ENABLING ASSESSMENTS TO BETTER INFORM GOAL SETTING AND TREATMENT PLANING FOR PATIENTS WITH ELBOW, WRIST AND HAND IMPAIRMENTS.

By

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ABSTRACT

JASON HUGHES, MS, OTR/L
Enabling Assessments to Better Inform Goal Setting and Treatment Planning for Patients with Elbow, Wrist, and Hand Impairments.
Under the direction of Leigh Lehman, PhD, MS, OTR/L

Musculoskeletal disorders, including elbow, wrist, and hand impairments, are the second most common disability worldwide and place a large burden on the health care system. Due to this prevalence and cost, accurate and precise assessment is critical to ensure that patient treatment is optimal (i.e. efficient and productive). Our first objective was to examine the item-level characteristics of the Elbow, Wrist, and Hand Computer Adaptive Test (EWH CAT) using Rasch analysis, including item difficulty measures, person ability measures, item fit, and item-person match. A unique feature of Rasch analysis is its ability to plot person ability and item difficulty on the same continuum. Awareness of this relationship helped us discern that while our items matched our sample relatively well (i.e. sample mean .13 logits above the item mean) there were slight ceiling and floor effects indicating that the addition of some harder and easier items might increase the breadth of abilities in our sample that could be accurately measured.

After identifying the item-level properties of the EWH CAT, our second objective was to develop a data collection form to assist clinicians in goal setting and treatment planning. Using the Winsteps Rasch analysis program, a keyform was generated. Based on this keyform, a data collection form was created that could be used to illustrate how patient responses to specific items (i.e. difficulty indicated) differ from admission and discharge, thus helping to guide clinicians in goal setting and treatment planning.

Our third objective was to identify factors that increase the probability of favorable outcomes for patients with elbow, wrist, and hand diagnoses. Seven variables were found to be associated with the likelihood of a poorer outcome: being female, having greater than three comorbidities, having a history of surgery, acuity of $\geq$ 22 days, exercising less than 3 times a week, no medication use, and payer source. Four variables were significantly associated with a greater probability of a good outcome: no history of surgery, no medication use, shorter acuity, and payer source. This knowledge might indicate when a treatment approach different from traditional rehabilitation may be required and/or additional consults may be necessary.

KEY WORDS: (Musculoskeletal disorders, item response theory, outcomes

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I. INTRODUCTION

A. Statement of the Problem and specific aims of the overall project

Musculoskeletal disorders (MSDs), including elbow, wrist, and hand impairments, are the second most common disability worldwide and place a large burden on the health care system (Southerst et al., 2015; Walker-Bone & Linaker, 2016). MSDs involving the upper extremity are among the leading work-related health concerns in the United States, accounting for up to 30% of all injuries requiring time away from work (Gardner, Dale, VanDillen, Franzblau, & Evanoff, 2008). For example, the cost of medical care and lost work time associated with lateral and medial epicondylitis is more than $22 billion annually in the United States (Menta et al., 2015). Furthermore, carpal tunnel syndrome with prevalence estimates ranging from 2.7% to 7.8% is one of the most costly work-related upper extremity disorders, accounting for direct and indirect costs in excess of $2 billion per year in the United States (Menta et al., 2015).

Due to the prevalence and cost associated with elbow, wrist, and hand impairments, accurate and precise assessment is critical to ensure that patient treatment is optimal (i.e. efficient and productive) (Badalamente et al., 2013a). Potential benefits of accurate and precise assessments for this population include guiding therapists in goal setting. Additionally, identifying factors that increase the probability of favorable outcomes for patients with elbow, wrist, and hand, diagnoses can assist in treatment planning.

Overall, the purpose of this study was to examine the Elbow, Wrist, and Hand Computer Adaptive Test (EWH CAT) at the item-level and additionally, to establish its predictive value. Using Rasch analysis, we were able to investigate the item-level properties of this assessment and develop a testing form that will assist clinicians in goal setting. Using multiple regression, we identified guiding factors (i.e. different characteristics of individuals) that will assist in planning treatment. More specifically, our aims were as follows.

Specific Aim 1:

Examine the item-level characteristics of the EWH CAT using Rasch analysis, including item difficulty measures, person ability measures, item fit, and item-person match.

Specific Aim 2:

Based on identified item characteristics, we created data collection forms to guide clinicians in goal setting and treatment planning. The general keyform we obtain through Rasch analysis, will provide the basis for this form.

Specific Aim 3:

Identify the best predictors for high functional recovery based on age, gender, comorbidities, acuity, surgical history, exercise status, payer type, medication use, functional status change, and total visits.

B. Literature Review

Significance of Elbow, Wrist, and Hand Impairments

Musculoskeletal disorders (MSDs) are the second most common disability worldwide and place a large burden on the health care system (Southerst et al., 2015; Walker-Bone & Linaker, 2016). Elbow, wrist, and hand (EWH) functional deficits are frequent consequences of various orthopedic injuries and disorders (e.g., fracture, tendonitis, carpal tunnel syndrome, arthritis, sprains, and strains) affecting individuals of all ages (Gardner et al., 2008; Menta et al., 2015). Musculoskeletal disorders of the upper extremity (UE MSDs) including the elbow, wrist, and hand are among the leading work-related health concerns in the United States, accounting for up to 30% of all injuries requiring time away from work (Gardner et al., 2008). Some of the most common conditions affecting the elbow, wrist, and hand include lateral epicondylitis, medial epicondylitis, and carpal tunnel syndrome (Menta et al., 2015). Lateral epicondylitis affects as many as 15% of workers with jobs requiring the performance of repetitive hand motions (Menta et al., 2015). Further, the cost of medical care and lost work time associated with lateral and medial epicondylitis is more than $22 billion annually in the United States (Menta et al., 2015). Additionally, carpal tunnel syndrome is common with prevalence estimates ranging from 2.7% to 7.8% (Menta et al., 2015). Carpal tunnel syndrome is one of the most costly work-related upper extremity disorders, accounting for direct and indirect costs in excess of $2 billion per year in the United States (Menta et al., 2015).

Role of Assessment

Accurate and precise assessment is critical in the clinic and in research to ensure that patient treatment is optimal and practice advances (Badalamente et al., 2013a). Treatment planning and goal setting must be guided by accurate and precise assessment results to optimally benefit the client (Badalamente et al., 2013a). When standardized assessments are used clinicians are able to make comparisons against norms and objectively evaluate effectiveness of their interventions (Velozo & Woodbury, 2011). Since assessment is a vital component in advancing practice and improving patient care, the decision about which evaluation tool to use is crucial.

