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Evaluating Factors that Affect Hand Dexterity after Distal Radius Fracture

Pavlos Bobos, *The University of Western Ontario*

Supervisor: Dr. Joy C MacDermid, *The University of Western Ontario*

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Abstract

Objectives: The primary objective of this study was to determine the effect of age and gender on hand dexterity after distal radius fracture (DRF). The second aim of this study was to evaluate the recovery of hand dexterity in 1-year follow-up of DRF. The third purpose of this study was to determine the extent to which loss of range of motion (ROM) and grip strength predicts hand dexterity 6-months after injury

Methods: A prospective cohort study of 242 patients with DRF examined the recovery of hand dexterity across 3 time-points (3, 6 and 12 months). Dexterity testing was performed using the small, medium and large objects subtests of the NK Dexterity testing; in both hands. The mean of two trials was computed. A generalized lineal model (GLM) multivariate analysis was performed to determine the effect of age and gender on hand dexterity. Repeated measures (GLM) was performed to test recovery over time controlling for age and gender. A second prospective study of 391 patients examined if physical impairments predict hand dexterity at 3 months and 6 months after the DRF. A stepwise multiple regression was performed. Scatter plots were analyzed and the probability level was set at $\alpha=0.05$, CI 95%

Results: Age was a statistically significant predictor for hand dexterity for all size of objects $R^2=0.227$, $p<0.001$ (n=242) with older adults have slower times. Gender was associated with less dexterity to manipulate both large and medium objects, ($R^2=0.038$, $p=0.003$, $R^2=0.044$, $p=0.01$) but no significant effects were found on small objects ($R^2=0.000$, $p=0.860$). Males had better hand dexterity scores on large and medium objects in the 3 to 6-month period. From 6-months to 12-months showed that males on medium objects were worsened while females had a slightly worst dexterity scores on that period. The manipulation of small objects indicated that females were performing much better in all three evaluation time points. Age, sex and radial-ulnar deviation arc of motion were significant predictors of large hand dexterity explaining the 23.2% of the variation in scores while, age and flexion-extension were significant predictors for the manipulation of small objects explaining the 10.9% of the variable at 3-months after fracture (n=391). At 6-months post injury, grip strength, ROM flexion-extension and age were found to be significant predictors explaining 34% of the variation in large hand dexterity. For the small objects, age, grip strength, sex and radial-ulnar deviation were significant predictors explaining 25.3% of the variation (n=319).

Conclusion: This study indicates that dexterity improves rapidly in between 3 and 6 months, and slowly worsened until 1-year following DRF; and it does not recover to the state of the uninjured hand even by 1 year. This would support the need for greater attention to hand dexterity during rehabilitation. Also, this study confirms that demographics and wrist impairments determine dexterity following DRF. At the 3-month follow-up, hand dexterity is determined primarily by ROM radio-ulnar deviation and flexion-extension. At the 6-month follow-up hand dexterity is determined primarily by grip strength and flexion-extension ROM. Identifying predictors of hand dexterity following a DRF can assist clinicians understand the relationship between hand dexterity and physical impairments to improve hand function

Keywords: Distal radius fracture, hand dexterity, functional outcome, dexterity predictors

Co-Authorship Statement

Thesis design and the research questions were formulated by Pavlos Bobos under the supervisory and assistance of Dr. Joy C. MacDermid. My advisory committee members Dr. Emily A. Lalone and Dr. Ruby Grewal reviewed the whole project and provide valuable feedback and suggestions. Data collection was performed by a research assistant in Roth McFarlane Hand and Upper Limb clinic at St. Joseph's Hospital in London, Ontario. Data analysis, interpretation of results and the manuscripts preparation for publication were formulated by Pavlos Bobos.

CHAPTER 1: INTRODUCTION

Pavlos Bobos- sole author

CHAPTER 2: DETERMINE THE EFFECT OF AGE AND GENDER ON HAND DEXTERITY AND EVALUATE THE RECOVERY OF HAND DEXTERITY AFTER DISTAL RADIUS FRACTURE IN 1-YEAR FOLLOW-UP

Pavlos Bobos – primary author, study design, data analysis, interpretation of the results, manuscript preparation

Dr. Joy C. MacDermid- study design, statistical consultation, suggestions for revision of the manuscript

Dr. Emily A. Lalone- suggestions for revisions of the manuscript

Dr. Ruby Grewal- suggestions for revisions of the manuscript

CHAPTER 3: DO IMPAIRMENTS PREDICT HAND DEXTERITY AFTER DISTAL RADIUS FRACTURE

Pavlos Bobos – primary author, study design, data analysis, interpretation of the results, manuscript preparation

Dr. Joy C. MacDermid- study design, statistical consultation, suggestions for revision of the manuscript

Dr. Emily A. Lalone- suggestions for revisions of the manuscript

Dr. Ruby Grewal- suggestions for revisions of the manuscript

CHAPTER 4: GENERAL DISCUSSION AND FUTURE DIRECTION

Pavlos Bobos- sole author

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Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1 Introduction

Distal radius fracture (DRF) is one of the most common fractures and can affect all ages (MacIntyre & Dewan, 2016). One of the characteristics of DRF is that they commonly occur due to low energy falls. A DRF occurs around 2 cm above the distal articular surface at the point where the cortical bone is thinner and is supported by the trabecular bone network (Resnik, 2000). The most commonly described mechanism of DRF is a fall on the outstretched hand typically from a standing position or low height. The older patients tend to sustain an extra-articular DRF in the metaphyseal area; whereas, younger individuals tend to sustain an intra-articular fracture (Goldfarb, Yin, Gilula, Fisher, & Boyer, 2001). Loss of range of motion, swelling and potential deformities can follow a DRF (Ilyas & Jupiter, 2010). Effective management of the DRF must take into consideration the injured muscles and the soft tissue around the hand area as well as, to restore successfully the alignment of the involved bones. There are common features to DRF rehabilitation despite the uniqueness of each injury (Cherubino, Bini, & Marcolli, 2010).

1.1.1 Types and Classification of Distal Radius Fracture

Colles fracture was named from Dr. Abraham Colles in 1814 (Ellis, 2012). The current definition of Colles fracture can be described as a fracture of the radius within 2 cm from the distal radius with dorsal displacement of the dorsal segment (Altizer, 2008). The mechanism of injury is usually reported as a fall on outstretched hand. The evaluation of each fracture is assessed individually since the degree of the injury varies from person to person. One of the main objectives for the management of this type of fracture is to restore the anatomical position of the distal radius with no pain in the wrist (Altizer, 2008). Another type of fracture is the Smith's fracture which sometimes maybe defined as "reversed Colles". Initially, this type of fracture was described by Robert William Smith in 1847 (Paterson, 1966). Smith's fracture is a type of fracture of the distal radius within 2 cm of the articular surface, associated with subluxation of the distal fragment and the carpus (Richard & Terry, 1984). This type of fracture has 3 different categories of classification depending on the obliquity and location of the fracture. Type I fractures are transverse fractures extending from the dorsal cortex to the volar cortex, whereas type II injuries are extending from the dorsal lip of the distal radial articular surface to the volar metaphyseal region. Type III are extending from within the articular surface of the distal radius obliquely to involve its volar aspect (Paterson, 1966). The mechanism of injury on Smith's fracture is commonly described by falling on back of the hand. Moreover, the Barton's fracture should be confined to the anterior fracture dislocation in which a wedge-shaped fragment of radius of varying dimension is sheared of the anterior margin of the radius and displaced with the carpus forward and proximal (de Oliveira, 1973).

1.2 Epidemiology of Distal Radius Fracture

Every year almost 90.000 individuals in USA suffer from DRF commonly by fall from standing height and most often during outdoor activities (yen, Rohde, Hochberg, Johnsen, & Haugeberg, 2010; Chung, Shauver, & Birkmeyer, 2009; Chung, Shauver, Yin, & Birkmeyer, 2010). DRF injuries cause annual expenses in health care exceeding 230 million dollars in the USA (Shauver, Yin, Banerjee, & Chung, 2011). Moreover, these fractures can lead to functional limitations and particularly to the elderly population which can result in loss of independence (Diaz-Garcia, Oda, Shauver, & Chung, 2011; Rozental, Branas, Bozentka, & Beredjiklian, 2002). The highest incidence of DRF has been recorded during the winter months on the grounds that, the falls might be related to outdoor activities and slippery walkways (Jacobsen, Sargent, Atkinson, O'Fallon, & Melton, 1999; Thompson, Taylor, & Dawson, 2004). More recent studies found that an increasing incidence of DRF and reported that lifestyle might play a significant role (Porrino et al., 2014). In the pediatric population, DRF incidence is most common during puberty where the level of the bone mineralization is considered relatively low. DRF injuries have been recorded to be more common to young boys than girls (yen, Rohde, Hochberg, Johnsen, & Haugeberg, 2010; Chung, Shauver, & Birkmeyer, 2009; Chung, Shauver, Yin, & Birkmeyer, 2010). It has been estimated that the cost in USA for the pediatric population extents to 2 billion US dollars annually (yen, Rohde, Hochberg, Johnsen, & Haugeberg, 2010; Chung, Shauver, & Birkmeyer, 2009; Chung, Shauver, Yin, & Birkmeyer, 2010). Since bone remodelling in the pediatric population is faster, better outcomes can usually be achieved (Nellans, Kowalski, & Chung, 2012). Overall, children are less likely to incur a DRF compared to the adult population (Jupiter, 2012). It has been recorded that between the ages 19 to 49, the DRF incidence ratio is higher in men than women. Above the age of 50, the incidence is higher to women than men, partially because of the effect of osteoporosis (Koo, Tan, & Chong, 2013). The common mechanism of injury for the young adult individuals involves outdoor activities and motor vehicle accidents (Nellans et al., 2012). In the elderly population, 85.000 individuals are suffering from DRF annually (Koo et al., 2013; Nellans et al., 2012). Fall from standing height has been reported to be the most common mechanism of injury for this type of population (Nellans et al., 2012). The elderly population has several functional limitations after the incidence and potential medical complications after the injury (Shauver et al., 2011). The impact of a DRF on older adults can affect their ability to be independent in tasks of daily living (Shauver et al., 2011).

1.2.1 Risk Factors of Distal Radius Fracture

Age and gender have been considered as risk factors for DRF; although the gender risk varies age. (MacIntyre & Dewan, 2016). According to recent epidemiological studies (Chung et al., 2010; Giladi et al., 2014; MacIntyre & Dewan, 2016), DRF incidence seems to have two periods of increasing rate during the lifespan. Individuals above the age of 50 and children 18 years old or lower experience higher rates of DRF (MacIntyre & Dewan, 2016). The distribution of gender and age has shown that boys 18 years old or younger they have relatively higher risk compared to girls (Court-Brown & Caesar, 2006). This male predominance it seems to be maintained until the age of 49. After this age, the incidence rate of DRF is much higher for women; who overall have a 15% lifetime risk (Cummings, Black, & Rubin, 1989; Haentjens et al., 2003). The DRF risk levels of men above the age of 50 remain low until the age of 80 (Cummings et al., 1989; Haentjens et al., 2003).

Other risk factors that has been reported in the literature are lifestyle and seasonal factors (MacIntyre & Dewan, 2016). Sport and outdoor activities as well as motor vehicle accidents are among the most common causes of DRF in the pediatric and young adult population respectively (Tsai et al., 2011). Interestingly, a low energy fracture (fall from standing height) seems to be the most common way of injury in the older adult population (Earnshaw, Cawte, Worley, & Hosking, 1998; Tsai et al., 2011; Vogt et al., 2002). Individuals who live in rural areas they have higher chance to sustain high energy fracture even after the adjustment of other risk factors such as age and gender (Diamantopoulos et al., 2012). This study (Diamantopoulos et al., 2012) reported that DRF incidence was higher in winter months. This finding highlights the higher risk of people who living in colder places with snow and ice. In contrast, a study from Tsai et al. (2011) (Tsai et al., 2011) found that the higher chance of DRF incidence in Taiwan is during the summer months because of the typhoons and rains. The epidemiologic literature suggests that environmental factors, lifestyle and the density of the population are sources of risk for DRF.

1.3 Management of Distal Radius Fractures

The management of the DRF is based on many factors such as the type of fracture, the quality of the bone, the patient and the personal experience of the clinicians (Cherubino et al., 2010). The diagnostic criteria, indications or type of fracture that indicate the surgical treatment is needed varies. There is a variety of surgical techniques for DRF and there is no clear indication for a gold standard treatment approach (Cherubino et al., 2010).

The rehabilitation management of DRF aims to manage pain and restore range of motion, grip strength and hand function (Diaz-Garcia & Chung, 2012),(Weinstock, 1999). During the immobilization phase therapy goals are to control the degree of oedema and range of motion exercises for the digits (Weinstock, 1999),(D. W. Smith & Henry, 2002). After the immobilization phase (mobilization phase) therapy goals include oedema and pain control, restore hand, wrist and forearm range of motion and improve grip strength and hand function (Weinstock, 1999). The last rehabilitation phase involves exercises and functional patterns to restore the hand function in their normal activity levels (Michlovitz, LaStayo, Alzner, & Watson, 2001).

