80 = large effect (Cohen, 1992).

The primary researcher determined the compliance with the OT program by calculating the percentage of OT sessions the participant attended compared to those scheduled. The primary researcher determined compliance to the home exercise sessions by reviewing the HEP log sheets returned by the participants.

Results

Twenty-two individuals agreed to participate in the study; however, three discontinued due to financial issues, one declined due to anxiety issues, one moved, and one missed the reassessment, with 16 participants remaining. The remaining 16 participants had a mean (standard deviation) age of 61.31 (14.76) years. The majority ($n = 15, 93.8\%$) of the participants were female, 12 (75\%) were right-hand dominant, and 8 (50\%) injured their dominant hand. Compliance with attendance at OT sessions ranged from 50\% to 100\%, with all but two participants having greater than 75\% attendance. Nine of 16 participants returned their HEP logs for the four weeks of 10-minute exercise sessions. Of those who returned the HEP logs, three completed 100\% of the sessions; three completed 98\% of the sessions; one completed 91\% of the sessions; one completed 88\%, and one completed 86\%. 
Michigan Hand Questionnaire

There was a statistically significant improvement in the overall MHQ ADL and total MHQ scores ($p < .001$). There was also a statistically significant improvement ($p < .001$) for all domains except for the work performance, the RUE aesthetics, and the LUE aesthetics. More details are provided in Table 3.

London et al. (2014) established a 13-point difference for the MCID for the combined total MHQ score and a MCID range of 10.9 to 14.4 for each of the six domains. There was significant clinical improvement in the majority of the measurements with the percentage of participants who had a clinical improvement ranging from 25% (aesthetics and satisfaction of RUE) to 100% (total MHQ score for injured LUE). Table 4 shows the number and percentage of participants who reached the MCID of 13 points.

Purdue Pegboard Test

Results of the comparison pretest and posttest for PPT are found in Table 5. There was a statistically significant improvement ($p < .001$) for the subtests of the RUE peg placement, LUE peg placement, bilateral hand peg placement, and bimanual assembly peg placement. The effect size (ES) for the bimanual assembly task was large, $d = 1.50$.

Discussion

The purpose of our study was to determine if adding bimanual activity to a standard OT treatment protocol and HEP would increase the speed of bimanual activity and functional skills for individuals who had sustained a DRF requiring ORIF. By adding bimanual activity to the standard OT treatment and HEP, we expected our participants to improve bimanual hand function and dexterity by the end of the four-week time frame. Participants significantly increased functional skills as measured by the overall MHQ ADL for the RUE and LUE and
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MHQ domain of ADL with BUE. The majority of the MHQ measurements showed clinical improvement based on the London et al. (2014) established 13-point MCID. Likewise, the large ES for the bimanual assembly of the PPT confirmed clinical improvement.

**Dexterity and Hand Avoidance**

The MHQ domain of ADL BUE showed a statistically significant increase post-treatment reflecting improved performance in bimanual activities. The greatest number of participants showed a clinically important improvement, with 15/16 (93.8%) participants exceeding the MCID of 13 points (London et al.; 2014). The mean difference in pretest/posttest scores was more than two times the clinical change. The PPT posttest scores demonstrated a statistically significant increase in peg placement speed for unilateral, bilateral, and bimanual skills. The bimanual assembly task showed the greatest level of improvement with an ES of 1.50 (large effect) in pretest/posttest comparisons. The PPT and MHQ results showed that after adding bimanual activity to a standard OT treatment and HEP, our participants had increased dexterity speed and improved function during a four-week time frame.

The immobilization required to protect healing bone after a DRF can reduce fine motor coordination, dexterity, and bimanual interaction (Dilek et al., 2018; Karagiannopoulos et al., 2013; Wollstein et al., 2019). Though immobilization is necessary for recovery, it reinforces the avoidance of the hand and loss of sensory feedback with splints and casts restricting the functional motion of the injured hand (Wollstein et al., 2019). Bobos et al. (2018b) found that although dexterity improved for the first six months, coordination declined six to twelve months after DRF. Bobos et al. (2018b) also indicated that men and women were still limited in functional dexterity at one and two years following a DRF. Ydreborg et al. (2015) reported that a decline after completing therapeutic intervention could occur after one year if the patient had
increased pain limiting fine motor skills. Because our participants’ performance was measured only within a four-to-five-week time frame, we cannot know if their improvements would be sustained.

Although we did not solicit participants’ views of their performance, three participants verbalized that two-handed activities reduced their fear of reinjury. Bimanual activity may have reduced avoidance of using the injured hand and prevented overuse of the uninjured hand, resulting in improved use of both hands. The decreased avoidance contrasts with Dekkers and Nielsen (2011), who noted that one week after casts were removed, individuals with UE fractures reported that two-handed tasks were routinely performed with a one-handed technique. Dekkers and Nielsen (2011) believed that continued functional deficits following unilateral UE fractures requiring cast immobilization were due to the limited change in strength and coordination. Our participants’ improvement in bimanual speed and function supports incorporating more bimanual activities into OT therapeutic interventions to improve dexterity and enhance functional return.

**Pain**

The MHQ domain of pain showed a statistically significant improvement for the RUE and LUE. Clinically important improvement in pain was shown for the RUE in 5/16 (31.3%) participants and for the LUE in 7/16 (43.8%) participants. When change in pain was analyzed for the injured hand, clinically important improvement was found for the RUE for 4/6 (66.6%) participants and the LUE for 6/10 (60%) participants. This level of change supports that bimanual activities may contribute to reducing pain after ORIF for DRF.