This choice is complicated by the wealth of assessments available to clinicians. These assessments may be grouped into three common categories: generic health measures, disease-specific measures, and region-specific measures (Badalamente et al., 2013a). Generic health measures are used extensively. However, the results of these assessments will only have meaning when the diagnosis has an impact broadly on general health (Badalamente et al., 2013a). Diagnoses that affect the wrist or hand (e.g. osteoarthritis of the first CMC joint and de Quervain's tenosynovitis) have very specific effects on daily life that are not likely to be captured by a generic health measure. Alternatively, disease-specific measures can more precisely evaluate changes in a specific condition (Badalamente et al., 2013a). Nevertheless, one problem with disease-specific measures is that they are not well suited to evaluate a variety of disorders or ailments (Badalamente et al., 2013a). Region specific scales are distinct in that scores on these scales reflect total status of the limb as a unit (Badalamente et al., 2013a). Even though this type of assessment is widely utilized with musculoskeletal researchers and clinicians, they may not be the best to show changes if the main problems are in one joint (e.g. wrist) of the limb (Badalamente et al., 2013a).

Although assessments are commonplace in clinical arenas (de Boer, Hazes, Winia, Brand, & Rozing, 2001), they fail to directly guide practice. Reliability and validity has been demonstrated for many assessments, including those assessing upper extremity impairment (Lehman, Sindhu, Johnson, & Velozo, 2011; Schulzer, Mak, & Calne, 2003; Van der Lee et al., 2001). Even with proven reliability and validity these assessments are underutilized in therapy clinics because they lack the ability to clearly guide clinicians in evaluating specific functional ability, developing patient-centered goals and guiding treatment planning (de Boer et al., 1999; Woodbury & Velozo, 2005). Clinicians may view assessment administration as cumbersome, taking away time for therapeutic intervention. Often therapists only use assessments to adhere to requirements set forth by clinic management, accrediting agencies, or reimbursement parties (Velozo & Woodbury, 2011; Woodbury & Velozo, 2005).

For an assessment to be beneficial in directing clinical practice, it must illustrate the skills of a patient and identify the tasks that are the best next goals for a patient (Lehman, Sindhu, et al., 2011; Woodbury & Velozo, 2005). Many assessments produce an overall, total score. Total scores are not easily understood as they disguise the tasks the patient is not able to complete (Lehman, Sindhu, et al., 2011).

To highlight a way in which assessment total scores are unclear about actual ability, imagine a patient with a score of 70 (out of a possible 100) on the Mayo Clinic Performance Index Scale, one of the most commonly used elbow assessments (Badalamente et al., 2013b). The score of 70 does not highlight the difficulties the patient is experiencing and what goals should be determined to help overcome the obstacles they face. A host of problems could attribute to the overall, score of 70/100, such as, pain, abilities in daily function, range of motion, or stability. Furthermore, a total score does not elucidate for the clinician important aspects of care such as the degree that pain is contributing or assist in determining treatment goals for the client (Lehman, Sindhu, et al., 2011; Woodbury & Velozo, 2005). Musculoskeletal disorders come with a complicated set of problems including pain, dysfunction in daily tasks, and reduced strength/range of motion necessitating more defined measurement of ability than one single total score allows.

Predictive Capability of Assessment Results

Further complicating assessment and treatment, a complex range of physical, psychosocial, and occupational factors interact and influence an individual’s response and subsequent rehabilitation and recovery from musculoskeletal disorders (Walker-Bone & Linaker, 2016). When treating such disorders, some patients benefit from conservative treatment while others do not. In order to effectively manage musculoskeletal disorders and predict the course of progression, it is essential to identify factors (e.g., epidemiological factors) that help determine outcomes (Armijo-Olivo, Woodhouse, Steenstra, & Gross, 2016).

Research suggests that elbow, wrist, and hand pain is common; however, literature focusing on prognostic factors is underdeveloped (Whibley, Martin, Lovell, & Jones, 2015). Only a few studies have examined prognostic factors for the elbow, wrist, and hand and there is a lack of consistency in diagnoses and etiologies studied, as well as, results acquired (Armijo-Olivo et al., 2016; Whibley et al., 2015). If clinicians could identify, a priori, those patients that are at high risk of a poor functional recovery compared with visit utilization versus those patients who are at low risk of a poor functional recovery compared with visit utilization, this may assist with stratifying resources and save healthcare dollars (Salamh et al., 2017). With other diagnoses, predictive variables have been identified.

For example, similar studies with individuals receiving therapy for impairments in the neck region (Cook, Rodeghero, Cleland, & Mintken, 2015), knee impairments (Salamh et al., 2017), and shoulder impairments (Rodeghero, Cleland, Mintken, & Cook, 2017) have shown that it is possible to identify characteristics of individuals with low and high probability of functional recovery. Factors such as age, acuity, surgical history, payer type, and functional status at intake, total visits, and total episode duration may impact functional status scores and perceived change ratings in patients with elbow, wrist, and hand impairments (Rodeghero et al., 2017).

In regards to individuals with neck pain, Cook and colleagues (2015) examined data from 3,137 patients. Statistically significant ($p < .05$) predictors of low risk for poor prognosis included patients who were younger in age ($p<.01$), less than 22 days of symptoms ($p<.01$), no surgical history ($p<.01$), fewer comorbidities ($p=.03$), and higher comparative disability levels of function at baseline ($p<.01$). In contrast, statistically significant predictors of high risk for poor prognosis included longer duration of symptoms (>22 days) ($p<.01$), history of surgery ($p=.02$), and lower comparative levels of disability at baseline (p<.01). The results of this study provided insights on what variables might be predictors of functional outcomes for patients with elbow, wrist, and hand diagnoses.

In a similar study, Salamh and colleagues (2016), examined 4,387 patients with knee pain who received therapy. This study involved retrospective analyses of outcomes data from a cohort of patients who presented with knee pain. When considering factors that predict outcomes, through hierarchical multinomial regression modelling, the authors determined that there were significant differences between age, duration of symptoms, surgical history, insurance/payer type, functional status at intake, total visits, and total episode duration in days when comparing low risk and high risk individuals. Of those, significant predictors of high risk of a poor outcome included individuals who were older (p<.01), female (p=.02), had a history of surgery (p=.02), had Medicare/Medicaid (p<.01), litigation, workers' compensation and automotive insurance (p<.01), and higher severity of functional status at baseline (p<.01). Significant predictors of low risk of a poor outcome included being younger (p<.01), having no surgical history (p<.01), having Medicare/Medicaid (p<.01), litigation, workers' compensation and automotive insurance (p<.01), experiencing a shorter duration of symptoms (<22 days) (p<.01), and having lower severity of functional status at baseline (p<.01).