1.4 Hand Dexterity

Speed, force, endurance and dexterity are among the basic physiological mechanisms in order a normal subject to manipulate objects (Wiesendanger & Serrien, 2001). Force directed to task manipulation depends on the ability of the muscles to produce force and speed. Endurance requires the previous two elements to be sustained over time. Dexterity is the complex integration of higher brain functions (Wiesendanger & Serrien, 2001). A study from Lemon et al. (2011)(Lemon, Mantel, & Muir, 2011) in conscious monkeys showed that the motor cortex through the pyramid tract and the cortico-motoneuronal connections are involved during the reaching to grasp movement, to the formation of precise grip and to independent finger actions. Also, the sensorimotor cortical areas in grasp actions haven been very well established through transcranial magnetic stimulation in human subjects (RN, RS, Westling, Lemon, & Johansson, 1995). The hand can be described as the most active and interactive tool in the upper extremity in daily life. Manual hand dexterity is defined as a term that can address the combination of different abilities during task movements (Martin, Ramsay, Hughes, Peters, & Edwards, 2015). Martin et al. (2015) (Martin et al., 2015) address those task movements by underlying different elements in order to describe the hand dexterity. Reaction time, hand preference, finger tapping speed, aim, stability of arm and wrist range of motion speed were the terms that were used to describe the combination of hand abilities (Martin et al., 2015).

1.4.1 Measurement of Hand Dexterity as Functional Test

Hand dexterity performance is pivotal to execute daily tasks and can be affected after each injury (Yancosek & Howell, 2009). With respect to the available evidence hand dexterity can be classified as static which does not require any manipulative skills or dynamic which includes power grip and precision together (Aaron & Jansen, 1992). Also, dexterity can be subcategorized as manual dexterity which describes the ability to move hands skillfully or as fine finger dexterity which is the ability to manipulate objects by fingers (Weintraub, Gilmour-Grill, & Weiss, 2010; Yancosek & Howell, 2009). Many tests have been developed for the measurement of hand dexterity however the most widely used are the Jebsen-Taylor Hand Functional Test (JTHFT)(Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969), the Box and Block Test (BBT)(V. Mathiowetz, Volland, Kashman, & Weber, 1985), the Purdue Pegboard Test (PPT)(Tiffin & Asher, 1948), the Nine-hole Peg Test (NHPT)(Virgil Mathiowetz, Weber, Kashman, & Volland, 1985), the Functional Dexterity Test (FDT)(Aaron & Jansen, 1992), the NK Hand Dexterity Board (NKHDT)(Turgeon, MacDermid, & Roth, 1999) and the ReSense Test(Kalron, Greenberg-Avrahami, & Achiron, 2014). All these instruments have been developed to assess the hand dexterity after neurological and musculoskeletal disorders. A brief description of these instruments is the different task execution against time by using your hand and your fingers to manipulate objects. It is important to understand that such assessments are very pivotal to understand a person's hand function after an injury. The evaluation of hand dexterity can be very challenging and complex especially when the dexterity tests have been shown poor clinimetric properties. A systematic review and a meta-analysis from Lucelle et al. (2009) (van de Ven-Stevens, Munneke, Terwee, Spauwen, & van der Linde, 2009) identified 5 different hand dexterity tests from the 23 that their clinimetric properties have been adequately described. In conclusion, none of the instruments was found with a positive rating of their clinimetric properties. This highlights the lack of gold standard for measuring hand dexterity.

1.5 Description of the Gap in the Existing Literature

Although there are many studies evaluating hand dexterity for healthy subjects, the existing literature is very incomplete regarding hand dexterity and DRF. There are many studies that are using hand dexterity as a functional outcome evaluation test to identify impairments. Two hand dexterity tests have been found to stratify upper limb and hand function after stroke (Thompson-Butel, Lin, Shiner, & McNulty, 2014). Hand dexterity test has also been used to evaluate hand function in Parkinson's disease(Mak, Lau, Tam, Woo, & Yuen, 2015). Physiotherapists and Occupational Therapists evaluate hand function to have a baseline for their treatment plan. Dexterity is a performance-based assessment of hand function, that can provide information useful for treatment planning. Previous clinical studies such as therapy practice patterns (Michlovitz et al., 2001) and randomized controlled trials (Kay, McMahon, & Stiller, 2008; Maciel, Taylor, & McIlveen, 2005) focused on improving activity after DRF but, none of them provided hand dexterity exercises or used any hand dexterity test to evaluate the hand function.

1.6 Objectives of this Thesis

The purpose of this thesis is to determine factors that affect hand dexterity and investigate hand dexterity recovery after DRF injury. There were specific 3 research questions addressed with respect to dexterity following DRF:

1) Do age and gender affect hand dexterity scores?
2) Do hand dexterity scores change across 3 intervals 3, 6 and 12-months after DRF?
3) Do physical impairments in range of motion (ROM) and grip strength predict hand dexterity at 3-monts and 6-months after DRF injury?

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Chapter 2: Determine the effect of age and gender on hand dexterity and evaluate the recovery of dexterity after distal radius fracture (DRF). A 1-year prospective cohort study

Abstract

Background

Factors that predict hand dexterity as an advanced functional outcome following a distal radius fracture (DRF) have not yet been examined. The first objective of this study was to determine the effect of age and gender on hand dexterity. The second objective was to evaluate the recovery of hand dexterity after DRF during 1-year period

Methods

Hand dexterity was examined bilaterally for the manipulation of 3 different objects (small, medium and large). The measurements took place at 3-months, 6-months and 12-months after DRF was occurred. Generalized linear model (GLM) multivariate analysis and GLM repeated measures was performed with variable predictors age and gender.

Results

Overall, 242 DRF patients participated in this study. Age was a statistically significant predictor for hand dexterity for all size of objects R^2=0.227, p<0.001 (n=242) with older adults have slower times. Gender was associated with less dexterity to manipulate both large and medium objects, (R^2=0.038, p=0.003, R^2=0.044, p=0.01) but no significant effects were found on small objects (R^2=0.000, p=0.860). Males had better hand dexterity scores on large and medium objects in the 3 to 6-month period. From 6-months to 12-months showed that males on medium objects were worsened while females had a slightly worst dexterity scores on that period. The manipulation of small objects indicated that females were performing much better in all three evaluation time points.

Conclusions

Our study found that age and gender mediate hand dexterity scores after DRF on 12-months period. Therapists should compare recovery of dexterity to the age-and gender matched comparisons. Recovery is rapid between 3 and 6-months and continues up until 12-months. Greater attention to

tracking dexterity may guide hand therapists in designing and monitoring recovery of had function following DRF.

Key words: hand dexterity, hand fracture, distal radius fracture

Level of evidence: Prognosis, 2a

2.1 Introduction

Distal radius fracture (DRF) has become a very common injury among all age groups (Porrino et al., 2014). A common complication after distal radius fracture is impaired mobility and function of adjacent upper limb joints, usually worsened in the presence of post traumatic oedema (Dekkers & Søballe, 2004; Gutow, 2005; Warwick, Field, Prothero, Gibson, & Bannister, 1993). Rigid forearm and wrist motion is one of the most pervasive implications affecting the individuals' daily activities and hand performance (Dekkers & Søballe, 2004; Gutow, 2005; Warwick et al., 1993). Also, it has been reported that individuals with high self-reported disability following a DRF not only risk absence from work (MacDermid, Roth, & McMurtry, 2007) but also, long term-disability (Holmberg et al., 2006; Valtola et al., 2002). The assessment of hand dexterity provides a distinct method of evaluating the neuromotor function of the whole hand on the basis that sensation, hand movement and strength are combined to execute detailed dextrous tasks (Yancosek & Howell, 2009). Hand skill assessment is very critical during rehabilitation recovery periods because dexterity is one of the pivotal elements for hand functionality and a skill dexterity test provides an indication of functional ability to hand therapists (Cederlund, 1996). However, it seems that dexterity is an undervalued functional outcome since most DRF studies focus on grip strength, wrist range of motion, wrist stability and to a lesser extent swelling (Dias, Wray, Jones, & Gregg, 1987; McAuliffe, Hilliar, Coates, & Grange, 1987; Millet & Rushton, 1995). The main goal of a hand therapy program is to optimize hand activity (Cherubino et al., 2010). There is no clear guidelines for managing hand dexterity (Kay et al., 2008; Maciel et al., 2005; Michlovitz et al., 2001). Initial steps to defining interventions that optimize hand dexterity are understanding what deficits occur, how they change over time and the factors that predict dexterity. The primary aim of this study was to investigate the predictors that may contribute to hand dexterity after DRF. The second aim of this study is to evaluate the recovery of hand dexterity followed by a DRF.

2.2 Materials and Methods

2.2.1 Study design

This study was a prospective cohort study design that was conducted at the Roth McFarlane Hand and Upper Limb Centre at St. Joseph's Health Care in London Ontario. Institutional research ethics was obtained. The study design complied with the STROBE reporting guidelines (Vandenbroucke JP, von Elm E, Altman DG, et al., 2007)

2.2.2 Recruitment and Participants

Individuals were eligible to participate in the study if they had a DRF. Participants were excluded if they could not speak English or if they had neurological disorders or any other pre-fracture comorbidities limiting their ability to easily manipulate objects. A consent form was signed by all participants. Patients were recruited between 18 to 65 years old. Demographic features were collected by a research assistant such as injured hand, the mechanism of fracture, dominant hand, treatment, age, gender and medical history. Assessments took place from September 2011 until August 2015 and the dexterity data were recorded at 3 time points, 3 months, 6 months and 12 months after the DRF by a research assistant who was responsible for the measurements.

2.2.3 Outcome Variable

The dependent variable was hand dexterity. Hand dexterity was measured bilaterally 3 months after DRF (affected and unaffected hand) using 3 sizes of objects (small, medium and large). Dexterity was measured with NK dexterity board (NKHDT) which the reliability and validity have been tested in previous studies (MacDermid & Mulè, 2001; Turgeon et al., 1999) ranging from fair to excellent reliability and validity from moderate to strong. Previous studies have been found that the NKHDT is a responsive test to evaluate the dexterity recovery from DRF (Amadio, Silverstein, Ilstrup, Schleck, & Jensen, 1996). The NKHDT (FIGURE 1) is a computerized timing evaluation tool which comprises of three different levels of hand dexterity tests (small, medium large). The NK hand dexterity board measures the ability of the individual to manipulate objects against time (seconds). The testing procedure and the testing protocol was adopted by Turgeon et al. (1999)(Turgeon et al., 1999)

The independent variables were the demographic data. Demographic data were collected by an initial evaluation form from the research assistant and included age (18-85), gender (male or female), dominant hand (left or right), injured hand (left or right) and mechanism of fracture (1=Fall on ice or snow, 2=other fall, 3=motor vehicle accident, 4=industrial accidents, 5=during sports, 6=other).

2.3 Statistical Analysis

Descriptive analysis was used to identify the demographic and clinical features of our sample. Hypothesis was tested with multivariate analysis generalized linear model (GLM) to evaluate predictors (age and gender) that affect hand dexterity and with repeated measures to analyze the hand dexterity recovery between 3 and 12-months period (3 times points). A post hoc statistical power analysis for multiple regression was performed to identify the power of the sample. Plots were used for both available predictors to examine the data relationship and the hand dexterity recovery between 3-months and 12-months period. An SPSS 22.0 software was used and significance level was set at $\alpha=0.05$

2.4 Results

Overall, 242 patients with mean age 60.2 years old, SD ±11.26 with DRF were found eligible and agreed to participate in the study. Our sample included 45 males and 197 females with 217 patients having right hand dominance and 23 the left (2 were not reported). The right hand was injured from 44% of the included sample and the left hand from 54% (Table 1). The highest incidence of mechanism of fracture was by “fall from standing height” at a total of 76.1% (24.4% “Fall on ice or snow” and 51.7% “other fall”) (Table 1). A post hoc statistical power analysis for multiple regression was performed. The number of predictors were 2 (age and gender), the number of the average observed $R^2=0.127$ for large hand dexterity, $R^2=0.173$ for medium dexterity and $R^2=0.056$ for small hand dexterity. The probability level was set at $\alpha=0.05$ and the sample size at 238 DRF patients. Therefore, the observed power was 0.99 for large and medium objects hand dexterity and 0.92 for the small objects.

None of the individuals were excluded from the study since all recruited patients met our eligibility criteria. 240 patients completed the 3-month evaluation time point, 237 at the 6-month and 240 at the 12-month period (Figure 2 Flow diagram). Multivariate analysis showed that age was a statistically significant predictor for hand dexterity for all size of objects $R^2=0.227$, $p<0.001$ (n=242) with older adults have slower times (Table 2). Gender as variable was associated with less dexterity to manipulate both large and medium objects, ($R^2=0.038$, $p=0.003$, $R^2=0.044$, $p=0.01$) but no significant effects were found on small objects (R^2=0.000, p=0.860) (Table 2). Significant improvements in large object dexterity were found between 3-months to 6-months and from 3-months to 12-months period (p=0.002) but no statistical difference was observed from 6-months to 12-months (p=0.977) indicating that the majority of improvement occurred by 6 months (Figure 3-5)**,** (Table 3). Medium object dexterity improved from 3-months to 6-months period (p=0.002) and from 6-months to 12-months (p=0.016), but no statistically significant difference was observed from the 3-months to 12-months period (p=0.773) (Figure 3-5)**,** (Table 3). Hand dexterity recovery analysis for small objects showed a statistically significant difference from 3-months to 6-months period (p=0.013) and from 6-months to 12-months period (p=0.024) but no statistically significant difference was found from 3-months to 12-months (p=0.152) (Figure 3-5)**,** (Table 3). Moreover, the injured performed significantly poorer than the injured hand compared at all three evaluation time points during the 12-month period.