To determine the effect of pain on overall MHQ ADL and total MHQ score, pretest/posttest scores were compared according to which hand was injured. Clinically important improvement in total MHQ score was demonstrated for the injured RUE in 4/6 (66.7%)
participants and injured LUE in 10/10 (100%) participants. In contrast, 13 participants showed increased MHQ ADL scores, although three did not rate a change in pain levels and one rated increased pain in the injured hand. The improved function may support that pain levels were not the leading cause of the change in functional ability, as previously reported (Boersma et al., 2018; Dekkers and Nielsen, 2011; Terkelsen et al., 2008; Wollstein et al., 2019). Including bimanual activities in the participants’ OT interventions may have decreased their fear of using the extremity rather than reduced their pain, resulting in improved functional change.

Other researchers have measured pain and functional disability for this population at later stages of recovery. Ydreborg et al. (2015) used a longitudinal study to assess function, pain, and disability over 24 months. Their study results noted that the expectation of pain affected disability rating scores, while the DASH scores continued to decrease over time showing improved function (Ydreborg et al., 2015). Ydreborg et al. (2015) found that though the pain decreased in the first 12 months, it would increase between 12 and 24 months with no apparent cause, while functional skills continued to improve. This continued functional improvement with increasing pain demonstrates that the pain did not prevent using the extremity. Our study supports this outcome with three participants having no change in pain levels while still improving in the overall MHQ ADL and total MHQ scores. There is a possibility that the incorporation of bimanual activities reduced the number of one-handed adaptations used with activities, thereby decreasing pain levels in the uninjured UE. Although pain levels decreased in the injured hand, there is no evidence that the injured hand's sensory awareness improved.

**Function**

The pretest/posttest comparison differences for overall MHQ ADL and total MHQ scores, and the domains of raw overall hand function and satisfaction with the RUE and LUE,
and ADL for the RUE, LUE, and BUE showed a statistically significant improvement in a four-to-five-week time frame. Participants demonstrated an overall increase in function with positive differences in each MHQ domain showing a clinically important improvement, except for the RUE raw hand function, RUE ADL, RUE and LUE pain, and RUE aesthetics. This change showed that participants experienced improved ability to use the RUE, LUE, and BUEs in daily functional tasks.

DRF can cause long-lasting negative effects that can persist for one-to-two years impeding the individual's ability to perform functional tasks requiring gripping and lifting. Changes in self-care, household, and work function due to pain and immobilization during recovery can reduce sensation, mobility, dexterity, and strength in the injured hand (Dilek et al., 2018; Karagiannopoulos et al., 2013; Lövgren & Hellström, 2012; Martinez-Mendez et al., 2018; Nielsen & Dekkers, 2013; Sirniö et al., 2019). Karagiannopoulos et al. (2013) noted that the sensory changes in light touch and proprioception, and motor impairments decreased the individual's ability to perform functional activities. By adding bimanual activity to the standard OT treatment protocol, we anticipated that the tactile stimulation and cortical use of bilateral hemispheres would improve the sensory and proprioceptive feedback, thus reducing pain levels and improving functional skills. We cannot directly compare sensory changes measured by others to the change in pain in our study. However, changes in MHQ and PPT scores could reflect the improvement in sensation required by the bimanual activity in the current study.

In Dekkers and Nielsen's (2011) research, participants identified ten activities on the DASH, of which seven were bilateral tasks that were moderately or severely difficult. They noted that the functions most limited were those requiring two hands, with participants changing tasks requiring two hands to a one-handed approach (Dekkers & Nielsen, 2011). Their
participants also identified activities for cleaning, hygiene, cooking, dressing, laundry and ironing, and eating as continued problem areas at one-to-two years post-injury (Dekkers & Nielsen, 2011). After incorporating bimanual activities in OT treatment protocols, our research demonstrated a statistically significant improvement in the MHQ ADL two hands domain, with bimanual interaction showing the greatest functional improvement. The MHQ does use similar two-handed tasks as the DASH, such as opening a jar, cutting food, and carrying a grocery bag, allowing for some comparisons with our study. Our study showed participants improved their functional skills as they incorporated more bimanual tasks into their rehabilitation. Even though the participants’ function improved within this study, there is no evidence that functional skills would improve past the four-to-five-week time frame. Although our study showed that our participants had an improved functional ability, the limited number of participants does not allow for generalization.

Our results did not include strength assessments for gripping or lifting as the OT treatment protocol established adding resistive activities in the sixth week. Three participants initiated OT past the six-week post-operative period allowing them to start at the strengthening stage. The remaining participants’ four-to-five-week time frame was earlier in the OT protocol, not allowing for strengthening activities, so the effect of incorporating bimanual functional skills on strength levels was not determined.

**Work Performance**

Data for the MHQ did not show a statistically significant change in the domain for work performance. The change in scores did meet the MCID 13-point change showing a clinically important improvement for 8/16 (50%) participants. The participants may have scored work performance based on employment rather than the broader-based definition of the MHQ,
including housework and school. It is noted that the MHQ work domain assesses work activities based on a four-week reflection versus the one-week time frame used in the other domains. Some participants began OT treatment closer to their post-operative date. Hence, a four-week review was impossible due to the recent injury and surgery preventing them from using the injured hand initially. The compensation of one-handed activities may have caused individuals to express a greater ability to perform functional tasks initially. Once they were farther in the healing process and using the injured hand, they may have noted more difficulties and reported increased functional deficits with work level activities and attempts to perform more involved tasks.

The number of retired individuals may also have affected the scores for work performance since they had no plans to return to work. Six participants continued to work during the four-to-five-week time frame that included performing bimanual activities. These participants’ work sites adjusted work tasks to accommodate their injuries. Because they were working, their fears of reinjury or inability to use the injured hand were possibly reduced. Of the remaining participants, three had not returned to work, and one was a teacher on summer break.

**Aesthetics**

Participants in our study did not show a statistically significant change in the aesthetics domain for the RUE or LUE. The LUE aesthetics domain did show a clinically important improvement in the pretest/posttest difference for 7/16 (50%) participants. But the aesthetic domain score of the RUE met the clinically important improvement level for only 4/16 (25%) participants. It is unclear why the aesthetics of the affected and unaffected hands did not show a statistically significant change. Koopman et al. (2021) noted they could not determine a minimally important change for the aesthetics domain for individuals with trigger finger releases. They stated this was due to a low correlation with the anchor question and felt that the different
domains' clinical significance depended on the injury being assessed and that aesthetics were not a specific issue for their participants.