In a similar study, Rodeghero and colleagues (2017), examined data from 5,214 patients with shoulder pain. Their aims included identifying predictive characteristics of patients who have increased risk of a poor prognosis, as well, as those who are at decreased risk of a poor prognosis. Univariate multinomial regression analyses revealed significance for low risk of a poor prognosis in patients who were younger (p<.01), had a shorter duration of symptoms (p<.01), no surgical history (p<.01), those with Medicare or Medicaid (p<.01), and those with litigation, workers' compensation and automotive insurance (p=.03). Significant predictors of the high risk classification included older age (p=.04), having a surgical history (p=.02), having litigation, workers' compensation and automotive insurance (p<.01), and having three or more comorbidities (p=.03).

Also, in regards to predicting outcomes for individuals with shoulder impairments, Kennedy and colleagues (2006) conducted a randomized control trial with aims to predict change in disability and level of disability after treatment. In total, 118 therapists were randomly selected. Therapists worked in a variety of settings, with private practices representing the largest percentage (60%). Inclusion criteria included, having greater than

5 years of clinical experience and practice in which shoulder conditions were one of the top three conditions treated. Each therapist collected data from five consecutive patients who were beginning their rehabilitation treatment. The final study sample included 381 patients. Univariate models were constructed to build the best model. When looking at patients who report shoulder musculoskeletal disorders, Kennedy, et al. (2006) found that predictors of greater disability at discharge included higher initial disability (p<.0001), workers' compensation claims (p=.0036), female (p=.0219), and older age (p=.0004). Shoulder surgery within the past 6 months (p<.0001), higher pain intensity (p=.0448), younger age (p=.0243), and shorter duration of symptoms (p=.001) were all found to be predictors of greater improvement (Kennedy et al., 2006).

Conclusions

In summary, we need accurate and efficient methods of evaluation and assessment for elbow, wrist, and hand diagnoses. Potential benefits of this type of knowledge would include assessments that better guide goal setting and treatment planning by identifying factors that increase probability of favorable outcomes for patients with elbow, wrist, and hand diagnoses. To help achieve this end, the purpose of this study was to examine the EWH CAT at the item-level and additionally, to establish its predictive value. More specifically, we had the three following aims: 1) Examine the item-level characteristics of the EWH CAT using Rasch analysis, including item difficulty measures, person ability measures, item fit, and item-person match. 2) Based on identified item characteristics, create data collection forms to guide clinicians in goal setting and treatment planning. 3) Identify the best predictors for high functional recovery based on age, gender, comorbidities, acuity, surgical history, exercise status, payer type, medication use, functional status change, and total visits.

II. PUBLISHED MANUSCRIPTS

1. Risk Stratification of Patients with Elbow, Wrist, or Hand Orthopedic Impairments Seeking Outpatient Therapy Services

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Running head: Risk stratification

ABSTRACT

Rationale, aims and objectives

Patients who experience elbow, wrist, and hand musculoskeletal pain are frequently seen in therapy. The aim of this study was to determine immutable and mutable characteristics of patients who responded well to therapy with low visit utilization and patients who responded poorly despite high visit utilization.

Methods

This is a cross-sectional study. Demographic information pertaining to a sample of 89,422 patients in 3,400 outpatient therapy clinics for elbow, wrist, and hand impairments was analyzed. Multinomial regression analysis was used to identify significant patient characteristics predictive of treatment response.

Results

Based on odds ratios, the immutable patient characteristic that was statistically significant of low risk of a poor outcome categorization was no history of surgery. Statistically significant mutable patient characteristics included acuity of less than 22 days, no medication use, and payer source. When compared to private insurance, individuals at low risk of a poor outcome were more likely to use private companies than worker's compensation, litigation, or automotive. Conversely, they were more likely to have Medicare or Medicaid than to use private insurance. Based on odds ratios, immutable patient characteristics of those in the high-risk category were being female, having greater than three comorbidities, and having a surgical history. Mutable patient characteristics of those in the high-risk category were acuity of 22 days or greater, exercising less than 3 times a week, medication use, and payer source. Individuals who were at high risk of a poor outcome were more likely to use worker's compensation, litigation, or automotive compared to having private insurance.

Conclusion

Patient characteristics were found which allow for the identification of individuals who are likely to benefit more from rehabilitation services versus those whose care should include a more multidisciplinary approach. We are not suggesting withholding treatment from these individuals. However, knowledge of predictive factors early in treatment could be beneficial in prioritizing rehabilitation needs and acknowledging when consults for other services are needed. Further research is needed on the prognosis of patients seeking rehabilitation for elbow, wrist, and hand diagnoses related to cost, timing of care, and cost/benefit ratios.

Keywords: Cost; outcomes; rehabilitation

INTRODUCTION

Musculoskeletal disorders, including elbow, wrist, and hand impairments, are the second most common disability worldwide and place a large burden on the health care system (Southerst et al., 2015; Walker-Bone & Linaker, 2016). Musculoskeletal disorders involving the upper extremity are among the leading work-related health concerns in the United States, accounting for up to 30% of all injuries requiring time away from work (Gardner et al., 2008). The cost of medical care and lost work time associated with lateral and medial epicondylitis is more than $22 billion annually in the United States (Menta et al., 2015). Furthermore, carpal tunnel syndrome with prevalence estimates ranging from 2.7% to 7.8% is one of the most costly work-related upper extremity disorders, accounting for direct and indirect costs in excess of $2 billion per year in the United States (Menta et al., 2015).

A complex range of physical, psychosocial, and occupational factors interact and influence an individual's response and subsequent rehabilitation and recovery from musculoskeletal disorders (Walker-Bone & Linaker, 2016). When treating such disorders, some patients benefit from conservative treatment while others do not. In order to effectively manage musculoskeletal disorders and predict the course of progression, it is essential to identify factors that help determine outcomes (Armijo-Olivo et al., 2016).

Research suggests that elbow, wrist, and hand pain is common; however, literature focusing on prognostic factors is underdeveloped (Whibley et al., 2015). Only a few studies have examined predictive factors for treatment outcomes of patients with elbow, wrist, and hand impairments. Moreover, diverse diagnoses and etiologies have been studied and results differ in regards to predictors found to be significantly related to a better outcome (Armijo-Olivo et al., 2016; Whibley et al., 2015). If clinicians could identify patients that are at high risk of a low functional recovery despite more treatment sessions versus those patients who are at low risk of a poor functional recovery with fewer treatment sessions, this may assist with stratifying resources and save healthcare dollars (Salamh et al., 2017).