2.5 Discussion

This study indicates that dexterity improves more in between 3 and 6 months, and slowly worsened until 1-year following DRF; and it does not recover to the state of the uninjured hand even by 1 year. This would support the need for greater attention to hand dexterity during rehabilitation. This study also determined that age and gender are predictors of hand dexterity, so that scores should only compared between people or groups when these factors have been controlled for. Age-gender based norms are important for comparison.

The proportion of females compared to males was large (197 females and 45 males) which is reflective in part to the higher predominance of females having DRF; but may also indicate some volunteer bias. Since we did record all eligible fractures we cannot determine this. However, our drop out in the three evaluation time point was negligible.

This study indicated 2 factors (age and gender) influence on hand dexterity scores. The association between poor hand dexterity and increasing age has been reported in previous studies (Amrhein, Stelmach, & Goggin, 1991; Cerella, 1985; Jakobson & Goodale, 1991; Martin et al., 2015; C. D. Smith et al., 1999; Wishart, Lee, Murdoch, & Hodges, 2000). Furthermore, several studies have shown that the reduction of mass muscles with increasing age also has an effect on reduced neuromuscular junctions (Dorfman & Bosley, 1979; Kurokawa, Mimori, Tanaka, Kohriyama, & Nakamura, 1999; Mackenzie & Phillips, 1981), proprioception (Ribeiro & Oliveira, 2007) and degeneration changes in the central nervous system (Lexell, 1997; Payne & Delbono, 2004) (motor cortex) which may be linked to reduced hand dexterity performance. Although general exercise used to improve ROM and strength may also have a positive effect on dexterity exercise specificity would suggest that dexterity exercises might have a role in changing the hand dexterity and therefore improving the hand function.

Gender was a significant predictor. With respect to the available evidence from the literature our preliminary literature review identified two studies (Haward & Griffin, 2002; Macdermid, 2001) that examined the relationship of gender and hand dexterity scores on healthy subjects. More specifically, the two studies showed conflicting results about hand dexterity scores and gender. Haward and colleagues (2002) (Haward & Griffin, 2002) found no difference on 72 healthy subjects while the other study from MacDermid and colleagues (2001)(Macdermid, 2001) found that gender was a significant predictor for dexterity scores on 50 healthy individuals. The latter study was conducted with the NK dexterity test so the results are more comparable to the present. Although few studies of dexterity have specifically tested age and gender as predictors, many have assumed that these are predictors when presenting norms as these are often used to subcategorize the data. Males had better (faster) hand dexterity scores on large and medium objects in the 3 and 6-month period. Our visual plot (Figure 4) for medium objects from 6-months to 12-months showed that males were worsened while females had a slightly worst dexterity scores on that period. The data analysis for the manipulation of small objects indicated that females were performing much better in all three evaluation time points. This interesting observation may be explained by the fact that females may be more capable on the manipulation of small objects because these tasks require fine coordination, repeated precise performance of more selective accurate movements and are not based on grip strength. However, it is a limitation of our study that male population with DRF was underrepresented in our sample and there is a lack of gold standard for hand dexterity tests, this may indicate some potential biases to our results.

2.6 Conclusions

Our study found that dexterity improves between 3 and 6 months and slightly worsened between 6 and 12 months after fracture; without reaching the unaffected side by 12-months following fracture. Age and gender influence both dexterity scores and recovery patterns during the year following DRF. Greater attention to measuring and treating dexterity may be investigated which means to provide more complete recovery after DRF.

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Table 1. Demographic features of 242 DRF patients

	n	%	Average	SD
Gender				
Male	45	18%		
Female	197	82%		
Age group			60.2	11.2
18-44	20	8.%		
45+	222	92%		
Dominant Hand				
Left	23	9%		
Right	217	90%		
Injured Hand				
Left	130	54%		
Right	108	45%		
Both	1	1%		
Mechanism of injury				
Fall on snow or ice	59	24%		
Other Fall	125	51%		
MVC	1	1%		
Industrial accident	30	12%		
During Sports	2	2%		
Other	22	10%		

Table 2. Results of GLM multivariate analysis with variable predictors age and gender

Dependent Variables	Variable Predictors	B	Std. Error	t	R^2	p-value	95% CI Lower Bound	95% CI Upper Bound
3m Dexterity-Large	Gender	4.55	1.52	2.99	.037	.003	1.56	7.55
	Age	.26	.05	5.14	.098	p< .001	.16	.36
6m Dexterity-Large	Gender	2.91	.95	3.04	.038	.003	1.02	4.80
	Age	.21	.03	6.85	.164	p< .001	.15	.27
1y Dexterity-Large	Gender	2.14	1.02	2.10	.019	.036	.13	4.15
	Age	.18	.03	5.70	.118	p< .001	.12	.25
3m Medium-Medium	Gender	6.14	1.93	3.17	.041	.002	2.3	9.96
	Age	.4	.06	6.43	.150	p< .001	.28	.52
6m Medium-Medium	Gender	5.05	1.52	3.3	.044	.001	2.04	8.06
	Age	.39	.04	8.31	.227	p< .001	.3	.48
1y Dexterity-Medium	Gender	-1.84	3	-.61	.002	.538	-7.76	4.06
	Age	.37	.1	3.69	.055	p< .001	.17	.56
3m Dexterity-Small	Gender	.96	5.45	.17	.000	.860	-9.78	11.7
	Age	.65	.18	3.59	.052	p< .001	.29	1.01
6m Dexterity-Small	Gender	-.55	2.12	-.26	.000	.794	-4.74	3.63
	Age	.47	.06	7.2	.181	p< .001	.34	.6

1y Dexterity-Small	Gender	-2.12	2.27	-.93	.004	.351	-6.61	2.35
	Age	.57	.06	8.37	.231	p< .001	.44	.71

Table 3. Mean comparisons and significance levels on hand dexterity recovery

Evaluation Time point (months)		Mean Difference (seconds)	Std. Error	p-value	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Large Dexterity	3-6	1.35	.42	.002	.52	2.19
	3-12	1.36	.43	.002	.50	2.22
	6-12	.01	.32	.977	-.63	.65
Medium Dexterity	3-6	1.66	.52	.002	.62	2.7
	3-12	-.23	.81	.773	-1.85	1.37
	6-12	-1.9	.78	.016	-3.43	-.36
Small Dexterity	3-6	3.29	1.31	.013	.69	5.88
	3-12	1.87	1.3	.152	-.69	4.44
	6-12	-1.41	.62	.024	-2.64	-.19

Figure 1. NK Hand dexterity device

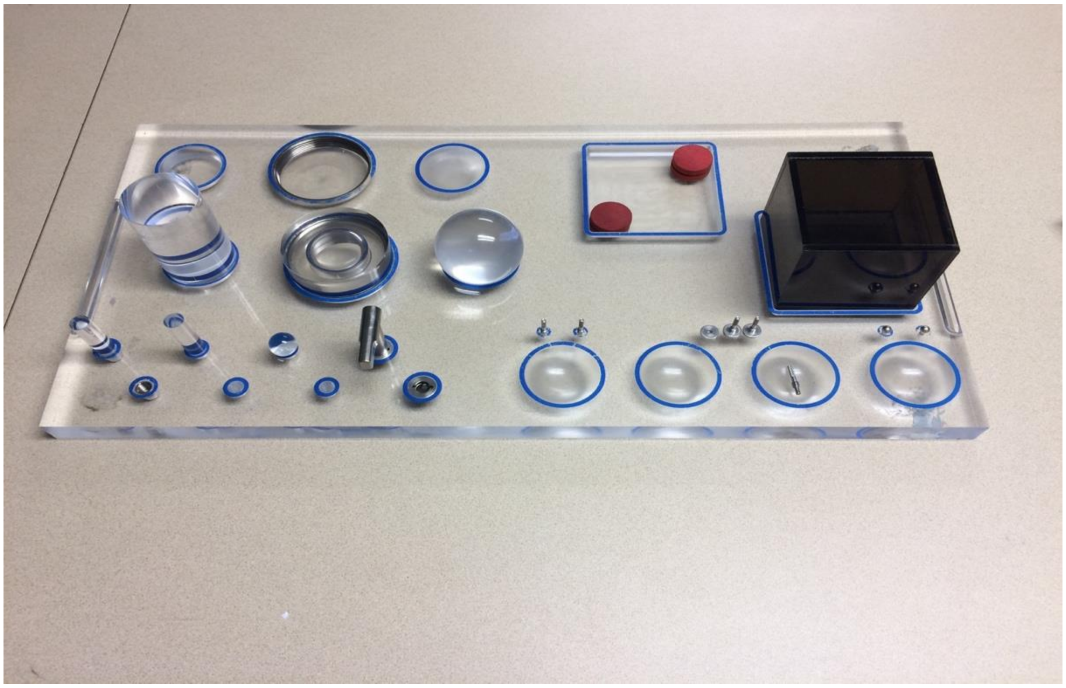


Figure 2. DRF Patients Flow diagram

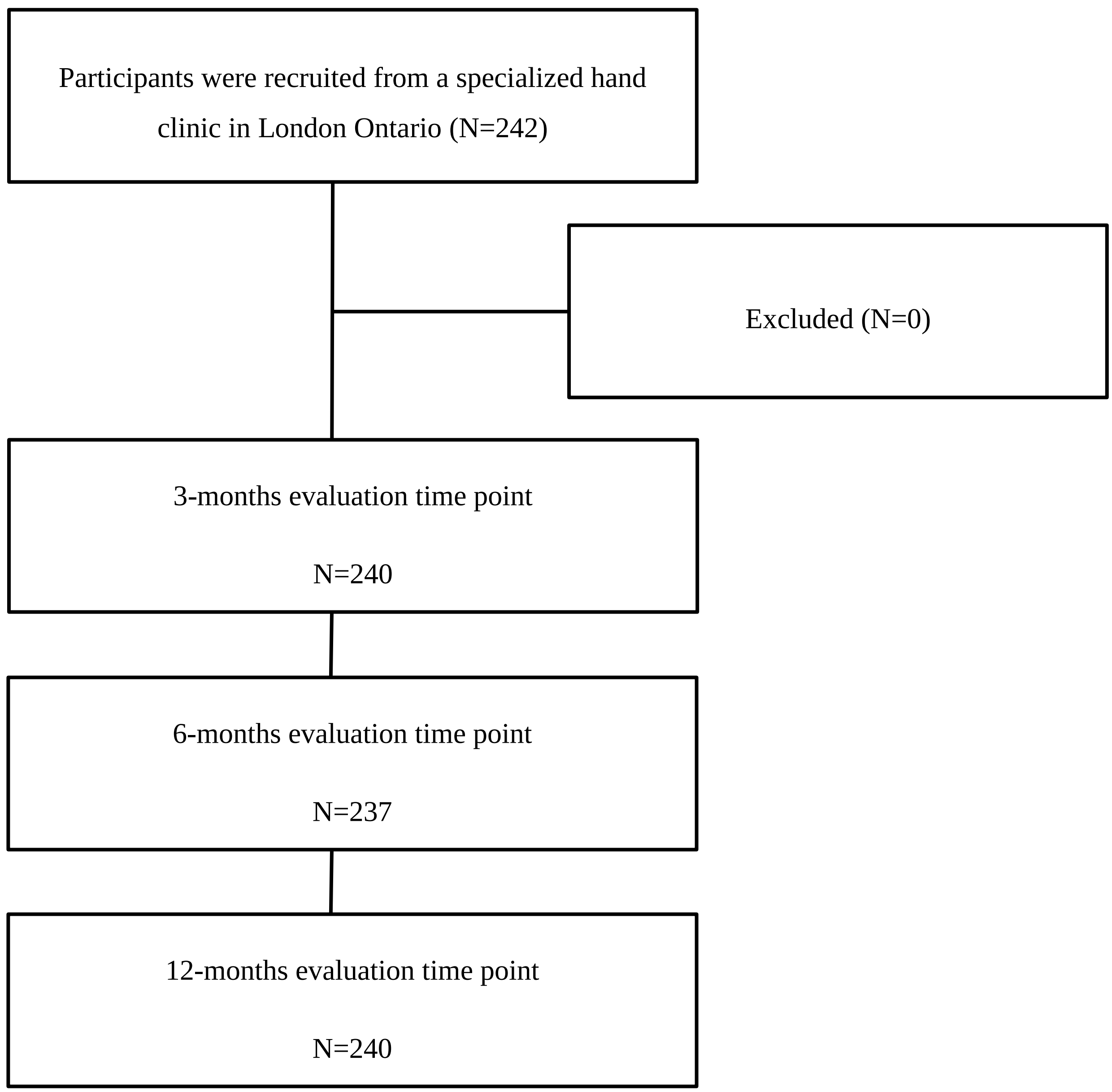
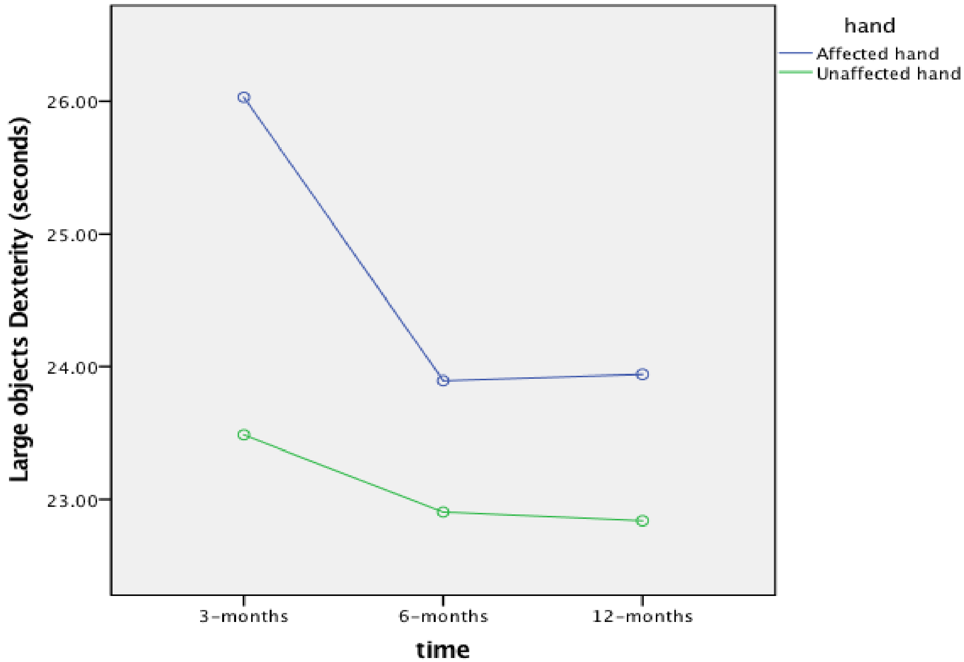