In our study, the unaffected hand often did not score low in aesthetics initially, so we could not establish a marked change for this domain. Changes for the affected hand seemed to improve, but at one month, participants showed minimal differences in how they viewed their hands.

**Contribution to the Field**

Our study demonstrated that when bimanual activities are added to standard OT treatment starting in the second to tenth week postoperatively, patients with ORIF after DRF can make clinical improvements in bimanual activities, dexterity, ADL function, and pain within a four-to-five-week time frame. In contrast, other researchers all noted in longitudinal studies that clients had continued limitations in functional skills and dexterity, including two-handed tasks (Dekkers & Soballe, 2004; Nielsen & Dekkers, 2013; Yderborg et al., 2015). Their findings, in combination with ours, support the early introduction of bimanual activities after DRF. We located no studies incorporating bimanual activities in standard OT treatment protocols when reviewing the literature for this patient population. Therefore, further research into using bimanual activity for patients with DRF after ORIF is warranted.

Routine assessment for bimanual activity performance by OT practitioners may increase the awareness of hand avoidance and enhance the inclusion of bimanual activities in OT treatment for this population. Alotaibi et al. (2009), Grice (2015), and Ziebart et al. (2021) all noted that bimanual testing was limited in the assessment of clients in hand clinics. The lack of assessing bimanual skills eliminates the therapists' awareness of a problem and may prevent incorporating bimanual activities with the patient’s rehabilitation. If the OT practitioner does not
include bimanual activity in the individual’s OT session, the fear of increased pain or re-injury of their hand could cause avoidance of the hand and the delay of the recovery of strength and dexterity.

Researchers acknowledge that sensory changes, fear, and pain cause the client to avoid the use of the injured hand, with a resulting long-term functional deficit (Dekkers & Nielsen, 2011; Dilek et al., 2018; Karagiannopoulos et al., 2013; Lövgren & Hellström, 2012; Martinez-Mendez et al., 2018; Nielsen & Dekkers, 2013; Sirniö et al., 2019). Our results demonstrated that participants improved dexterity and hand function with bimanual activity, enhancing functional scores. This improvement in dexterity and ADL BUE scores supports the use of bimanual activity in the OT treatment of a DRF. Our study had a small sample size, so further research into the effect of bimanual activities within OT treatment with DRF requiring ORIF may improve the OT treatment protocols for future clients.

**Study limitations**

Our study showed decreased pain and improved dexterity and functional skill in a four-to-five-week time frame. However, it is unclear if the change in functional skills and pain would be sustained or increased after this time frame. Longitudinal studies are needed to confirm this patient population's long-term benefits of bimanual activity.

Our design did not include a control group, nor were our participants randomized to standard care or standard care plus bimanual activities. Based on our design, we cannot know if a unilateral treatment protocol with no bimanual interaction for a DRF with ORIF would have created the same improvements in the bimanual activity we measured.

Initiation of OT treatment was dependent on the referring physician, with participants beginning OT one-to-ten weeks postoperative, depending on when the physician referred. The
reassessment time also fluctuated between participants as their appointment times were not always scheduled on a specific four-week time frame. We performed all reassessments within the fourth week, with a range of four-to-five weeks for the final assessment. Varying initiation times also limited our ability to determine from this study when starting the bimanual activity would create the best improvement in functional skills. However, we believe earlier sensory and proprioceptive facilitation would benefit the patients. In future, researchers should consider when therapists start their bimanual OT activities.

Compliance in our study was determined by the participants’ OT clinic attendance and by the completion of a HEP log. Attendance at the OT clinic sessions showed good consistency, with 88% of the participants completing 75% of the OT sessions. Not all participants completed or returned the HEP logs. Bimanual activities were used in all OT treatments, but completion of the bimanual activities by participants as a part of the HEP may have been less consistent.

**Recommendations**

Follow-up studies using a mixed methods design may be beneficial as conducting interviews with the participants may facilitate a greater understanding of their fear of using the extremity, pain, and functional abilities. Several participants expressed their views on the hand outcomes, but a more in-depth interview may have clarified functional return and fear issues. Likewise, extending the study duration to two-to-three months would have clarified outcomes beyond the four to five-week time frame and the long-term effects of the bimanual activities.

**Conclusion**

Bimanual intervention can improve the bimanual activity in individuals with a DRF requiring ORIF. Our research results demonstrated improved bimanual activities and ADL skills,
while decreasing pain after using bimanual activities. The statistically significant changes following intervention showed improved hand dexterity and bimanual skills with increased speed. Applying bimanual activities in participants' daily routines improved function. The results support incorporating bimanual activities into the OT intervention for individuals with a DRF requiring an ORIF.
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https://doi.org/10.1016/j.cub.2009.03.065


https://doi.org/10.1111/j.1744-6570.1956.tb01061.x


Table 1

<table>
<thead>
<tr>
<th></th>
<th>ADL RUE</th>
<th>ADL LUE</th>
<th>Total Score</th>
<th>Total Score</th>
<th>ADL BUE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RUE</td>
<td>LUE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.89</td>
<td>.64</td>
<td>.90</td>
<td>.43</td>
<td>.62</td>
</tr>
<tr>
<td>Trial 2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>No variance</td>
<td>1.0</td>
<td>.94</td>
<td>.85</td>
<td>No variance</td>
</tr>
</tbody>
</table>

*Note.* MHQ = Michigan Hand Outcomes Questionnaire; ADL = activities of daily living; RUE = right upper extremity; LUE = left upper extremity; BUE = bilateral upper extremities.