The aim of this study was to identify the best predictors for high functional recovery based on age, gender, comorbidities, acuity of symptoms, surgical history, exercise status, payer type, medication use, functional status change, and total visits. Based on previous studies examining these characteristics of patients with diverse impairments, such as shoulder (Rodeghero et al., 2017), knee (Salamh et al., 2017), and neck (Cook et al., 2015), we hypothesize that we can predict poor outcomes despite a high number of visits, as well as, favorable outcomes despite a low number of visits in patients with elbow, wrist, and hand pain who seek therapy.

METHODS

Participants

This study involves analysis of survey question data that was de-identified and provided by Focus On Therapeutic Outcomes, Inc. (FOTO) (Knoxville, TN, USA). FOTO is a web based patient assessment system that reports functional status measures. It is used nationwide in 3,400 clinics by 15,000 clinicians. Data were selected from the FOTO database if patients a) were 18 years old or older; b) were treated for an orthopedic impairment of the elbow, wrist, and/or hand; c) received outpatient therapy; and d) completed the Elbow, Wrist, and Hand Computer Adaptive Test (EWH CAT).

Coding of variables

The following continuous patient variables were categorized as follows. All variables were treated as categorical except functional status (FS) code, which was coded as continuous. Dichotomous variables included age (18 to 50 years of age, and 51-89 years of age); gender (male, female); comorbidities (0-2 conditions, 3 or more conditions), and medication use (no, yes). Onset of symptoms, defined as the number of days from when the patient first notices the condition being treated until the day of the therapy intake evaluation, was recoded as 1=acute (<22 days) and 2=chronic (22 days or greater) (Cook et al., 2015; Rodeghero et al., 2017; Salamh et al., 2017). History of surgery was classified into two categories 'none' (no) and '1 or greater' (yes). Exercise status prior to being seen by therapy was sorted into 1=less than 3 times a week and 2=at least 3 times a week. Numerous payer sources were represented. We grouped these payer sources analogous to the groupings used by Rodeghero and colleagues (Rodeghero et al., 2017) in a similar study examining shoulder diagnoses. Automotive, litigation, and workers compensation were recoded as (1), Medicare and Medicaid as (2), and all others as (3). Percentage of change in function was computed by change of the baseline functional score on the EWH CAT and discharge functional score on the EWH CAT and multiplying by 100. This resulted in a favorable or unfavorable percentage change.

Risk stratification profile

To represent groups at each end of the sample's distribution, we created a variable for prognosis. This unique variable represented groups that present with a low risk of a poor functional outcome with minimal total visits and a group that present with a high risk of a poor overall functional outcome even though they received multiple therapy visits. To create the variable of prognosis, we compared the percentage of change of functional status and total visits. The group at the high risk of a poor outcome was the highest 30% for total visits and the bottom 30% for functional outcome. The group that represented a low risk of poor outcome was the highest 30% for functional outcome and the bottom 30% of total visits. All other individuals who were neither at increased nor decreased risk of poor outcomes were placed in the medium risk group (Cook et al., 2015; Rodeghero et al., 2017; Salamh et al., 2017).

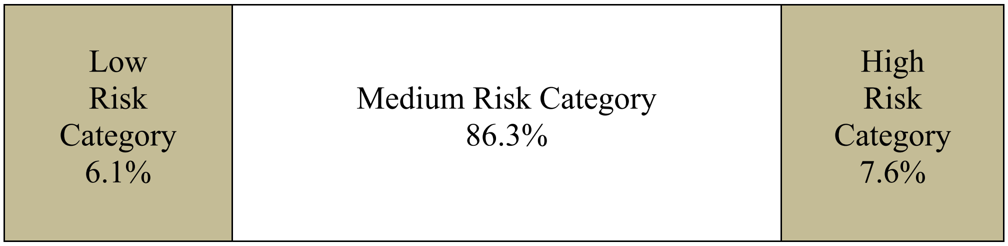

Figure 1 Risk Stratification of Low, Medium, and High-Risk Categories

Data Analyses

All analyses were performed using the Statistical Package for the Social Sciences, Version 22.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics are reported for each of the variables (age, gender, co-morbidities, acuity of symptoms, surgical history, exercise status, payer source, medication use, functional status change, and total visits).

Univariate multinomial regression analyses were used to predict the probability of category membership for a dependent variable with two or greater classifications, based on multiple independent variables. Maximum likelihood estimation was used to estimate model parameters. Multicollinearity was evaluated by analyzing correlation matrixes, variance inflation factors (VIFs), and tolerance values for each independent variable. A correlational finding of $R>0.7$ between independent variables was used to assess the potential of multicollinearity (Shen & Gao, 2008). Findings in the univariate analyses that yielded p values of 0.20 and under were included in a hierarchical multivariate multinomial predictive model. For predictive factors to be considered significant a p-value of .05 or less was required.

RESULTS

Descriptive representation of the complete sample, as well as the sample categorized according to risk is outlined in Table 1. Chi-square analyses indicated a significant ($p <$ .001) difference between the frequencies in each risk category (i.e. low, moderate, and high) for each of the variables except exercise (i.e. age, gender, co-morbidities, acuity, surgical history, payer source, and medication). One-way ANOVAs indicated a significant difference ($p < .001$) between risk categories in the means for change in functional status and total number of visits. Post-hoc Tukey tests revealed that differences existed between all risk groups for both change in functional status and total visits.

Each independent variable presented acceptable tolerance levels and Variance Inflation Factors (VIFs), as well as, low item to total-item correlations (<0.20). Our initial univariate multinomial regression model is shown in Table 2. Statistically significant immutable predictors of high risk of a poor outcome (moderate risk as referent category) were being female (OR = 0.88; 95% CI .83, .92), having a history of surgery (OR = 1.33; 95% CI 1.26, 1.40), and having greater than three comorbidities (OR = .89; 95% CI .85, .94). Statistically significant mutable predictors of high risk of a poor outcome (moderate risk as referent category) were payer source of auto insurance, litigation, or workman's compensation compared to private companies (OR = 1.18; 95% CI 1.11, 1.27), acuity equal to or greater than 22 days (OR = 0.05; 95% CI .04, .06), exercising less than 3 times a week (OR = 0.94; 95% CI.89, .96), and medication use (OR = 0.85; 95% CI .80, .89).

Age was not a significant predictor of high risk of a poor outcome (OR = 1.03; 95% CI .98 1.09) or low risk of a poor outcome (OR = 1.10; 95% CI .95 1.08) and therefore was removed from the model. There was one immutable predictor of low risk of a poor outcome, no prior surgeries (OR = 0.87; 95% CI .82, .93). Mutable predictors of low risk of a poor outcome included payer source of auto insurance, litigation, or workman's compensation compared to private companies (OR = .88; 95% CI .81, .96) and Medicaid/Medicare compared to private companies (OR = 1.07; 95% CI 1.00, 1.14). acuity less than 22 days (OR = 6.22; 95% CI 5.87, 6.59) and no medication use (OR = 1.10; 95% CI 1.03 1.17).