Figure 3. Hand dexterity recovery plots on large objects by hand and by gender



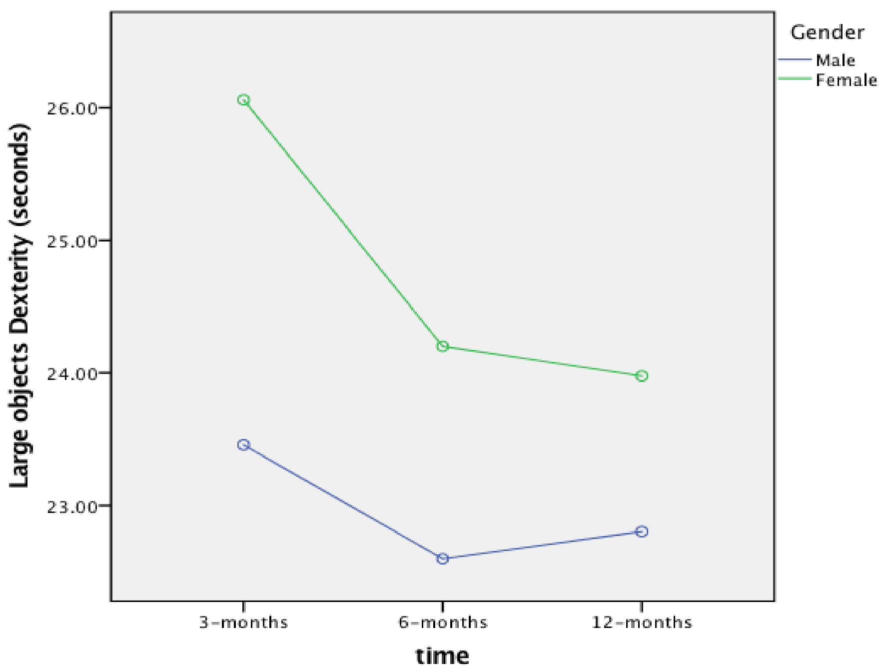
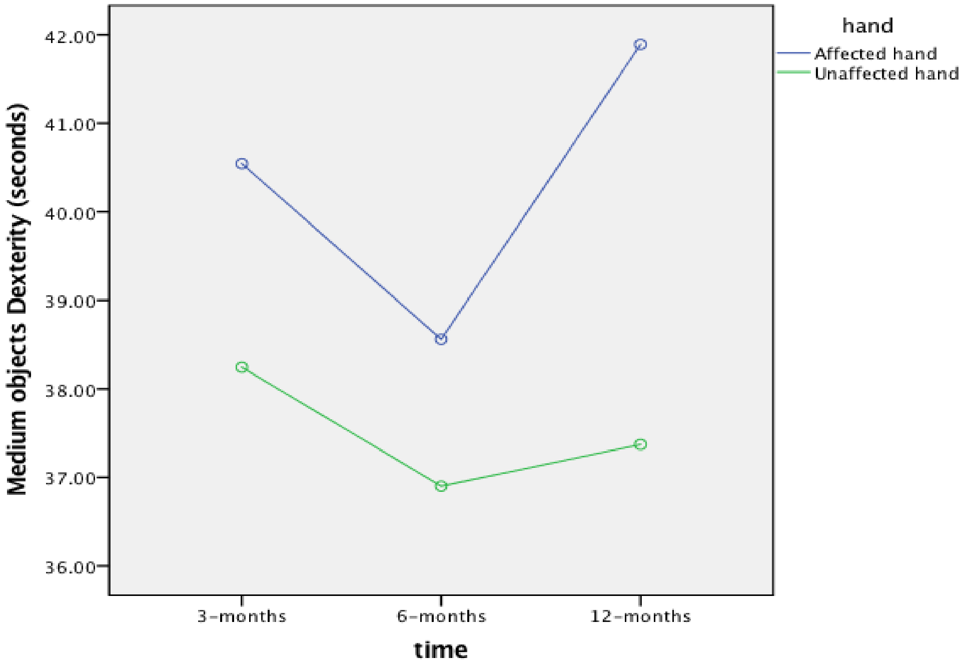


Figure 4. Hand dexterity recovery plots on medium objects by hand and gender



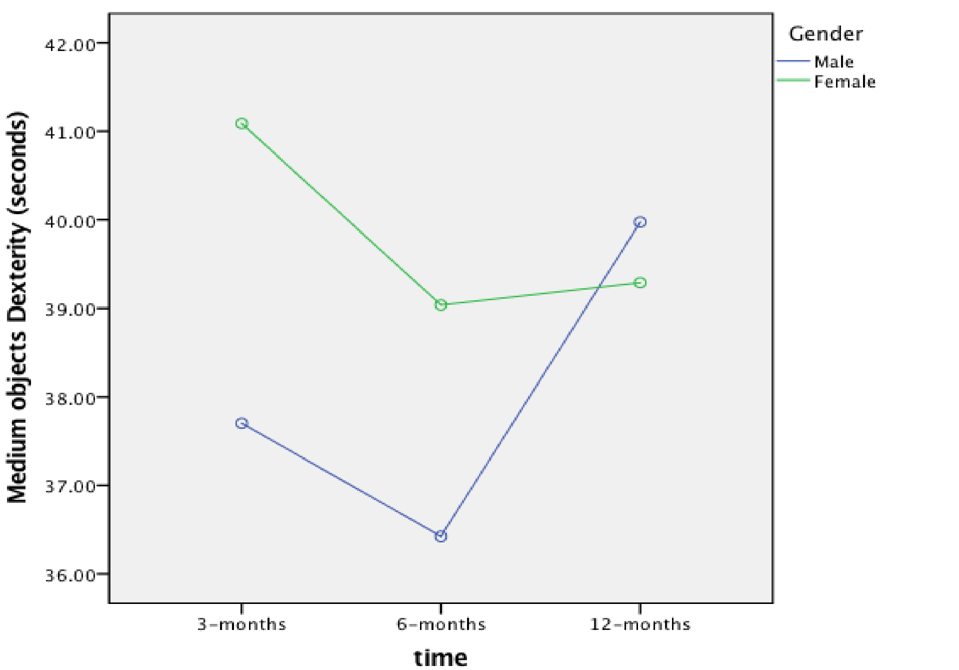
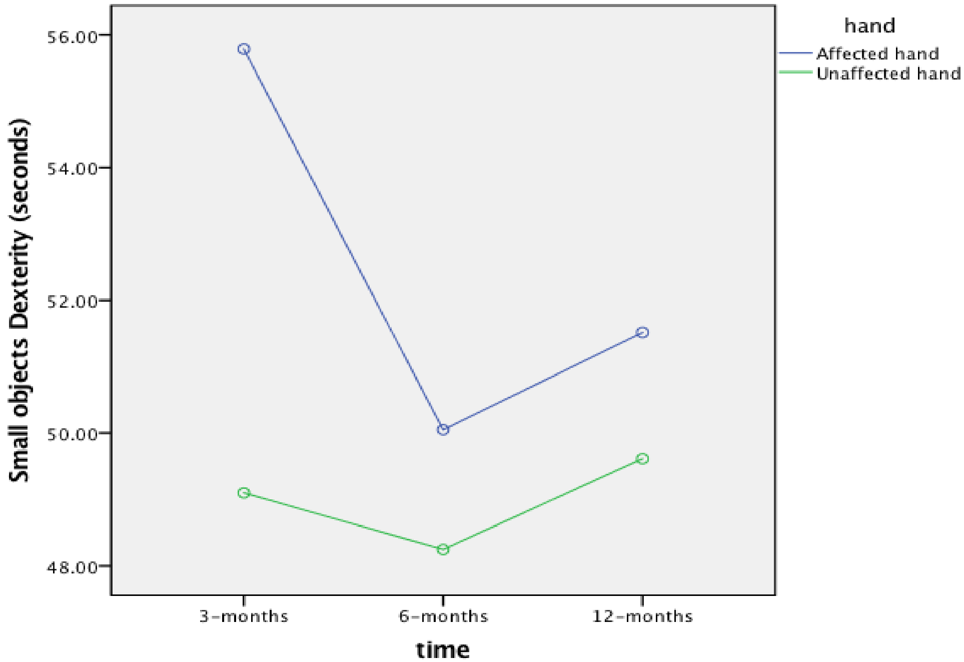
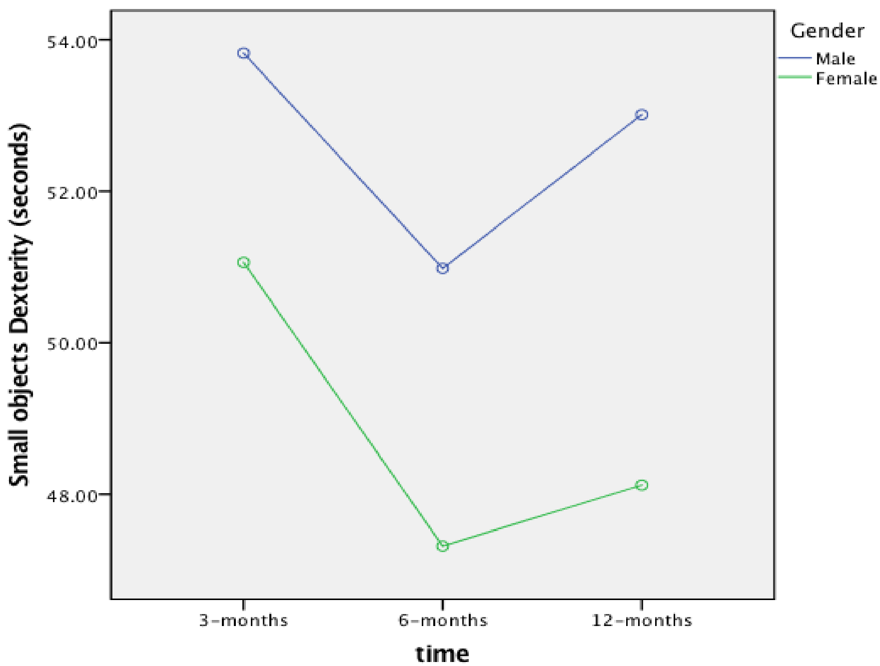


Figure 5. Hand dexterity recovery plots on small objects by hand and gender





Chapter 3 Do impairments predict hand dexterity after distal radius fracture. A 6-month prospective cohort study

Abstract

Background

The relationship of hand dexterity and physical impairments after distal radius fracture (DRF) has not yet been thoroughly examined. The purpose of this study was to investigate if loss of range of motion (ROM) and grip strength predict hand dexterity following a DRF 6-months after injury.