<sup>a</sup> N = 6

<sup>b</sup> N = 4
Table 2

*Interrater Reliability Intraclass Coefficient for the Purdue Pegboard Assessment*

<table>
<thead>
<tr>
<th></th>
<th>RUE</th>
<th>LUE</th>
<th>BUE</th>
<th>Summation</th>
<th>Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First trial with three trials for each subtest</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICC</td>
<td>.59</td>
<td>.89</td>
<td>.89</td>
<td>.81</td>
<td>.84</td>
</tr>
<tr>
<td><strong>Second trial with one trial for each subtest</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICC</td>
<td>.80</td>
<td>.80</td>
<td>.70</td>
<td>.81</td>
<td>.95</td>
</tr>
</tbody>
</table>

*Note.* RUE = right upper extremity; LUE = left upper extremity; BUE = bilateral upper extremities; ICC = intraclass correlation coefficient; SEM = standard error of the measurement.

<sup>a</sup><em>N = 6</em>

<sup>b</sup><em>N = 4</em>
Table 3

Comparison of Pretreatment and Posttreatment Michigan Hand Outcomes Questionnaire Scores
(N = 16)

<table>
<thead>
<tr>
<th></th>
<th>Pretreatment</th>
<th>Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mdn</td>
<td>IQR</td>
</tr>
<tr>
<td>Raw Hand Function RUE</td>
<td>87.5</td>
<td>70.0</td>
</tr>
<tr>
<td>Raw Hand Function LUE</td>
<td>48.4</td>
<td>37.6</td>
</tr>
<tr>
<td>ADL RUE</td>
<td>92.5</td>
<td>70.0</td>
</tr>
<tr>
<td>ADL LUE</td>
<td>22.5</td>
<td>98.0</td>
</tr>
<tr>
<td>ADL BUE</td>
<td>31.7</td>
<td>24.6</td>
</tr>
<tr>
<td>Work performance</td>
<td>30.6</td>
<td>22.6</td>
</tr>
<tr>
<td>Pain with RUE</td>
<td>5.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Pain with LUE</td>
<td>92.5</td>
<td>70.0</td>
</tr>
<tr>
<td>Aesthetics of RUE</td>
<td>100.0</td>
<td>48.4</td>
</tr>
<tr>
<td>Aesthetics for LUE</td>
<td>55.5</td>
<td>32.0</td>
</tr>
<tr>
<td>Satisfaction with RUE</td>
<td>83.3</td>
<td>65.7</td>
</tr>
<tr>
<td>Satisfaction with LUE</td>
<td>33.4</td>
<td>90.7</td>
</tr>
<tr>
<td>Overall MHQ ADL RUE</td>
<td>48.8</td>
<td>32.1</td>
</tr>
<tr>
<td>Overall MHQ ADL LUE</td>
<td>37.3</td>
<td>29.7</td>
</tr>
<tr>
<td>Total MHQ Score RUE</td>
<td>69.4</td>
<td>42.1</td>
</tr>
<tr>
<td>Total MHQ Score LUE</td>
<td>46.4</td>
<td>28.0</td>
</tr>
</tbody>
</table>

Note: LUE = left upper extremity; ADL = activities of daily living; RUE = right upper extremity.

a Reported as means, standard deviations, compared with paired t-test.
Table 4

*Number of Participants Who Met the Threshold for Meaningful Change on the Michigan Hand Outcomes Questionnaire*<sup>a</sup> (*N* = 16)

<table>
<thead>
<tr>
<th>Domain</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Hand Function RUE</td>
<td>7/16</td>
<td>43.7</td>
</tr>
<tr>
<td>Raw Hand Function LUE</td>
<td>10/16</td>
<td>62.5</td>
</tr>
<tr>
<td>ADL RUE</td>
<td>6/16</td>
<td>37.5</td>
</tr>
<tr>
<td>ADL LUE</td>
<td>10/16</td>
<td>62.5</td>
</tr>
<tr>
<td>ADL BUE</td>
<td>15/16</td>
<td>93.8</td>
</tr>
<tr>
<td>Work Performance</td>
<td>8/16</td>
<td>50.0</td>
</tr>
<tr>
<td>RUE pain</td>
<td>5/16</td>
<td>31.3</td>
</tr>
<tr>
<td>LUE pain</td>
<td>7/16</td>
<td>43.8</td>
</tr>
<tr>
<td>Aesthetics of RUE</td>
<td>4/16</td>
<td>25.0</td>
</tr>
<tr>
<td>Aesthetics of LUE</td>
<td>8/16</td>
<td>50.0</td>
</tr>
<tr>
<td>Satisfaction of RUE</td>
<td>4/16</td>
<td>25.0</td>
</tr>
<tr>
<td>Satisfaction LUE</td>
<td>8/16</td>
<td>50.0</td>
</tr>
<tr>
<td>Overall MHQ ADL RUE</td>
<td>13/16</td>
<td>81.1</td>
</tr>
<tr>
<td>Overall MHQ ADL LUE</td>
<td>15/16</td>
<td>93.8</td>
</tr>
<tr>
<td>Total MHQ score RUE</td>
<td>7/16</td>
<td>43.8</td>
</tr>
<tr>
<td>Total MHQ score LUE</td>
<td>11/16</td>
<td>68.8</td>
</tr>
<tr>
<td>Total MHQ score injured RUE</td>
<td>4/6</td>
<td>66.7</td>
</tr>
<tr>
<td>Total MHQ score injured LUE</td>
<td>10/10</td>
<td>100.0</td>
</tr>
<tr>
<td>Injured RUE pain change</td>
<td>4/6</td>
<td>66.7</td>
</tr>
<tr>
<td>Injured LUE pain change</td>
<td>6/10</td>
<td>60.0</td>
</tr>
</tbody>
</table>
Note: MCID = minimally clinically important difference; RUE = right upper extremity; LUE = left upper extremity; ADL = activities of daily living; BUE = bimanual upper extremity; MHQ = Michigan Hand Outcomes Questionnaire.