For our final hierarchical univariate multinomial logistic regression model (see Table 3), all variables were significant for either high risk of a poor outcome or low risk of a poor outcome. As with the initial model, the referent category was moderate risk. Immutable variables associated with high risk of poor outcome category were being female (OR = 0.88; 95% CI .83, .92) and having a history of surgery (OR = 1.33; 95% CI 1.26, 1.40). Several mutable variables were associated with the high risk of poor outcome. These included having greater than 3 comorbidities (OR = .89; 95% CI .85, .94), payer source of auto insurance, litigation, or workman's compensation compared to private companies (OR = 1.18; 95% CI 1.11, 1.27), acuity of 22 days or greater (OR = 0.05; 95% CI .04, .06), exercising less than 3 times a week (OR = 0.94; 95% CI .89, .96), and no medication use (OR = 0.85; 95% CI .80, .89). The only immutable variable significantly associated with low risk of a poor outcome was no history of surgery (OR = 0.87; 95% CI .82, .93). Three mutable variables were significantly associated with low risk of a poor outcome including acuity less than 22 days (OR = 6.22; 95% CI 5.87, 6.59), no medication use (OR = 1.10; 95% CI 1.03 1.17), payer source of auto insurance, litigation, or workman's compensation being less likely than private insurance to be low risk than moderate risk (OR = .88; 95% CI .81, .96), and payer source of Medicaid/Medicare being more likely than private insurance to be low risk than moderate risk (OR = 1.07; 95% CI 1.00, 1.14).

DISCUSSION

Clinics and therapists routinely struggle with determining the appropriate treatment strategy for patients because forecasting patient outcomes based on time and intervention is such an enormous task. The main objective of our study was to use data from clinics around the nation to investigate characteristics of patients with elbow, wrist, and hand diagnoses who were more or less likely to have favorable outcomes. Three immutable variables were found to be associated with the likelihood of a poorer outcome: being female, having greater than three comorbidities, and having a history of surgery. Four mutable variables were found to be associated with the likelihood of a poorer outcome: acuity of 22 days or greater, exercising less than 3 times a week, no medication use, and payer source. When compared to private insurance, individuals at low risk of a poor outcome were more likely to use private companies than worker's compensation, litigation, or automotive. Conversely, they were more likely to have Medicare or Medicaid than to use private insurance. One immutable variable was significantly associated with a greater probability of a good outcome: no history of surgery. Three mutable variables were significantly associated with a greater probability of a good outcome: no medication use, shorter acuity, and payer source. Individuals who were at high risk of a poor outcome, were more likely to use worker's compensation, litigation, or automotive compared to having private insurance.

These findings for the high risk of a poor outcome are similar to that of other musculoskeletal disorders (Cook et al., 2015; Rodeghero et al., 2017; Salamh et al., 2017). Having greater than three co-morbidities was also identified as a prognostic indicator of a high risk of a poor outcome with patients with shoulder pain (Rodeghero et al., 2017). Rodeghero and colleagues (2017) also report that patients with more acute symptoms, no surgical history, and Medicare/Medicaid as a payer source were more likely to have high outcomes with low visits. In contrast studies with patients with knee pain (Salamh et al., 2017), back pain (Rodeghero, Cook, Cleland, & Mintken, 2015), and neck pain (Cook et al., 2015) have reported that individuals with Medicare and Medicaid are less likely to be exceptional responders to therapy intervention. Consistent with findings of Salamh and colleagues (2017) using patients who experience knee pain, our results indicate that females are at high risk of a poor outcome.

Our analyses generated significant models that might assist in the identification of patients who would require less rehabilitation (those with low risk of a poor outcome) and others who may respond poorly to extensive rehabilitation (those with high risk of a poor outcome). The group of patients with low risk of a poor outcome achieved significant change in functional status with very few visits. Conversely, the patients categorized as high risk of a poor outcome had limited improvement in functional status despite numerous visits. Identifying the variables predictive of outcomes could be of benefit in guiding the plan of care for individuals at high risk of a poor outcome. This does not in any way suggest that treatment should not be given to individuals with potential for a poor prognosis. However, it does suggest that a treatment approach different from traditional rehabilitation may be required (e.g. longer duration with goals for maintenance) and/or additional consults (e.g. for psychiatry/counseling or medication management) may be necessary.

Due to the increased use of rehabilitation services throughout the nation, efficient and effective medical care is crucial. As previously noted, musculoskeletal disorders, including elbow, wrist, and hand impairments, are the second most common disability worldwide (Southerst et al., 2015; Walker-Bone & Linaker, 2016) and the leading work-related health concern in the United States (Gardner et al., 2008). The growing financial demand placed on the healthcare system by these disorders should stimulate increased efforts to make care efficient.

There are several limitations related to our study. Previous studies have noted the inherent limitations associated with the use of retrospective data from a commercial database (Childs, Harman, Rodeghero, Horn, & George, 2014; Resnik & Hart, 2003). Our sample was comprised of patients extracted from a commercial database. The use of such a database presents threats to both internal and external validity. Only patients with complete data were used for the analyses. There was no attempt to determine the amount of missing data for each group. Imputation of missing data for the independent variables was not conducted as this could potentially add further threats to validity. Moreover, information on the type of care received by the patients was not available in the dataset and thus, could not be considered in interpretation of the findings. Although our sample was large, these findings are preliminary and thus should not be generalized to all patients with elbow, wrist, and hand diagnoses. Even though we considered many potential predictor variables including those found significant in past studies (Cook et al., 2015; Rodeghero et al., 2017; Salamh et al., 2017) there are other potentially influential variables for which we did not have data on.

Future studies would be beneficial to validate the findings from our study. Knowledge of additional variables, such as types of treatment provided, would further help guide therapists in determining ideal treatment strategies for diverse individuals with elbow, wrist, and hand diagnoses. Supplementary knowledge about clinic types and locations might also add to predictive ability. Economic analysis of implementation of knowledge gained through this and other similar studies might elucidate any gains in efficiency of treatment.

CONCLUSIONS

This study explores predictive factors for patients receiving rehabilitation therapy for elbow, wrist, and hand diagnoses. Our analyses determined significant prognostic variables, allowing us to create models that could identify patients who were likely to benefit more from rehabilitation services versus those whose care might should include a more multidisciplinary approach. We are not suggesting withholding treatment from these individuals. However, knowledge of predictive factors early in treatment could be beneficial in prioritizing rehabilitation needs and acknowledging when consults for other services are needed. Further research is needed on the prognosis of patients seeking rehabilitation for elbow, wrist, and hand diagnoses related to cost, timing of care and cost/benefit ratios. Our study seems to indicate that while some patients require minimal resources and achieve excellent outcomes; others improve very little despite utilizing extensive resources.