Methods

Descriptive statistics for all variables were utilized to capture the clinical characteristics of study subjects. A stepwise multiple regression was performed, with 6-month large and small hand dexterity scores in the affected hand as the outcome (dependent) variables; and grip, ROM and age and sex as the potential independent predictors. Scatter plots were analyzed and the probability level was set at $\alpha=0.05$

Results

Age, sex and ROM radial-ulnar deviation were significant predictors of large hand dexterity explaining the 23.2% of the variations while, age and flexion-extension were significant predictors for the manipulation of small objects explaining the 10.9% of the variation at 3-months after fracture. At 6-months post injury, grip strength, ROM flexion-extension and age were found to be significant predictors explaining 34% of the large hand dexterity. For the small objects, age, grip strength, sex and radial-ulnar deviation explained 25.3% of the variation.

Conclusions

The impairments of ROM and grip that occur after DRF, predict dexterity but to a maximum of 1/3 of the variation, leaving other contributors open to investigation.

Keywords: hand dexterity, grip strength, range of motion, distal radius fracture

Level of evidence: Prognosis, 2a

3.1 Introduction

The annual incidence of distal radius fractures (DRFs) in the adult population is increasing (Mellstrand-Navarro, Pettersson, Tornqvist, & Ponzer, 2014). DRF incidence peaks have been recorded in the literature for young children, middle age men and elderly women (Court-Brown & Caesar, 2006). The reasons behind the peaks in incidence rate of DRF for certain age groups can be multi-factorial (Koo et al., 2013). Restoring the hand functioning after distal radius fracture (DRF) is the primary goal. The management of patient and injury characteristics plays an important role in customizing the rehabilitation program. Regardless of whether the fracture is treated surgically or not, DRF patients are expected to gain back their optimum strength and their normal range of motion by 6 months' (MacDermid et al., 2007). Despite the expectations for a positive outcome, this is not always predictable (Grewal, MacDermid, Pope, & Chesworth, 2007). Hand functioning is dictated by the level of impairment in range of motion, grip strength, hand dexterity and the absence or presence of pain. A hand fracture is causes variable levels of impairments and tracking the patients progress and how it compares to expect outcome trajectories is fundamental to target and adapt the rehabilitation program. Most of the available literature has focused on physical impairments such as hand range of motion or hand grip strength as functional outcome measures after DRF. Hand dexterity is a combination of different hand abilities that are used to manipulate objects efficiently, hence time is used as an indicator of hand function. Hand dexterity has been used to identify neurological deficits after stroke (Thompson-Butel et al., 2014) and many other neurological conditions (Ghandi Dezfuli, Akbarfahimi, Nabavi, Hassani Mehraban, & Jafarzadehpur, 2015; Kalron, Greenberg-Abrahami, Gelav, & Achiron, 2013; Lee et al., 2010) because it indicates the neurological impairment that is reflected in coordination of movement.

So far, there is no current evidence-based clinical practice guideline that provides strong support for the treatment of DRF surgical or conservative (Bruce et al., 2016). Hand dexterity is not addressed in either the AAOS practice guideline (Bruder, Taylor, Dodd, & Shields, 2013; Cherubino et al., 2010; Ilyas & Jupiter, 2010; Lichtman et al., 2010), or the Cochrane review of DRF rehabilitation. This suggest that hand dexterity is not a major focus in the literature, or consequently, in rehabilitation programs. Furthermore, impaired grip strength and range of motion after DRF does not necessarily means presence of pain or disability (MacDermid, Donner, Richards, & Roth, 2002). By determining the relationship between physical impairments and functional hand performance following a DRF we can better understand how impairment-based interventions and changes are likely to impact on hand function. This may lead to better therapeutic interventions. The purpose of this study was to investigate if impairments in range of motion and grip strength predict hand dexterity followed by a DRF in a 6-months follow-up period.

3.2 Materials and Methods

3.2.1 Study design

A prospective cohort study was conducted and is reported according to the STROBE reporting guideline checklist (Vandenbroucke JP, von Elm E, Altman DG, et al., 2007). All measurements took place in an orthopaedic upper limb specialized clinic (HULC) at St. Joseph Hospital in London Ontario, Canada. Ethical approval was given by Faculty of Health Sciences Ethics Committee of Western University

3.2.2 Recruitment and Participants

Individuals between 18 to 65 years old were eligible to participate in the study if they had a DRF and they could do the evaluation at 3-months after DRF. DRF patients were excluded from the study if they had any neurological deficit or any other comorbidities that impaired their ability to manipulate large and small objects. An evaluation form was completed by the participants with written consent that they agree to participate in the study. A research assistant was responsible for the measurements and gathered basic information regarding the demographic characteristics of the DRF patients. Age, sex and dominant hand side, and a medical history was taken. In total, 391 DRF participants were recruited and agreed to participate in the study. Two-point evaluation timeframe measurements were recorded in a 6-months follow up period in the clinical lab of Roth|McFarlane Hand and Upper Limb Centre at St. Joseph's hospital after the DRF.

3.2.3 Outcome variable

The dependent variable was hand dexterity and was measured in two different variables for the manipulation of small and large objects in the affected hand. The manipulation of large and small objects was measured with the NKDHT board in seconds.

The independent variables were range of motion, grip strength, age, gender and demographic data. Range of motion was measured with a manual goniometer in the affected hand and included several variables such as, forearm supination and pronation, wrist flexion and extension, ulnar and radial deviation (Armstrong, MacDermid, Chinchalkar, Stevens, & King, 1998)(Bashardoust Tajali, MacDermid, Grewal, & Young, 2016). The reliability, validity and responsiveness of manual goniometer has been examined in elbow and forearm in previous studies and was found very high (Armstrong, MacDermid, Chinchalkar, Stevens, & King, 1998). From the six-different range of motion variables, three summary variables were created (arc of flexion-extension, supination-pronation and ulnar-radius deviation). Grip strength was measured in the affected hand with JT medical digital strength dynamometer at 3-months and 6-months (J. MacDermid, Alyafi, Richards, & Roth, 2001). Demographic features such as gender, age, injured hand, dominant side and mechanism of fracture were collected to capture the characteristics of the included sample.

3.2.4 NK Hand dexterity board device

The NK hand dexterity board (NKHDT) is a valid (J C MacDermid & Mulè, 2001), reliable (Turgeon et al., 1999), and responsive (Amadio et al., 1996) device. NKHDT board (FIGURE 1) which is a computerized timing assessment and measures the hand dexterity on three different levels (small, medium and large). For the purpose of this study only two levels of hand dexterity were measured (small and large) for the affected hand. The measurement testing protocol and procedure was performed according to Turgeon et al. (1999)(Turgeon et al., 1999) criteria.

3.2.5 JTech medical grip strength device

The hand grip strength was measured with JTech medical grip strength device (FIGURE 1). The tracker computerized grip dynamometer is a wireless grip device that provides reliable hand grip strength evaluation. The reliability of the JTech device has been tested in previous studies (Clerke, Clerke, & Adams, 2005)(J. MacDermid et al., 2001) and the test re-test reliability on 149 healthy was excellent (ICC=0.954-0.973). Instructions for the testing procedure for the hand grip strength was given by the research assistant according to Clerke et al. (2005) (Clerke et al., 2005) testing protocol.

3.3 Statistical analysis

An SPSS software was used for the data analysis. A descriptive statistic for all variables was utilized to capture the clinical characteristics of DRF individuals. A stepwise multiple regression was performed with 95% Confidence Interval (CI) in a 6-months follow-up period. Scatter plots and standardized residual plots were analysed. Variables were retained if the residual errors followed a normal distribution and the variation from homoscedasticity was constant. Probability level was set at alpha 0.05. Primary metrics of interest were the R^2

3.4 Results

In 3-months after the DRF, 391 patients (Table 4) participated in the study (Males 23.2%, Females 76.8%) with mean age 58.53 ± 12.82. The majority of the dominant hand side of individuals were the right hand (90.8%). The proportion of the right injured hand was 43.2% and 53.9% on left side while only the 0.2% injured both sides. The average completion time of hand dexterity for the manipulation of large objects was 27.11 ±9.41 seconds while the small was 54.38 ±27.51 seconds. The average arch measurement of range of motion (ROM) flexion-extension was 91.31° ±23.60°, ROM supination-pronation was 138.72° ±38.54° and ROM ulnar-radius deviation 36.38° ±12.40°. The average measurement of hand grip strength was 21.21 ±8.99 kg force. In 6-months follow-up 319 DRF patients (Table 4) in total completed the second assessment. The average time of large hand dexterity was 24.63 ±6.54 seconds while for the small objects the average was 49.58 ±14.43 seconds. The average arch measurement of ROM flexion-extension was 102.08° ±23.32°, ROM supination- pronation 146.07° ±18.44° and the ROM ulnar-radius deviation was 40.46° ±13.23°. The average of hand grip strength after 6-months was 21.17, ±8.82 kg of force. A multiple regression post hoc statistical power analysis was calculated where, the number of predictors were six (grip strength, age, gender and three variables of the arch of range of motion), the minimum observed R^2=0.142 in 3-months period and the minimum observed R^2=0.070 for 6-months period. Probability level was set at alpha 0.05 and therefore, the observed statistical power was 0.99 for 3-months and 0.97 6-months period for 391 and 319 DRF patients respectively.

Predictors of the large and small hand dexterity in 3-months period

The stepwise multiple regression revealed that flexion-extension arc, age, sex and radial-ulnar deviation were significant predictors of large hand dexterity, explaining the 23.2% of the variability in the scores (Table 5) (Figure 6). Our multivariate analysis showed that age and ROM flexion-extension were significant predictors for the manipulation of small objects explaining the 10.9% of the variability of the scores (Table 5) (Figure 7)

Predictors of the large and small hand dexterity in 6-months period

Multiple regression analysis found significant predictors of the large hand dexterity grip strength, ROM flexion-extension and age explaining 34% of the variability scores (Table 6) (Figure 8). For the manipulation of small objects our model found significant predictors age, grip strength, sex and ROM ulnar-radius deviation by explaining the 25.3 of the variability scores (Table 7) (Figure 9).

3.5 Discussion

This study was a 6-month prospective cohort study and investigated if physical impairments such as range of motion (ROM) and grip strength predict dexterity after DRF. Evaluating predictors of functional outcome such as dexterity can be very difficult to fully analyze since there is a large variation in the samples and in the therapeutic interventions on the long-term follow-ups. A recent systematic review and a meta-analysis from Walenkamp et al. (2016) (Walenkamp, Aydin, Mulders, Goslings, & Schep, 2015) found that the small sample size was one of the main drawbacks for a further understanding the predictors after DRF. The aim of this study was to address a fuller understanding and define the predictors of hand dexterity following DRF. Our power analysis (Power=0.97-0.99) indicated that our sample size was sufficient to obtain adequate power, despite the 72 persons that dropped-out during the 6-month period. The percentage of males was underrepresented in our study but this can be partially explained by volunteer bias. Furthermore, an interesting observation to our descriptive data (Table 4) is the slight improvement on dexterity scores for both objects with less variability in 6-months. This small improvement can be either explained as a learning effect or that the recovery of dexterity is getting better or both. Also, the ROM was improved which was expected to be back at the normal ranges from 3 to 6 months period (Joy C. MacDermid et al., 2007). However, in our sample the hand grip strength was not statistically improved from 3 to 6 months, a controversial finding as previous studies showing the recovery of hand grip strength improved after DRF (Swart, Nellans, & Rosenwasser, 2012). A potential explanation is that hand grip strength was already back to the normal range and therefore, the improvement was a small.

Multiple regression analysis indicated four significant predictors for large hand dexterity explained 23.2% of the variability scores. ROM flexion-extension and ROM ulnar-radius deviation as physical impairments after DRF determined approximately the 15% of the variation in hand dexterity. Usually, postoperatively or conservatively the range of motion wrist ROM is restricted for about 6 weeks after the fracture. This has an immediate impact on soft tissue and on the surrounding engaged muscles. This ROM deficit might impair the manipulation of large objects after DRF. Previous studies (Swart et al., 2012) showed that supination-pronation ROM predicts hand patient related disability after DRF. For the manipulation of small objects in 3-months age and ROM flexion-extension were significant predictors determining the 11% of the variability scores (Table 6). ROM flexion- extension physical impairment explained 3% of the total score indicating a small incremental contribution to small hand dexterity scores. This less predictable proportion could be justified by the fact that small dexterity probably is based more on the fingers motion than the wrist flexion-extension arc. The results at the 6-month follow-up identified 3 variables as significant predictors (grip strength, ROM flexion-extension and age) explaining 34% of the variation in large object dexterity scores (Table 7). For the small hand dexterity, significant predictors were: age, grip strength, sex and ROM ulnar-radius deviation determining 25.3% of the variation. Grip may contribute to small object dexterity as the finger flexors have to tightly hold an object for stability e.g for screwing a pin into a socket. The findings of our multiple regression analysis suggest that the restoration of grip and ROM should contribute to better hand dexterity. Additionally, this relationship could provide a more direct way for clinicians to improve the hand function. This suggests that dexterous movements require a combination of skills. The presence of variations in hand muscle strength after injury influences the capability to produce a higher quality movement. Previous studies (Martin et al., 2015) have showed that there is an association with increasing age and decreasing hand dexterity however, individuals practice greater hand dexterity in their daily tasks (Ralf Th Krampe, 2002) like musicians (R T Krampe & Ericsson, 1996) don’t display the same age-related reduction in hand dexterity .