Meaningful change is based on the MCID established as a change in score of 13 points or greater.
Table 5

Comparison of Pretreatment and Posttreatment Purdue Pegboard Scores (N=16)

<table>
<thead>
<tr>
<th>Test</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th>p</th>
<th>ES (^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M  SD</td>
<td>M  SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUE peg placement</td>
<td>11.50  4.00</td>
<td>12.50  3.00</td>
<td>0.041</td>
<td>0.78 (^c)</td>
</tr>
<tr>
<td>LUE peg placement</td>
<td>8.44  4.56</td>
<td>11.19  2.59</td>
<td>0.007</td>
<td>0.78 (^c)</td>
</tr>
<tr>
<td>Bilateral hand peg</td>
<td>7.63  4.32</td>
<td>9.94  1.29</td>
<td>0.049</td>
<td>0.54 (^d)</td>
</tr>
<tr>
<td>Bimanual assembly peg</td>
<td>19.13 8.37</td>
<td>27.13 6.09</td>
<td>&lt; 0.001</td>
<td>1.50 (^c)</td>
</tr>
</tbody>
</table>

\(^a\) Reported as median and IQR and compared using Wilcoxon signed-ranks test.

\(^b\) Cohen’s \(d\) reported

\(^c\) Large effect size

\(^d\) Medium effect size

Note. ES = effect size; LUE = left upper extremity; RUE = right upper extremity.
Appendix A

Purdue Pegboard Test


https://www.healthproductsforyou.com/p-lafayette-purdue-pegboard-test.html

Note: Assembly tasks

https://www.prohealthcareproducts.com/blog/purdue-pegboard-manual-dexterity-test
### Appendix B

**Purdue Pegboard Score Sheet**

Subject record

Subject study identification number ______ Preferred Hand used to eat: Right__ Left__ Both __

Test administrator: ___________________________                Date ___/____/____


Sex assigned at birth: male ____ female ______ other _____          Age: ________

Scoring Table Based on Number of Parts Placed

<table>
<thead>
<tr>
<th>Hand used</th>
<th>Trial One</th>
<th>Trial Two</th>
<th>Trial Three</th>
<th>Trial Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right hand in 30 seconds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left hand in 30 seconds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both hands in 30 seconds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pegs placed with Right +</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left + Both = summation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly in 60 seconds (all</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pieces)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Quick references of means in average of parts placed for ages 15 - 40

<table>
<thead>
<tr>
<th>Gender/hand</th>
<th>Mean peg placements for age group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>15-20</td>
</tr>
<tr>
<td>Preferred hand</td>
<td>15.56</td>
</tr>
<tr>
<td>Non-preferred hand</td>
<td>15.09</td>
</tr>
<tr>
<td>Both Hands</td>
<td>12.59</td>
</tr>
<tr>
<td>Assembly</td>
<td>40.25</td>
</tr>
<tr>
<td>Females</td>
<td>15-20</td>
</tr>
<tr>
<td>Preferred hand</td>
<td>16.69</td>
</tr>
<tr>
<td>Non-preferred hand</td>
<td>16.10</td>
</tr>
<tr>
<td>Both hands</td>
<td>13.76</td>
</tr>
<tr>
<td>Assembly</td>
<td>41.83</td>
</tr>
</tbody>
</table>

Note.

Data taken from the Purdue Pegboard Test Instruction Manual Table 14-22 using one trial for each person. Adapted from:


Quick references of means in average of parts placed for ages 15 - 40<sup>a</sup>

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40-49</td>
<td>50-59</td>
</tr>
<tr>
<td></td>
<td>3 trial</td>
<td>3 trial</td>
</tr>
<tr>
<td>Preferred hand</td>
<td>14.5</td>
<td>15.9</td>
</tr>
<tr>
<td>Non-preferred hand</td>
<td>14.4</td>
<td>15.0</td>
</tr>
<tr>
<td>Both hands</td>
<td>12.2</td>
<td>13.1</td>
</tr>
<tr>
<td>Assembly</td>
<td>34.9</td>
<td>39.8</td>
</tr>
</tbody>
</table>

<sup>a</sup>Data taken from the Purdue Pegboard Test Instruction Manual Table 14-25 by Lafayette Instrument using three trials for each person. Adapted from:


Appendix C

Standard OT treatment protocol for distal radius fracture with ORIF

<table>
<thead>
<tr>
<th>Initiation week</th>
<th>Therapeutic intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1 - S/P ORIF</td>
<td>Both volar and dorsal plates, pins, or bridging. No casting only. 2. The level of edema, AROM measurements, and post-operative time frames will be used to determine the participant’s initial treatment level by following the standard treatment protocol, which facilitates the selection of the therapeutic activities applied to the participant per industry standards after their initial assessment. No balance screening? It is in normal documentation but not in wrist protocol. CRPS would not exclude as most are not determined before 2 months generally. Pain is addressed with the MHQ.</td>
</tr>
<tr>
<td></td>
<td>1. Orthosis for protection of wrist per physician’s direction.</td>
</tr>
<tr>
<td></td>
<td>2. Wound care.</td>
</tr>
<tr>
<td></td>
<td>3. Edema control with elevation above the heart for 1-2 minutes every waking hour and compression wraps.</td>
</tr>
<tr>
<td></td>
<td>4. Active range of motion (AROM) for shoulder flexion/extension, internal/external rotation and abduction, elbow flexion/extension, digits for tendon glides (six-pack), and fingers/thumb for joint blocks, abduction/adduction and opposition, and extensor pollicis longus (EPL) and flexor pollicis longus (FPL) glides.</td>
</tr>
<tr>
<td></td>
<td>5. Passive range of motion (PROM) for digits</td>
</tr>
</tbody>
</table>
6. **Home exercise program instruction 3-5 days post-operative for**
   elevation, AROM for shoulder flexion/extension,
   internal/external rotation, and abduction; elbow
   flexion/extension; digits for tendon glides (six-pack); and
   fingers/thumb for joint blocks, abduction/adduction, and
   opposition; and EPL and FPL glides.