TABLES AND FIGURES

Table 1: Descriptive Variables

Variable		Total sample/ frequency (%)	High risk of poor outcome (n=6820)	Moderate Risk (77183)	Low risk of poor outcome (5419)
Age	18-50 years	34438 (38.5%)	2699 (39.6%)	29679 (38.5%)	2060 (38.0%)
	51-89 years	54984 (61.5%)	4121 (60.4%)	47504 (61.5%)	3359 (62.0%)
Gender	Male	34592 (38.7%)	2745 (40.2%)	29665 (38.4%)	2182 (40.3%)
	Female	54830 (61.3%)	4075 (59.8%)	47518 (61.6%)	3237 (59.7%)
Co-morbidities	0-2	44278 (49.5%)	3233 (47.4%)	38328 (49.7%)	2717 (50.1%)
	3 or more	45144 (50.5%)	3587 (52.6%)	38855 (50.3%)	2702 (49.9%)
Acuity	<22 days	13998 (15.7%)	56 (.8%)	11176 (14.5%)	2766 (51.0%)
	≥22 days	75424 (84.3%)	6764 (99.2%)	66007 (85.5%)	2653 (49.0%)
Surgical history	None	52003 (58.2%)	4256 (62.4%)	44563 (57.7%)	3184 (58.8%)
	One or more	37419 (41.8%)	2564 (37.6%)	32620 (42.3%)	2235 (41.2%)
Exercise status	< 3 times/week	52060 (58.2%)	3859 (56.6%)	44999 (58.3%)	3202 (59.1%)
	≥ 3 times/week	37362 (41.8%)	2961 (43.4%)	32184 (41.7%)	2217 (40.9%)
Payer source*	Group A	13072 (14.6%)	1138 (16.7%)	11218 (14.5%)	716 (13.2%)
	Group B	25285 (28.3%)	1815 (26.6%)	21809 (28.3%)	1661 (30.7%)
	Group C	51065 (57.1%)	3867 (56.7%)	44156 (57.2%)	3042 (56.1%)
Medication use	No	58506 (65.4%)	4187 (61.4%)	50557 (65.5%)	3762 (69.4%)
	Yes	30916 (34.6%)	2633 (38.6%)	26626 (34.5%)	1657 (30.6%)
		mean (SD)	mean (SD)	mean (SD)	mean (SD)
FSCH		20.84 (14.20)	4.40 (2.27)	21.27 (13.68)	35.38 (9.94)
Total visits		11.82 (9.11)	17.48 (8.95)	11.88 (9.04)	3.87 (1.05)

Table 2: Initial Model including All Variables Hypothesized to Influence Outcomes

(Referent variables are listed in parentheses.)

Variable	Level	Odds Ratio, 95%CI (L, U)	*p*-value
Age (Older)	High risk	1.03 (.98, 1.09)	0.21
	Low risk	1.10 (.95, 1.08)	0.69
Gender (Male)	High risk	.88 (.83, .92)	<.01
	Low risk	.99 (.94, 1.05)	0.8
Co-morbidities (None)	High risk	.89 (.85, .94)	<.01
	Low risk	1.01 (.95, 1.07)	0.79
Acuity (Less than 22 days)	High risk	0.05 (.04, .06)	<.01
	Low risk	6.22 (5.87, 6.59)	<.01
Surgical history (One or more)	High risk	1.33 (1.26, 1.40)	<.01
	Low risk	.87 (.82, .93)	<.01
Exercise status (3 or more times a week)	High risk	.94 (.89, .96)	<.01
	Low risk	1.02 (.96, 1.08)	0.62
Payer source*	High risk	a; 1.18 (1.11, 1.27)	<.01
		b; .97 (.91, 1.02)	0.23
	Low risk	a; .88 (.81, .96)	<.01
		b; 1.07 (1.00, 1.14)	0.04
Medication use (None)	High risk	.85 (.80, .89)	<.01
	Low risk	1.10 (1.03, 1.17)	<.01

*Group A = Auto Insurance, Litigation, or Workman's Comp, Group B = Medicare and Medicaid (Comparison Group = All Others)

Table 3: Final Model Including Only Variables Significant in Initial Model

(Referent variables are listed in parentheses.)

Variable	Level	Odds Ratio, 95%CI (L, U)	*p*-value
Gender (Male)	High risk	.88 (.83, .92)	<.01
	Low risk	.99 (.94, 1.05)	0.77
Co-morbidities (None)	High risk	.89 (.85, .94)	<.01
	Low risk	1.01 (.96, 1.07)	0.7
Acuity (Less than 22 days)	High risk	0.05 (.04, .06)	<.01
	Low risk	6.22 (5.87, 6.59)	<.01
Surgical history (One or more)	High risk	1.33 (1.26, 1.40)	<.01
	Low risk	.87 (.82, .93)	<.01
Exercise status (3 or more times a week)	High risk	.94 (.89, .96)	0.01
	Low risk	1.02 (.96, 1.08)	0.63
Payer source*	High risk	a; 1.18 (1.11, 1.27)	<.01
		b; .97 (.91, 1.02)	0.22
	Low risk	a; .88 (.81, .96)	0.01
		b; 1.07 (1.00, 1.14)	0.04
Medication use (None)	High risk	.85 (.80, .89)	<.01
	Low risk	1.10 (1.03, 1.17)	0.01

*Group A = Auto Insurance, Litigation, or Workman's Comp, Group B = Medicare and Medicaid (Comparison Group = All Others)

III. UNPUBLISHED RESEARCH

1. Investigation of the Item-Level Psychometric Properties of the Elbow, Wrist, and Hand Computer Adaptive Test (EWH CAT)

Introduction

Musculoskeletal disorders (MSDs), including elbow, wrist, and hand impairments, are the second most common disability worldwide and place a large burden on the health care system (Southerst et al., 2015; Walker-Bone & Linaker, 2016). MSDs involving the upper extremity are among the leading work-related health concerns in the United States, accounting for up to 30% of all injuries requiring time away from work (Gardner et al., 2008). For example, the cost of medical care and lost work time associated with lateral and medial epicondylitis is more than $22 billion annually in the United States (Menta et al., 2015). Furthermore, carpal tunnel syndrome with prevalence estimates ranging from 2.7% to 7.8% is one of the most costly work-related upper extremity disorders, accounting for direct and indirect costs in excess of $2 billion per year in the United States (Menta et al., 2015).