Our study has some limitations that need to be addressed. The male proportion in our sample size was low compared to females which makes it difficult to be confident in our findings with respect to males. Another limitation of our study is the data collection was done prospectively while the data analysis and the research question were generated retrospectively. For this reason, additional details that might have been useful predictors of dexterity, such as dexterity of work tasks, could not be collected. Moreover, the lack of gold standard about hand dexterity measurement means our results may be affected by our use of the NK dexterity test as compared to the many other options for assessing performance-based hand function. The paucity of literature addressing hand dexterity as an functional outcome after DRF, and different methodological techniques makes the comparison with other studies difficult. Finally, the assumption of time-based tests is that more rapid movement indicates better hand function, may be faulty. It may be that quality of task performance, or ability to do it “normally” are more valued by people following DRF than is speed of movement. That is, dexterity may be a faulty, or at least, incomplete, measure of hand function.

3.6 Conclusions

In conclusion, at the 3-month follow-up, hand dexterity is determined primarily by ROM radius-ulnar deviation and ROM flexion-extension. At the 6-month follow-up hand dexterity is determined primarily by grip strength and flexion-extension ROM. By identifying predictors of hand dexterity following a DRF we can assist clinicians understand the relationship between hand dexterity and physical impairments and therefore improve hand function. Future research is needed to determine what other factors and physical impairments predicts the unexplained proportion of the hand dexterity following a DRF. A more in depth research that can identify other neurophysiological elements for hand dexterity and the standardize of a test of hand dexterity can provide valuable information for further research.

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Table 4. Descriptive Analysis of DRF Patients

Data from 3-months follow-up		
N (sample)	391	
Sex	Males (23%)	Females (77%)
Dominant Side (%)	Right (91%)	Left (9%)
	Mean	**SD**
Dexterity- Large	27.11	9.41
Dexterity- Small	54.38	27.51
ROM flexion-extension	91.31	23.60
ROM supination-pronation	138.72	38.54
ROM ulnar-radius deviation	36.38	12.40
Age	58.53	12.82
Grip Strength	21.21	8.99
Data from 6-months follow-up		
N (sample)	319	
Sex	Males (22%)	Females (78 %)
Dominant Side (%)	Right (88%)	Left (12%)
	Mean	**SD**

Dexterity- Large	24.63	6.54
Dexterity- Small	49.58	14.43
ROM flexion-extension	102.08	23.32
ROM supination-pronation	146.07	18.44
ROM ulnar-radius deviation	40.46	13.23
Age	58.81	12.22
Grip Strength	21.17	8.82

Table 5. Predictors of Large Hand Dexterity in 3-months period

R^2	Model	Unstandardized Coefficients		Standardized Coefficients	t	p-value
		B	Std. Error	Beta		
.142	(Constant)	40.86	1.76		23.13	p< .001
	ROM flex-extension	-.15	.01	-.37	-8.03	p< .001
.203	(Constant)	28.26	2.88		9.79	p< .001
	ROM flex-extension,	-.13	.01	-.32	-7.06	p< .001
	Age	.18	.03	.25	5.4	p< .001
.219	(Constant)	24.28	3.17		7.65	p< .001

	ROM flex-extension,	-.13	.01	-.33	-7.25	p< .001
	Age,	.16	.03	.22	4.72	p< .001
	Sex	3.04	1.05	.13	2.89	.004
	(Constant)	24.27	3.15		7.7	p< .001
	ROM flex-extension,	-.09	.02	-.24	-4.26	p< .001
.232	Age,	.16	.03	.22	4.89	p< .001
	Sex,	3.29	1.04	.14	3.14	.002
	ROM ulnar-radius deviation	-.1	.04	-.14	-2.52	.012

Table 6. Predictors of Small Hand Dexterity in 3-months period

R^2	Model	Unstandardized Coefficients		Standardized Coefficients	t	p-value
		B	Std. Error	Beta		
.070	(Constant)	20.99	6.36		3.29	.001
	Age	.57	.1	.26	5.37	p< .001
.109	(Constant)	47.32	8.94		5.29	p< .001
	Age,	.48	.1	.22	4.57	p< .001
	ROM flex-extension	-.23	.05	-.20	-4.1	p< .001

Table 7. Predictors of Large Hand Dexterity in 6-months period

R^2	Model	Unstandardized Coefficients		Standardized Coefficients	t	p-value
		B	Std. Error	Beta		
.219	(Constant)	31.98	.84		37.91	p< .001
	Grip Strength	-.34	.03	-.46	-9.42	p< .001
.279	(Constant)	38.04	1.43		26.58	p< .001
	Grip Strength,	-.27	.03	-.37	-7.37	p< .001
	ROM flex-extension	-.07	.01	-.26	-5.14	p< .001

.340	(Constant)	28.11	2.3		12.21	p< .001
	Grip Strength,	-.19	.03	-.26	-5.09	p< .001
	ROM flex-extension,	-.07	.01	-.26	-5.48	p< .001
	Age	.14	.02	.26	5.37	p< .001

Table 8. Predictors of Small Hand Dexterity in 6-months period

R^2	Model	Unstandardized Coefficients		Standardized Coefficients	t	p-value
		B	Std. Error	Beta		
.142	(Constant)	23.29	3.71		6.27	p< .001
	Age	.44	.06	.37	7.23	p< .001
.200	(Constant)	39.52	4.93		8.01	p< .001
	Age,	.32	.06	.27	5.02	p< .001
	Grip Strength	-.43	.09	-.26	-4.79	p< .001
.242	(Constant)	61	7.04		8.66	p< .001
	Age,	.31	.06	.26	5.02	p< .001
	Grip Strength,	-.66	.1	-.4	-6.4	p< .001
	Sex	-8.89	2.13	-.25	-4.17	p< .001
.253	(Constant)	62.71	7.05		8.89	p< .001

Age	.32	.06	.26	5.07	p< .001
Grip Strength,	-.61	.1	-.37	-5.69	p< .001
Sex,	-7.76	2.18	-.21	-3.55	p< .001
ROM ulnar-radius deviation	-.12	.05	-.1	-2.11	.035