7. **Education in the healing process and ADL modifications.**

<table>
<thead>
<tr>
<th>Week 2 – S/P ORIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Continue orthosis for wrist support.</td>
</tr>
</tbody>
</table>
| 2. Continue wound care/ begin gentle scar management after
  suture removal for surrounding tissues. |
| 3. Edema control with elevation above the heart, shoulder pumps,
  and compression wraps. |
| 4. AROM in a pain-free range of all joints: AROM for shoulder
  flexion/extension, internal/external rotation, and abduction;
  elbow flexion/extension; digits for tendon glides (six-pack); and
  fingers/thumb for joint blocks, abduction/adduction, and
  opposition; and EPL and FPL glides. |
| 5. Gentle PROM to all fingers, including intrinsic muscle stretching
  exercises. |

<table>
<thead>
<tr>
<th>Week 3 - S/P ORIF</th>
</tr>
</thead>
</table>
| 1. Continue orthosis for wrist support with removal during the day
  for light activity and hygiene tasks with physicians’ approval. |
2. Continue scar management (myofascial release, silicone, otoform scar conformer, vibration).

3. Edema control with elevation above the heart, overhead shoulder pumps, isotoner glove, and compression wraps.

4. AROM in a pain-free range of all joints: shoulder flexion/extension, internal/external rotation, and abduction; elbow flexion/extension; forearm pronation/supination; wrist flexion, extension, radial deviation, and ulnar deviation; and digits for tendon glides, abduction/adduction, and opposition; and EPL and FPL glides.

5. PROM to all fingers, thumb, wrist, and forearm. Including intrinsic muscle stretch.

6. Initiate passive and active assistive ROM (A/AROM) in a pain-free range for wrist motion with flexion, extension, radial deviation, and ulnar deviation.

7. Three-point prehension exercise for light strengthening (clothespin, therapy putty, bead in a slotted container, coin pick up).

Week 4 and 5 - S/P ORIF

1. Continue orthosis for wrist support with removal during the day for light activity and hygiene tasks with physicians’ approval.

2. Continue scar management as needed (5-10 minutes).

3. Continue edema control as needed.
4. AROM in a pain-free range of all joints: shoulder flexion/extension, internal/external rotation, and abduction; elbow flexion/extension; forearm pronation/supination; wrist flexion and extension (fisted and non-fisted hand position), and radial deviation and ulnar deviation; and digits for tendon glides, abduction/adduction and opposition; and EPL and FPL glides

5. PROM to all fingers and thumb, including intrinsic muscle stretch.

6. Continue gentle passive and A/AROM in a pain-free range for wrist and forearm motion.

7. Three-point and lateral prehension exercise (clothespin, therapy putty, bead in a slotted container, coin pick up).

8. Place and hold for wrist extension and flexion.

9. Light grip strengthening below 36# (Digi-flex, calibrated gripper).

Week 6 to 8 – S/P ORIF

1. Continue orthosis for wrist support with resistive activity. Begin weaning from orthosis when at home with light activities during the day.

2. Continue scar management (10 minutes).

3. AROM in a pain-free range of all joints: shoulder flexion/extension, internal/external rotation, and abduction; elbow flexion/extension; forearm pronation/supination; wrist flexion and extension (fisted and non-fisted hand position); and
<table>
<thead>
<tr>
<th>Week 9-12 weeks – S/P ORIF</th>
<th>radial deviation and ulnar deviation; and digits for tendon glides, abduction/adduction and opposition; and EPL and FPL glides.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>PROM all digits, wrist, and forearm (10 minutes).</td>
</tr>
<tr>
<td>5.</td>
<td>Three-point and lateral prehension exercise with the progression of resistance as appropriate (clothespin, therapy putty, bead in a slotted container).</td>
</tr>
<tr>
<td>6.</td>
<td>Light resistive exercise with 1# -2# for wrist flexion, extension, radial deviation, and ulnar deviation; and forearm pronation and supination with physician approval.</td>
</tr>
<tr>
<td>7.</td>
<td>Initiation of grip strengthening with physician approval (Digi-flex, calibrated gripper, therapy putty).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week 9-12 weeks – S/P ORIF</th>
<th>Discontinue orthosis with a return to normal ADL routine.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>PROM for digits, wrist, and forearm as needed.</td>
</tr>
<tr>
<td>3.</td>
<td>AROM in a pain-free range of all joints: shoulder flexion/extension, internal/external rotation, and abduction; elbow flexion/extension; forearm pronation/supination; wrist flexion and extension (fisted and non-fisted hand position); and radial deviation and ulnar deviation; and digits for tendon glides, abduction/adduction and opposition; and EPL and FPL glides.</td>
</tr>
<tr>
<td>4.</td>
<td>Three-point and lateral prehension exercise with the progression of resistance as appropriate (clothespin, therapy putty, bead in a slotted container).</td>
</tr>
</tbody>
</table>
5. Progressive resistive exercise for wrist flexion, extension, radial deviation, and ulnar deviation, and forearm pronation and supination.

6. Grip strengthening (Digi-flex, calibrated gripper, therapy putty).

Note. The standard treatment protocol was developed by a certified hand therapist using therapy experience and consolidation of standard published protocols. It was reviewed and approved by six CHTs.


Appendix D

Home exercise sheet for distal radius fracture

Home Exercise program

Elevation above the heart. Elevate the _________ hand overhead for 1 to 2 minutes 8-10 times per day.

Tendon Glide exercises. Perform 10 times for each position __3__ times per day.