Due to the prevalence and associated cost of elbow, wrist, and hand impairments, accurate and precise assessment is critical in the clinic and in research to ensure that patient treatment is optimal and practice advances (Badalamente et al., 2013a). Treatment planning and goal setting must be guided by accurate and precise assessment results to optimally benefit the client (Badalamente et al., 2013a). When standardized assessments are used this allows clinicians to make comparisons against norms and objectively evaluate effectiveness of their interventions (Velozo & Woodbury, 2011). Because assessment is a vital component in advancing practice and improving patient care, the decision about which evaluation tool to use is crucial.

This choice is complicated by the wealth of assessments available to clinicians. These assessments may be grouped into three common categories: generic health measures, disease-specific measures, and region-specific measures (Badalamente et al., 2013a). Generic health measures are used extensively. However, the meaning of results of these assessments will only have implications when the diagnosis has an impact broadly on general health (Badalamente et al., 2013a). Diagnoses that affect the wrist or hand (e.g. osteoarthritis of the first CMC joint and de Quervain's tenosynovitis) have very specific effects on daily life that are not likely to be captured by a generic health measure. Alternatively, disease-specific measures can more precisely evaluate changes in a specific condition (Badalamente et al., 2013a). Nevertheless, one problem with disease-specific measures is that they are not well suited to evaluate a variety of disorders or ailments (Badalamente et al., 2013a). Region specific scales are distinct in that scores on these scales reflect total status of the limb as a unit (Badalamente et al., 2013a). Even though this type of assessment is widely utilized by clinicians and researchers treating musculoskeletal conditions, they may not be the best to show changes if the main problems are in one joint (e.g. wrist) of the limb (Badalamente et al., 2013a).

Although all three types of assessments (i.e. generic health measures, disease-specific measures, and region-specific measures) are commonplace in clinical arenas (de Boer et al., 2001), they fail to directly guide therapy sessions in terms of what skills the patient can and can't do and what the patient's next goals might include. Despite the fact that reliability and validity has been demonstrated for many assessments, including those assessing upper extremity impairment (Lehman, Sindhu, et al., 2011; Schulzer et al., 2003; Van der Lee et al., 2001), these assessments are underutilized in therapy clinics because they lack the ability to clearly guide clinicians in evaluating specific functional ability, developing patient-centered goals and guiding treatment planning (de Boer et al., 1999; Woodbury & Velozo, 2005). Clinicians may view assessment administration as cumbersome, taking time away from therapeutic intervention. Often therapists only use assessments to adhere to requirements set forth by clinic management, accrediting agencies, or reimbursement parties (Velozo & Woodbury, 2011; Woodbury & Velozo, 2005).

For an assessment to be beneficial in directing clinical practice it must illustrate the skills of a patient and identify the tasks that are the best next goals for a patient (Lehman, Sindhu, et al., 2011; Woodbury & Velozo, 2005). Many assessments report the results as an overall, total score. Total scores are not easily understood as they disguise the tasks the patient is not able to complete (Lehman, Sindhu, et al., 2011).

To highlight a way in which assessment total scores are unclear about actual ability, imagine a patient with a score of 70 (out of a possible 100) on the Mayo Clinic Performance Index Scale, one of the most commonly used elbow assessments (Badalamente et al., 2013b). The score of 70 does not highlight the difficulties the patient is experiencing and what goals should be determined to help overcome the obstacles they face. A host of problems could attribute to the overall, total score of 70/100, such as, pain, abilities in daily function, range of motion, and/or stability. Furthermore, a total score does not elucidate for the clinician important aspects of care such as the degree that pain is contributing or assist in determining treatment goals for the client (Lehman, Sindhu, et al., 2011; Woodbury & Velozo, 2005).

Musculoskeletal disorders come with a complicated set of problems including pain, dysfunction in daily tasks, and reduced strength/range of motion necessitating more defined measurement of ability than one single total score allows.

In conclusion, we need accurate and efficient methods of evaluation and assessment for elbow, wrist, and hand diagnoses. Evaluating item characteristics of assessments can help test results optimize goal setting for patients with elbow, wrist, and hand impairments. To help achieve this end, the purpose of this study is to examine the Elbow, Wrist, and Hand Computer Adaptive Test (EWH CAT) at the item-level. More specifically, we had the aim to examine the item-level characteristics of the EWH CAT using Rasch analysis, including investigating item difficulty measures, person ability measures, item fit, and item-person match.

Methods

Participants

This study involves analysis of survey question data that has been previously collected by Focus On Therapeutic Outcomes, Inc. (FOTO) (Knoxville, TN, USA). FOTO is a web based patient assessment system that reports functional status measures. It is used nationwide in 3,400 clinics by 15,000 clinicians. FOTO provided us with de-identified data from patients who met our inclusion criteria. Data were selected from the FOTO database if patients a) were 18 years old or older; b) were treated for an orthopedic impairment of the elbow, wrist, and/or hand; c) received outpatient therapy; and d) completed the EWH CAT. Data was analyzed to answer questions related to the purposes of study. Exact numbers of cases analyzed varied slightly from analysis to analysis due to missing data, however, approximately 72,202 cases were analyzed. Each patient at participating clinics was asked whether they would be willing to submit their data to FOTO. Data only from those who have consented is submitted to FOTO. The institutional review board (IRB) at Augusta University granted a waiver of need for IRB approval for this study since all data was de-identified when obtained by the investigators. See Table 4 for patient characteristics.

Assessments

A demographic questionnaire was used to collect information on age, number of visits, comorbidities, gender, acuity, exercise status, and medication use. Information was also collected on the EWH CAT. The EWH CAT is a self-report measure containing items asking about the difficulty of daily tasks such as "*Are you able to groom your hair with your affected arm?*" These items are rated on a scale from one to five either in regards to the difficulty of the task or the severity of the symptom. No previous studies have assessed the reliability and validity of the EWH CAT. See Appendix A for a complete list of items on the EWH CAT.

Analysis

SPSS Version 23 (SPSS Inc., Chicago, IL, USA) was used for data management and descriptive statistics. Winsteps version 4.0.1. (Linacre, 2018) was used to perform Rasch analysis. Mplus version 8 (Muthen & Muthen, 1998-2017) was used to conduct a confirmatory factor analysis (CFA). The analysis consisted of the following phases: (1) investigating local independence of items (2) evaluating the unidimensionality of the instrument (i.e. do all items represent a single construct of elbow, wrist, and hand ability or do some items, for instance, only measure elbow ability), (3) assessing monotonicity, (4) investigating the hierarchical order of item difficulty (i.e. rank order of challenge of items), and (5) determining the match between the items and the sample.