Figure 6. Large hand dexterity Scatter plot in 3-month period

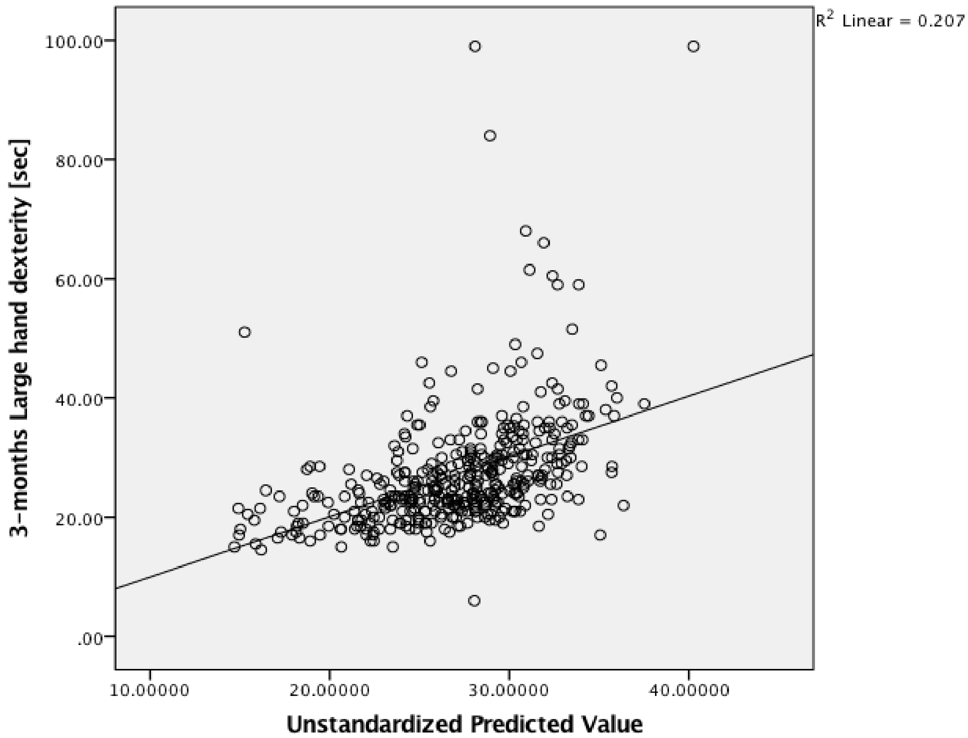


Figure 7. Small hand dexterity scatter plot in 3-month period

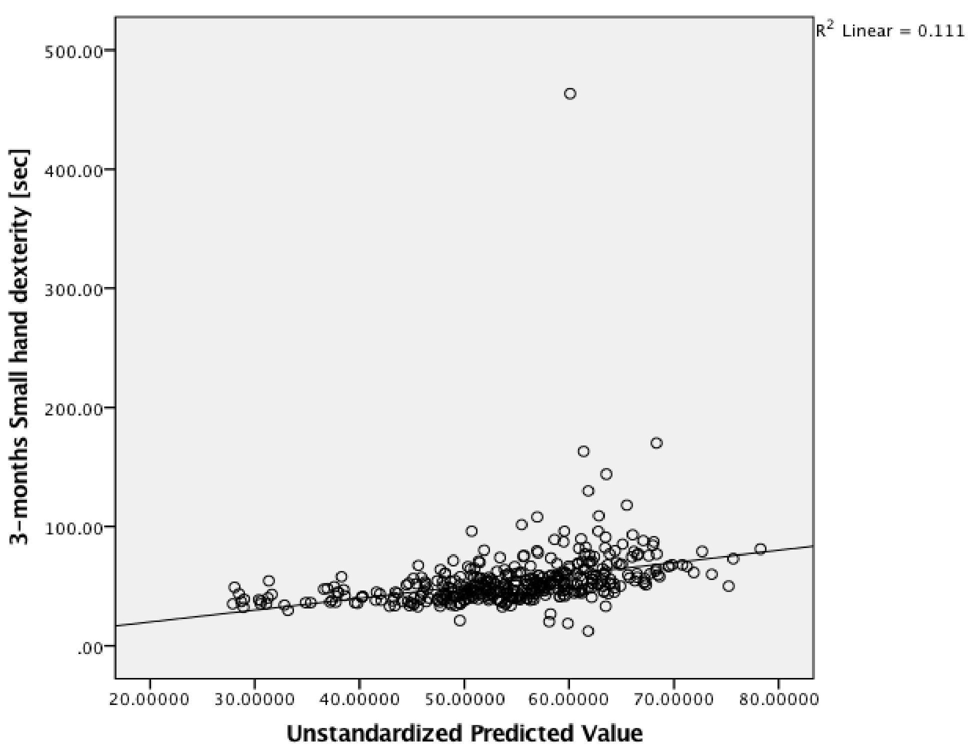


Figure 8. Large hand dexterity scatter plot in 6-month period

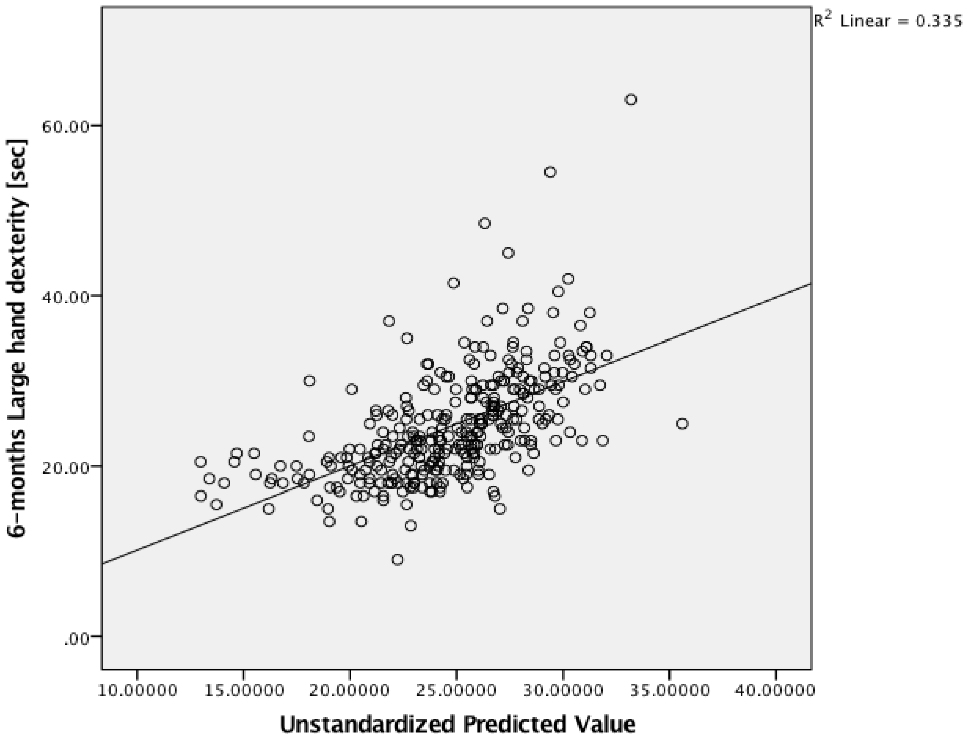
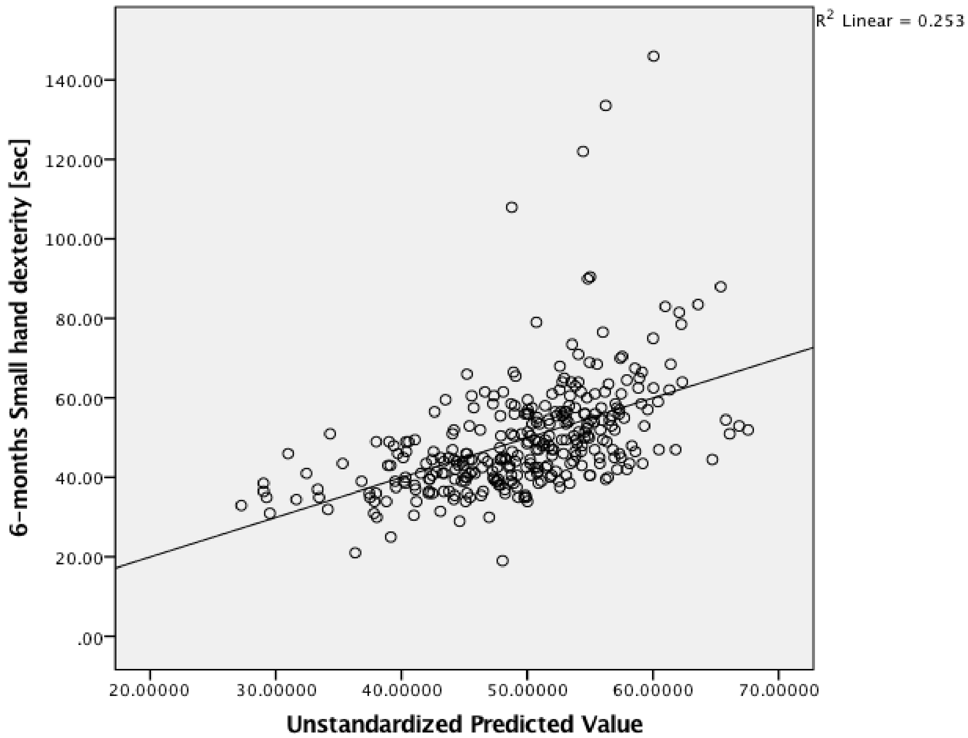


Figure 9. Small hand dexterity scatter plot in 6-month period



Chapter 4 Overall Discussion

4.1 Thesis Overview

The purpose of this thesis project was to evaluate factors that affect hand dexterity after distal radius fracture (DRF). More specifically, to investigate the relationship between hand dexterity with age, gender, evaluate the change over time on hand dexterity after DRF and how physical impairments (ROM and grip strength) related to hand dexterity after DRF. Individuals are using their hands in their daily living for daily activities however, all those hand activities are based on different factors. The anatomy or the structure of the bone, age, gender, proprioception, grip strength, presence of disease, range of motion and dexterity are among the factors that can influence the hand function (Cederlund, 1996),(Martin et al., 2015). Understanding the complexity of these factors will help clinicians improve the hand function assessment after DRF. Previous studies (Macdermid, 2001; Martin et al., 2015) have described the relationship of age or gender on hand dexterity however, they have done it on healthy subjects. Also, previous studies are primarily focused on grip strength and range of motion (Kay et al., 2008; Maciel et al., 2005; Michlovitz et al., 2001) after DRF. We conducted two prospective cohort studies firstly, to determine the effect of age and gender on hand dexterity after DRF and evaluate the recovery of hand dexterity in 1-year follow-up. Secondly, to examine if physical impairments such as ROM and grip strength predict hand dexterity after DRF.

Our results from the first study indicated that hand dexterity can be predicted by age and by gender. This finding is answering our first research question and therefore it was not a surprising outcome. Given the available results from previously studies the relationship of age and gender and hand dexterity on have been described on healthy subjects (Macdermid, 2001; Martin et al., 2015). Poor dexterity has been associated with the increasing age in recent studies (Bowden, Lin, & McNulty, 2014; Dayanidhi & Valero-Cuevas, 2014) and this can be attributed in the weaken hand muscles or alterations in the neural coupling between hand muscles (Shinohara, Latash, & Zatsiorsky, 2003). These may be natural consequences of aging, but activity has also been implicated. These studies were conducted on normal, whereas we found similar findings in those affected by DRF. Our results indicate deficits in hand dexterity due to DRF. This can be explained because the healing process of the bone after fracture has associated changes in the muscle activation (Einhorn & Gerstenfeld, 2015). The relationship of gender and hand dexterity on healthy individuals have been addressed in a very few studies (Kellor, Frost, Silberberg, Iversen, & Cummings, 1971; Macdermid, 2001). Our findings agrees with previous studies that physical features such as gender affect hand dexterity (Macdermid, 2001; Martin et al., 2015), and that women be inclined to have better hand dexterity than men. The NK hand dexterity test measures the manipulation of three difference objects (small, medium and large). It has been reported (Macdermid, 2001) that the size of the hand is linked has more impact on manipulation of large objects, than small. This can partially explain the differences on hand dexterity between men and women since larger hand size is an advantage for men in manipulating larger objects. However, our data analysis found that gender was less influential as predictor as compared to age. Age was consistent predictor for all the size of objects.

Our second research question was focused to examine the recovery of hand dexterity during 1-year after DRF. Our results showed an improvement on hand dexterity from 3 to 6 months for all kind of objects for both hands however, from 6 to 12-months hand dexterity worsened. This unexpected finding might relate loss of the learning effect of how the test was performed, or that gains attained during rehabilitation were not sustained in the long term after the therapy was discontinued. Clinical practice guidelines (Lichtman et al., 2010) of DRF and previously clinical randomized trials have tended to measure hand function with self-reported questionnaires such as the patient-reported wrist evaluation (PRWE) (Mehta, MacDermid, Richardson, MacIntyre, & Grewal, 2015). Despite the strong psychometric properties of PRWE (Mehta et al., 2015) a clinical test of hand dexterity would provide additional information on hand function that would benefit future studies. A combination of self-reported outcome and performance-based tests would provide a more thorough evaluation. Current clinical practice guidelines do not have specific prescription for hand dexterity exercises. Although this reflect the state of the literature, it would benefit practice if future CPG could make some recommendations on measurement and treatment of dexterity.

Our third research question was answered through a second prospective cohort study. The aim of this study was to investigate if impairments such as range of motion and grip strength predict hand dexterity. The evaluation of hand dexterity requires to understand the clinical condition of the patient after the DRF. Hand therapists in clinical practice use measurements of ROM and grip strength to evaluate the progress of the intervention. An assumption on this rehabilitation process is that these measurements reflect the level of hand functionality. However, according to World Health Organization (WHO) (World Health Organization, 2001), there is a possibility of having impairments with no activity limitations and vice versa. Our results showed that physical impairments such as loss of range of motion (arch flexion-extension, arch ulnar-radius deviation) predicts hand dexterity for the manipulation of large objects 3-months after DRF. Large hand dexterity is negatively correlated with ROM (flexion-extension and ulnar-radius deviation). Furthermore, impairments such as grip strength and ROM (flexion-extension) were the largest proportion of explaining large hand dexterity. Again those two impairments were negatively correlated with large hand dexterity on 6-months period. Consequently, the exploration of these relationships and the level of prediction from our results may indicate a basis to establish a true measurement of hand function after the DRF. Full range of motion and strength may not indicate return of normal dexterity since ROM and grip only partially explained dexterity.

4.2 Future Applications, Clinical and Research Implications

The present thesis project contributes new available evidence to the existing knowledge and provides useful information for further development for the evaluation of hand function after DRF. This work must be considered a small step in defining how dexterity should be measured and best rehabilitated following DRF. It provides evidence about recovery and predictors using one measure of dexterity, but much remains unknown. The relationship between dexterity and self-reported function, satisfaction with hand function or ability to return to work would further inform our understanding of dexterity. Further investigation of dexterity exercises on the recovery of hand dexterity after DRF should be defined. Such studies might stratify sampling or randomization based on age and gender; or must use analytical strategies that these can be controlled after data is collected. A variety of options for dexterity exist including tasks of daily life, home programs using readily available objects, standardized dexterity programs, dexterity apps/games, virtual/augmented reality programs/games and others.

Once the evidence permits, future clinical practice guidelines (Bruder, Taylor, Dodd, & Shields, 2013; Cherubino et al., 2010; Ilyas & Jupiter, 2010; Lichtman et al., 2010), after DRF should be able to make recommendations specific to hand dexterity as an index of hand function. Assessments of hand dexterity are lacking essential information regarding their clinimetric properties and this knowledge base needs to be strengthened for future research and clinical practice to be best informed by accurate measures. Recent published systematic review(van de Ven-Stevens et al., 2009) have reported inadequate information about the reliability, validity and responsiveness for current dexterity tests. For the purpose of the study we used NK dexterity board to measure hand dexterity. To our knowledge NK hand dexterity board was a very expensive device (5.000$) which likely will not be attractive to be used in clinical practice, nor consistently available for future researchers.

4.3 Limitations

We conducted two prospective cohort studies to evaluate factors that affect hand dexterity after DRF. Although, through study outcomes we provided some clinical recommendations regarding the hand function there are some limitations. The limitations need to be addressed and be considered for future investigations on hand dexterity. In our study the proportion of males compared to females was low however, we believe that our analysis regarding the effect of gender on hand dexterity was not affected. The power of our sample was adequate to draw conclusions regarding this research hypothesis; however, the results cannot be generalized. Furthermore, we used secondary data for our analysis and this can have some measurement bias.

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Appendix A: Ethics Approval

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Annual Continuing Ethics Approval Notice

Date: October 08, 2015
Principal Investigator: Dr. Joy MacDermid
Department & Institution: Schulich School of Medicine and Dentistry\Surgery,Western University

Review Type: Expedited
HSREB File Number: 5697
Study Title: Wrist and Elbow Outcomes Measures Database -15602E
Sponsor:

HSREB Renewal Due Date & HSREB Expiry Date:
Renewal Due -2016/11/30
Expiry Date -2016/12/10

The Western University Health Science Research Ethics Board (HSREB) has reviewed the Continuing Ethics Review (CER) Form and is re-issuing approval for the above noted study.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice (ICH E6 R1), the Ontario Freedom of Information and Protection of Privacy Act (FIPPA, 1990), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

[redacted]

Ethics Officer to Contact for Further Information

___ Erika Basile ebasile@uwo.ca	___ Grace Kelly grace.kelly@uwo.ca	___ Mina Mekhail mmekhail@uwo.ca	___ Vikki Tran vikki.tran@uwo.ca

This is an official document. Please retain the original in your files.

Western University, Research, Support Services Bldg., Rm. 5150
London, ON, Canada N6G 1G9 t. 519.661.3036 f. 519.850.2466 www.uwo.ca/research/ethics

Appendix: B Patient information and Consent Form

Project Title: Wrist and Elbow Outcome Measures Database

Investigators: **Dr. Joy MacDermid, PhD**
Dr. Ruby Grewal, MD
Dr. Douglas Ross, MD

Dr. George Athwal, MD
Dr. Graham King, MD
Dr. Ken Faber, MD

Dr. Darren DrosdowechMD
Dr. Bing Gan MD

What is the purpose?

At The Hand and Upper Limb Centre (HULC) we routinely measure the impact of care to ensure we evaluate the quality of our care. You are asked to participate because you have a wrist/elbow injury affecting your activities of daily living. The purpose of this measuring your status and keeping this information in a database is so that we can evaluate how much improvement you experience with treatment.

What is involved?

At the Hand and Upper Limb Centre we routinely test your motion and strength and use questionnaires that ask about your pain and disability. We do this to monitor your usual recovery. If you agree to participate in this study, you will be asked to fill out additional questionnaires that measure the impact of the wrist/elbow fracture on your participation in activities that are important to you. Follow-up visits for the study will be similar to our usual follow-up which takes place on multiple occasions over the early recovery and at visits scheduled at 3, 6, 9, and 12 months after your injury/surgery. For the study you will fill out forms at one early visit and the 4 later visits- 6 weeks, 3, 6, and

12 months after your injury/surgery. Sometimes, your standard care would require you to come back to the clinic every one-two years (depends on the type of your injury and treatment). In this case, we would like to meet with you again and assess your recovery progress. The usual forms take about 15 minutes and the study forms take another 10-15 minutes. You will be asked to complete the same forms at each visit. Once your wrist/elbow injury has healed completely, your strength and hand movement will also be measured according to our routine follow-up. We will test you strength (flexion/extension, and pronation/supination) by using the Biodex system and/or an isotonic torque dynamometer and your grip strength with NK system. A Research Assistant will explain all the tests to you before asking to perform them.