Straighten fingers Straight to bent knuckles Straight to hook Straight to fist

Elbow flexion/extension Repetitions ___ times/day ___
Home exercise program for active finger motion
   Repetitions ____ times/day ____

   Open and close fingers

   Touch thumb to each fingertip 10 times through
Home exercise program for

Active wrist motion: Complete 10-20 times 3 times per day

Wrist flexion

Wrist extension

Wrist toward thumb

Wrist toward small finger

active

wrist motion
### Appendix E

#### Bimanual activity with progression

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description of activity and progressive level of difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coin/Bean pick up and transfer</strong></td>
<td>Level 1&lt;br&gt;1. The client uses the affected hand to pick up one coin/bead at a time, placing the items into the unaffected hand&lt;br&gt;2. Using the affected hand, the client then picks up one coin/bead using a tip pinch and places it in a covered container through a slot on the top.&lt;br&gt;Level 2&lt;br&gt;1. The client uses the affected hand to pick up and palm 4 coins/beads.&lt;br&gt;2. The coins/beads are transferred to the unaffected hand&lt;br&gt;3. The client then uses the affected hand in a tip pinch motion using alternating fingers to pick up one coin/bead at a time from the unaffected hand and placing it into a covered container through a slot on the top&lt;br&gt;Level 3&lt;br&gt;1. The client uses the affected hand to pick up and palm 4 coins/beads.&lt;br&gt;2. The coins/beads are transferred to the unaffected hand&lt;br&gt;3. The client then uses the affected hand to pick up two coins/beads palming one coin/bead and pinching the other. Then the client places one coin/bead at a time into a covered container through a slot on the top.</td>
</tr>
<tr>
<td><strong>Shoelace tying</strong></td>
<td>1. Tie the first cross tie (no bow) of a shoelace on a shoe&lt;br&gt;2. Tie the first cross tie and a bow of a shoelace on a shoe.</td>
</tr>
</tbody>
</table>
3. Lace a shoelace through the eyelets and then tie the first cross tie and a bow of a shoelace on a shoe.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Braid three strands of Macramé ropes:</td>
</tr>
<tr>
<td></td>
<td>a. thick rope</td>
</tr>
<tr>
<td></td>
<td>b. medium thick rope</td>
</tr>
<tr>
<td></td>
<td>c. thin rope</td>
</tr>
<tr>
<td>Level 2</td>
<td>Tie square knots using two strands of Macramé ropes:</td>
</tr>
<tr>
<td>Macramé rope</td>
<td>a. thick rope</td>
</tr>
<tr>
<td></td>
<td>b. medium thick rope</td>
</tr>
<tr>
<td></td>
<td>c. thin rope</td>
</tr>
<tr>
<td>Level 3</td>
<td>Tie square knots using two strands using an alternating pattern</td>
</tr>
<tr>
<td></td>
<td>a. thick rope</td>
</tr>
<tr>
<td></td>
<td>b. medium thick rope</td>
</tr>
<tr>
<td></td>
<td>c. thin rope</td>
</tr>
<tr>
<td>Pass a ball</td>
<td>Pass a soft, light ball from hand to hand. Change size of ball with improved grip.</td>
</tr>
<tr>
<td>String pegs</td>
<td>String medium pegs onto a string</td>
</tr>
<tr>
<td>Safety pins</td>
<td>Level 1 – Open 3 safety pins.</td>
</tr>
<tr>
<td></td>
<td>Level 2 – Open then close 3 safety pins.</td>
</tr>
<tr>
<td></td>
<td>Level 3 – Open and remove 3 safety pins from a cloth.</td>
</tr>
<tr>
<td></td>
<td>Effect of Bimanual Activity after Radius Fracture</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Level 4 - Place 5 open safety pins into a cloth and then close.</td>
</tr>
<tr>
<td></td>
<td>Level 5 - Open 5 safety pins in a cloth and remove. Then replace the 5 safety pins into a cloth and close the safety pins.</td>
</tr>
<tr>
<td></td>
<td>Level 6 - Open and close 3 diaper pins.</td>
</tr>
<tr>
<td></td>
<td>Level 1 – Dealing cards with the affected hand holding the deck</td>
</tr>
<tr>
<td></td>
<td>Level 2 – Dealing cards with the affected hand dealing the cards.</td>
</tr>
<tr>
<td></td>
<td>Level 3 – Shuffling cards</td>
</tr>
<tr>
<td></td>
<td>Level 4 – Shuffling cards with a bridge</td>
</tr>
<tr>
<td></td>
<td>Level 1 – Unlink a string of 5 paper clips.</td>
</tr>
<tr>
<td></td>
<td>Level 2 – Link a string of 5 paper clips</td>
</tr>
</tbody>
</table>

*Note.* Pamela M Metzer, OTR, CHT, developed the bimanual activities protocol using occupational therapy experience and consolidated standard treatment protocol.
## Appendix F

**Bimanual activities for home exercise program**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Demonstration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tie shoelaces</td>
<td><img src="image1" alt="Demonstration" /></td>
</tr>
<tr>
<td>Pass a ball from hand to hand</td>
<td><img src="image2" alt="Demonstration" /></td>
</tr>
<tr>
<td><strong>Shuffle and deal cards</strong></td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td></td>
</tr>
<tr>
<td><img src="image1.jpg" alt="Images of shuffling cards" /> <img src="image2.jpg" alt="Images of dealing cards" /></td>
<td></td>
</tr>
</tbody>
</table>

<p>| <strong>Pick up coins with your affected hand.</strong> |
| <strong>Pass the coins to the unaffected hand.</strong> |
| <strong>Using the affected hand, remove one coin at a time from the unaffected hand and place it in a container.</strong> |
| <img src="image3.jpg" alt="Images of picking up coins" /> <img src="image4.jpg" alt="Images of passing coins" /> <img src="image5.jpg" alt="Images of removing coins" /> <img src="image6.jpg" alt="Images of placing coins" /> |</p>
<table>
<thead>
<tr>
<th>Braid Macramé rope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Braid three strands of Macramé rope:</td>
</tr>
<tr>
<td>a. thin rope</td>
</tr>
<tr>
<td>b. medium thick rope</td>
</tr>
<tr>
<td>c. thin rope</td>
</tr>
</tbody>
</table>

https://www.pinterest.com/pin/623748617113740973/

| 2. Braid four strands of Macramé ropes: |
| a. thick rope |
| b. medium thick rope |
| c. thin rope |

3. Tie square knots using four strands of Macramé ropes:
   a. thick rope
   b. medium thick rope
   c. thin rope

   ![Square Knot (Left Hand)](https://ya-webdesign.com/image/drawing-knots-sq)

<table>
<thead>
<tr>
<th>Paper clips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unlink a string of 5 paper clips. Link a string of 5 paper clips.</td>
</tr>
</tbody>
</table>

![Images of paper clips being unlinked and linked]
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Place 5 open safety pins into a cloth and then close.</td>
<td><img src="https://www.pinterest.com/pin/449093394067912259/uare/1037044.html" alt="Image" /> <img src="https://www.pinterest.com/pin/449093394067912259/uare/1037044.html" alt="Image" /> <img src="https://ya-webdesign.com/image/drawing-knots-sq" alt="Image" /> <img src="https://ya-webdesign.com/image/drawing-knots-sq" alt="Image" /></td>
</tr>
</tbody>
</table>

**Note:** Knot tying diagrams are free stock photos, retrieved from:


https://ya-webdesign.com/image/drawing-knots-sq
Appendix G

Study flier for participant information

Select Physical Therapy
Approved by the University of Indianapolis Institutional Review Board (IRB) on 6/29/21, study # 01276

IF YOU HAVE A DISTAL RADIUS FRACTURE, WE WOULD LIKE TO INCLUDE YOU IN A RESEARCH STUDY ABOUT THE EFFECT OF BIMANUAL ACTIVITY ON HAND FUNCTION

Study title: The Effect of Bimanual Activity Inclusion with Treatment After Distal Radius Fractures

Purpose of the Research Study: To determine if the addition of bimanual (two-handed) activity to a standard occupational therapy treatment protocol and home exercise program, increases the speed of bimanual activity and functional skills for clients with distal radius fracture after surgery for open reduction with internal fixation.

As a participant, you will:
- Complete all standard occupational therapy treatment for your distal radius fracture
- Complete an additional 10 minutes of bimanual activity after each session of standard occupational therapy treatment
- Complete the Purdue Pegboard Test to measure finger dexterity
- Complete the Michigan Hand Outcome Questionnaire to rate your ability to do daily tasks
- Complete 10 minutes of bimanual activity twice daily as part of your home exercise program and record the activity on a log sheet.

We hope to understand the value of adding bimanual activity to standard occupational therapy after surgery for distal radius fracture.

Are you eligible?
- You have a distal radius fracture that required surgery called open reduction with internal fixation
- You are an adult, 18 - 85 years of age
- You may have hand or wrist ligament tear, or metacarpal or ulna styloid fracture, in addition to distal radius fracture
- You speak and read English or have someone to interpret for you
- No complication of nerve injury to the arm involved
- No cognitive disorders limiting your ability to understand instruction for a home program
- No accompanying elbow fracture or rotator cuff injury
- No central nervous system disorder that includes residual impairments to the side of the fracture

Your occupational therapist will review your eligibility and interest in participation during your first occupational therapy session.

Study Locations:
The Woodlands, Texas
Select Physical Therapy,
1011 Medical Plaza Blvd, Ste 150

Conroe, Texas
Select Physical Therapy
1803 W White Oak Terrace, Ste C

And
Willis, Texas
Select Physical Therapy
9851 Fm 1097 Rd W, Ste 180

Possible Benefits
- Improved function for fine motor skills
- Increased speed of bimanual activity
- Less hand avoidance

Possible Risks
- Increased swelling
- Increased initial pain

Through the University of Indianapolis
Principal Investigator - Pamelia Metzger OTR, CHT - pmetzger@selectmedical.com 281-367-1912
Indy Faculty Advisor - Lucinda Dale EdD, OTR, CHT - ldale@indy.edu 317-788-3561
Co-Investigator - Jennifer Vasquez, OTR, CHT - 936-494-4211
# Home Exercise Log Sheet

<table>
<thead>
<tr>
<th>To Be Completed</th>
<th>Exercise Log Sheet</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AM</td>
<td>PM</td>
<td>AM</td>
<td>PM</td>
<td>AM</td>
<td>PM</td>
<td>AM</td>
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<tr>
<td>Edema – elevation 1-5 minutes every waking hour</td>
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<tr>
<td>Compression sleeve</td>
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<tr>
<td>Active motion - fingers</td>
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<td></td>
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<tr>
<td>Straight to tabletop</td>
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<tr>
<td>Straight to hook to flat</td>
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<tr>
<td>Finger abduction/adduction</td>
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<tr>
<td>Thumb to each finger - to fingertip</td>
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<td>to middle joint</td>
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<td>to base of finger</td>
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<td>Slide</td>
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<tr>
<td>Active motion - wrist</td>
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<tr>
<td>Wrist flexion/extension</td>
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<tr>
<td>Wrist side to side</td>
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<tr>
<td>Forearm pronation/supination</td>
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<tr>
<td>Active elbow flexion/extension</td>
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<tr>
<td>Wound/scar management</td>
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<tr>
<td>Dressing</td>
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<tr>
<td>Scar massage</td>
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<tr>
<td>Bimanual activity</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Coin pick up and transfer - level</td>
<td></td>
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<td></td>
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<tr>
<td>Shoelace tying - level</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Braid Macrame rope - level</td>
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<tr>
<td>Rope</td>
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</tr>
<tr>
<td>Pass a ball hand to hand - size</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Shuffle cards</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Paperclips - link together</td>
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<tr>
<td>Pull apart</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Safety pins - open close</td>
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**Participant ID #:**
Effects of Bimanual Activity Inclusion with Treatment After Distal Radius Fracture

Submitted to the Faculty of the
College of Health Sciences
University of Indianapolis

In partial fulfillment of the requirements for the degree
Doctor of Health Science
By: Pamela M Metzer, OTR

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