We will use information collected during your follow-up such as these measures to describe your injury and physical recovery. Other than the routine follow-up required for this type of injury, we will not ask you to return to clinic more often or perform additional x-rays for this study. With certain wrist/elbow injuries, participants over 50, we be offered an assessment for osteoporosis and evaluation of their postural stability.

Tests (optional for patients 50 and over)

Bone density scan will be performed on the lower spine and hips.

- Bone density testing is the most accurate method available for the diagnosis of osteoporosis and is also considered an accurate estimator of fracture risk. Bone densitometry is a simple, quick (30 min) and noninvasive procedure will be performed at 1 year visit.

- We will use the Biodex balance system SD to assess your ability to maintain dynamic bilateral postural stability on a static or unstable surface. You will be asked to perform the following two tests:

1. Postural Stability Test (PST) emphasizes a patient's ability to maintain centre of balance.
2. Fall Risk Test (FRT) allows identification risk of a potential future fall

You will be instructed to maintain the balance as instructed by the Research Assistant. Platform stability will be varied during the test. The researcher will instruct and help you during the test.

What are the benefits of having my data in the database?

You may not personally benefit from your allowing us to keep your data in the database his study. Your participation will allow HULC and those who develop implants to have a better understanding of the outcomes or complications with different treatment options. This information can be used for quality assurance or in the future for research – if we ask the ethics board for permission to do so. HULC is committed to improving the quality of care and participates in these processes ion a regular basis.

Is there any compensation

There is no payment for participating in this data collection. We will provide parking passes on the days that you complete the questionnaires, so that your parking will be free on the days you fill out study forms. We are trying to interact with the patients during their visits to the HULC, however, if it is not convenient for the patient, we will schedule another appointment that only includes a visit to the HULC research lab, and in this case coverage for parking will be provided.

Are there any risks of discomfort associated with this study?

The amount of radiation used is extremely small—less than one-tenth the dose of a standard chest x-ray, and less than a day's exposure to natural radiation. There is a small risk of losing the balance during the Postural Stability and Fall Risk Tests, however, a Research Assistant will always be behind you to help control instability during testing and to prevent you from falling. The system is equipped with safety features such as support handles and an “abort” button to stop the testing at any time.

Other than questionnaires

No additional testing for research purposes other than that stated above will be performed. The clinic routinely uses strength testing, motion testing, and x-rays to ensure your fracture is healing properly. This is normal care.

Will your results be kept confidential?

The overall results of the study will be available to you upon request. Your individual results will be held in strict confidence. No person, other than your doctor or therapist and the study co-investigators will have access to your records without your permission. Your data that is sent into the study database will have your personal identifying information removed or coded so that the study database will be anonymous.

In addition to the above, if you had a Distal Radius Fracture we will also share your coded information with McMaster University, in Hamilton. This information is protected by the use of a code which is an assigned number specific to your study file only. Only coded (de-identifies) information will be shared. Please note, the results of the study may be published in medical literature, but you will not be identified.

Your name and contact information will be kept secure by the research team at the site where the study is being performed. It will not be shared with others without your permission. Your name will not appear in any report or article published as a result of this study.

Information collected during the study may be presented to other doctors in a presentation or paper. Your results would be part of a group of anonymous data, and would not identify you in any way. Representatives of The University of Western Ontario Health Sciences Research Ethics Board or/and Lawson Quality Assurance Education may contact you or require access to your study-related records to monitor the conduct of the research.

Alternatives to Study Participation:

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your future care. You will receive a copy of the letter of information and consent form for your records. You do not waive any of your legal rights by signing the consent form.

If you decide not to participate in the study, your surgeon will determine which technique will be used based on his/her discretion and your discussions together. Currently, there is no preference among the surgeons.

Consent To Participate In: Wrist and Elbow Outcome Measures Database

I have read the letter of information, have had the nature of the study explained to me and

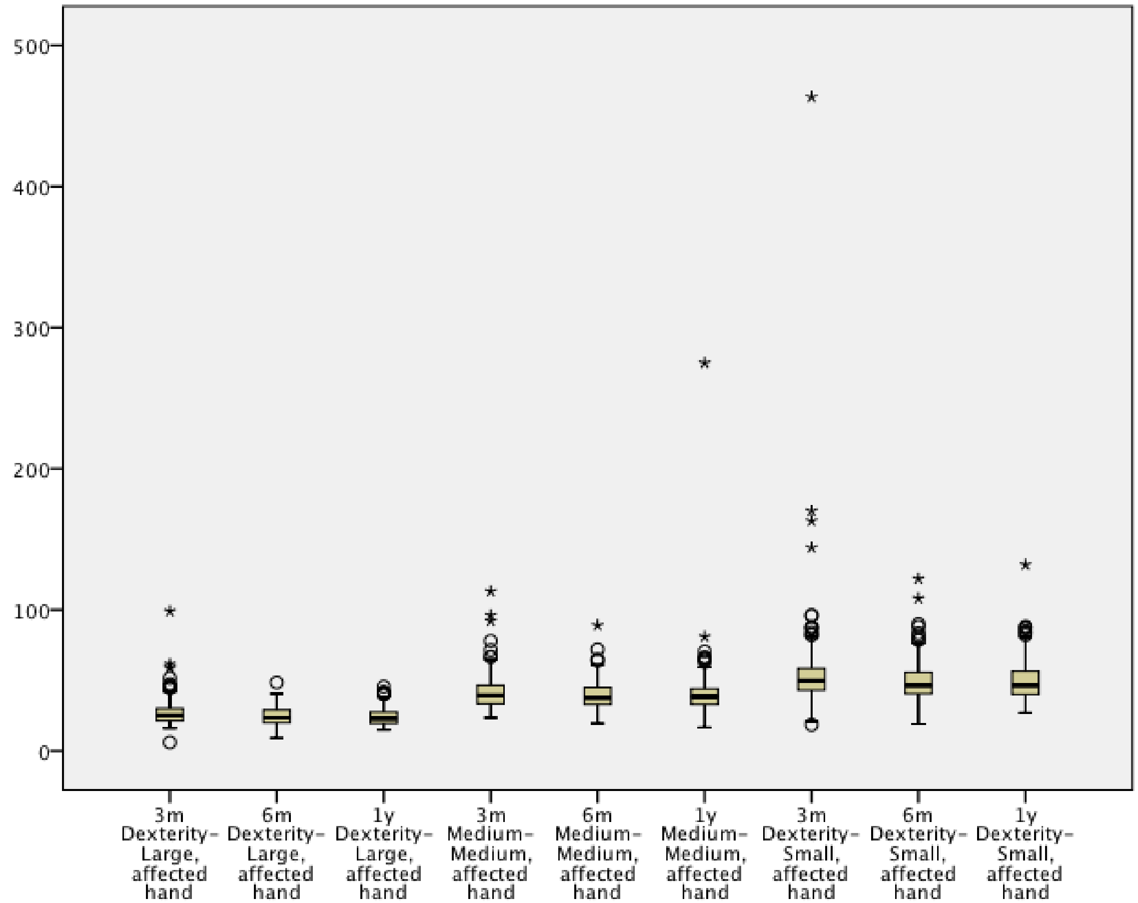
I agree to participate. All questions have been answered to my satisfaction

__________________________ __________________________ _____________

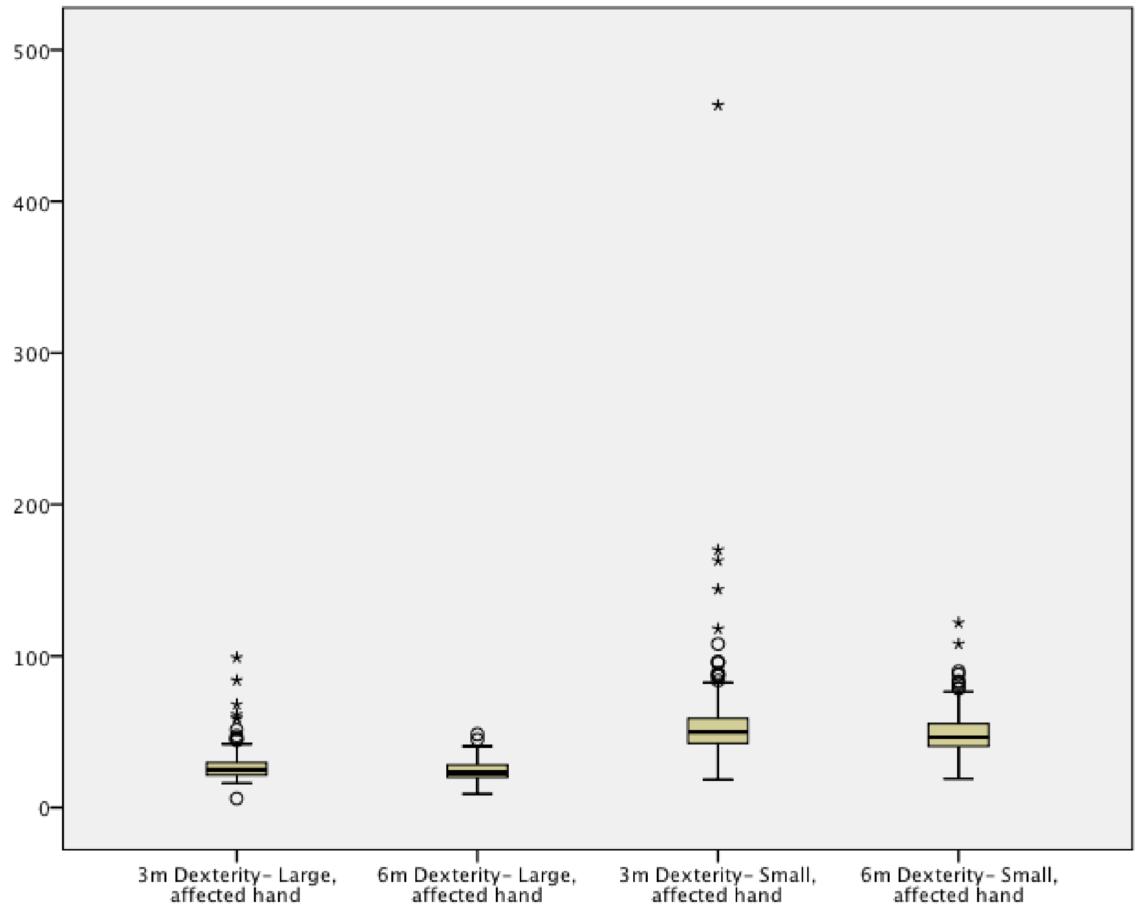
Signature of Participant	Print Name	Date
Signature of person obtaining consent	Print Name of person obtaining consent	Date

Appendix C: Boxplots for hand dexterity variables

Boxplot (chapter 2) for hand dexterity variables (Y-axis represents seconds and X-axis the type of hand dexterity)



Boxplot (Chapter 3) for hand dexterity variables (Y-axis represents seconds and X-axis the type of hand dexterity)



Appendix D: Curriculum Vitae

Name	Pavlos Bobos
Post-secondary Education and Degrees	2011-2015 Technological Educational Institute of Western Greece Physiotherapy degree (PT) 2004-2010 National and Kapodistrian University of Athens BSc in Physical Education and Sports Science, 1-year specialization in Biology of Exercise
Honors and Awards:	Western University Graduate Research Scholarship, 2015 -2016
Related Work Experience	Physiotherapy Assistant: Extendicare Home, Port Stanley, Ontario, Canada, 2016/06-2016/07 Physical Therapist:

General Hospital Asklepieio Voulas, Athens, Greece, 2015/02-2015/08

Research Assistant:

2014-2015 Department of Physical Therapy, TEI of Western Greece, Biomechanics lab, supervisor Professor Elias Tsepis: Strength measurements analysis in the lower extremities of professional soccer players,

2013-2014 Department of Physical Therapy, TEI of Western Greece, Neuromuscular Rehabilitation lab, supervisor, Associate Professor Billis Evdokia: Measurements and evaluation in patients with neck pain,

2012-2013 Department of Physical Therapy, TEI of Western Greece, supervisor Dr. Konstantinos Fousekis, Counter movement jump Kinetic and Kinematic analysis and measurements in track field athletes

Conference Presentations

4 - 8 July of 2016 IFOMPT Conference, Glasgow at the Scottish Exhibition and Conference Centre (SECC)

Topic: Is deep cervical neck flexors training more effective than general neck exercises or advice in patients with chronic neck pain? A prospective randomized controlled trial

4 - 7 May of 2016 17th ESSKA Congress (European Society of Sports Traumatology, Knee Surgery & Arthroscopy) Barcelona

Topic: Does deep cervical flexors' muscle training affect pain pressure thresholds of myofascial trigger points in patients with chronic neck pain? A prospective randomized controlled trial.

Certifications

Certificate of Graston Technique Module 1 Training, GT provider, 2016/05

Certificate Teaching Assistant Training Program, Teaching Support Center, Western University, 2016/05

Certificate Canadian Red Cross, Standard First Aid, CPR/AED Health Care Practitioner (HCP) Level, 2016/01

Certificate of Completion TCPS 2: CORE, Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans, 2015/10