Local independence of items

Local independence suggests that responses to items are unrelated to each other. Meaning, there is not a relationship linking the items. Local independence of items is not present if one item's correct response is dependent on another item or if the knowledge from one item provides content required to complete another item. To determine if items possess local independence, we examined residual item correlations. Pairs having residual correlations > 0.30 are generally considered to be locally dependent (Smith, 2002). We evaluated both residual correlations and conceptual relevance of items to determine criteria for removal (Lehman, Woodbury, et al., 2011).

Unidimensionality

A condition of measurement is that the items on a scale represent the same construct. Meaning, that the items must represent similar movements or activities. For instance, questions relating to hand movements might not involve elbow movement and thus, would be measuring a different ability (i.e. hand versus elbow function). CFA examines the theoretical structure and dimensionality of a set of items. Data in this study were ordinal and therefore, the CFA was conducted on the polychoric correlation matrix using a weighted least squares approach (Muthen & Muthen, 1998-2017). Data was imputed for 50% of the missing responses in Winsteps Rasch software program. Winsteps probabilistically generates data based on anchored parameter estimates. To confirm the validity of the data imputation process, a series of three simulations were conducted and examined for agreement. Evidence of adequate fit was determined by examination of standard indices: root mean square error (RMSEA) < .0.06, Tucker-Lewis Index (TLI) > 0.95, Comparative Fit Index (CFI) > 0.95, standardized factor loadings > .40 and R^2 > .0.60. The *a priori* hypothesis was that the items represented one domain, arm ability. Consequently, a one-factor CFA was fit to the data.

Additionally, using Rasch analysis, the extent to which items fit to the measurement model was evaluated through mean square standardized residuals (MnSq) which were produced for each item. MnSq represents observed variance (observed error in scores) divided by expected variance (the error that the Rasch model predicts). Thus, the desired value for MnSq is 1.0. The criteria used for model fit depend on the intended use of the measure and the degree of exactness desired. Wright and Linacre (1994) advise that for rating scales reasonable ranges for MnSq values fall between 0.6 and 1.4 with associated standardized *Z* values < 2.0. Low MnSq values (< 0.6) indicate that the item is failing to discriminate individuals with different levels of ability (i.e. people with different amounts of challenge using their elbow, wrist, and hands) or the item is redundant (i.e. other items on the assessment are measuring at the same level of difficulty). High MnSq values (i.e. >1.4) indicate that the item is variant or erratic, suggesting that the item is measuring a different construct than the other items or that the wording of the item is being misinterpreted. Items with high MnSq values thus represent more of a threat to validity and will be given greater consideration for removal.

Monotonicity

A main tenant of item response theory (IRT) models is monotonicity. The assumption of monotonicity means that the probability of choosing a response that indicates a higher level of functioning increases as the person's ability increases. We examined monotonicity of the EWH CAT in several steps using Linacre's three essential criteria (Linacre, 1997) for rating scales. First, the number of responses in each rating category was examined. To assure stable estimates of person ability and item-difficulty at least 10 responses are necessary for each rating. Second, mean person-ability measures were examined for each rating category. Higher rating categories should be associated with higher mean person ability measures than lower categories. Finally, outfit statistics were examined for each item. Outfit statistics assess whether or not the item was interpreted correctly. These statistics are given in mean square (MnSq) residuals. These residuals represent the difference between actual sample ratings and what ratings are expected by the Rasch model. Outfit MnSq values less than two have been suggested as being acceptable (Wright & Linacre, 1994).

Hierarchical order of item difficulty

The development of the item bank was based on a hypothesized hierarchy of item difficulty. For example, opening a door with your affected arm, was hypothesized to be easier than doing your usual hobbies, recreational or sporting activities with your affected arm. Rasch analysis offers the ability to examine the validity of the proposed hierarchy by calculating measures of difficulty. Furthermore, items signifying the same activity with differing characteristics were also compared. For example, lifting a bag of groceries to waist level should be easier than lifting a bag of groceries above your head.

Match between the items and the sample

Items were purposely designed to gauge a broad range of elbow, wrist, and hand abilities. To investigate how well the instrument included a large range of abilities, we used a feature of the Winsteps program that allows examination of the match of person ability and the item difficulty of the sample tested. Floor effects represent person abilities below item difficulties. Conversely, person abilities exceeding item difficulties represent ceiling effects. Furthermore, gaps may exist between items where individuals with different abilities may not be separated by the instrument. Gaps were determined using the formula, $t = (A\text{-B})/\surd(\mathrm{SE_A}^2 + \mathrm{SE_B}^2)$, where A and B represent the two item calibrations at the bottom category of one harder item (e.g. *Unable to Do*) and top category of the easier item (e.g. *With No Difficulty*) and $\mathrm{SE_A}^2$ and $\mathrm{SE_B}^2$ represent the standard errors of items A and B, respectively (Wright & Stone, 1979). Significant gaps are indicated with a t value greater than 1.96. Ceiling/floor effects and gaps suggest that the instrument has limitations differentiating individuals.

Internal Consistency and Separation

To investigate the internal consistency of the instrument, the person reliability index, analogous to coefficient α, was determined. In addition, the separation ratio (SR) was used to examine the instrument's precision. The SR is defined as the ratio of the standard deviation of the sample in logits adjusted due to error to the standard error of measurement. It was calculated using the formula (4Gp+1)/3 where GP is the person separation index (Mallinson, Stelmack, & Velozo, 2004; Wright & Masters, 1982; Wright & Stone, 1979).

Results

Local independence of items

Examination of residual correlations revealed one item-pair had a very strong correlation, slightly greater than .90 (r =-.909). This pair included the questions*: Are you able to do heavy household chores (e.g. washing windows or floors) with your affected arm?* and *Are you able to launder clothes (e.g. wash, iron, fold) with your affected arm?* The authors decided to retain the item representing a more general activity (doing heavy household chores) than the item representing a more specific activity (laundering clothes). Therefore, the item relating to laundering clothes was removed from the rest of the analyses, leaving 41 items. All other items were retained based on the authors' clinical judgments. For example the questions, *Are you able to open a jar with your affected arm?* and *Are you able to open a tight or new jar with your affected arm?* (r = .816) were both retained based on the logic that although they represented the same activity they represented differing degrees of difficulty of that activity and could be rationally used to identify patient progress.

Unidimensionality

A one-factor CFA was conducted with the remaining 41 items. Standard indices supported evidence for adequate fit of a one-factor model: root mean square error (RMSEA) = .017, Tucker-Lewis Index (TLI) = .998, Comparative Fit Index (CFI) = .998, standardized factor loadings > .40 and R^2 = .75.

Only six out of the 41 items (15%) had high MnSq values (> 1.40). Two of these items were more symptom related than related to a specific task (weakness in arm, MnSq = 1.77, *Z* = 8.2; stiffness in arm, MnSq = 1.55, *Z* = 6.9), while three involved tasks overhead (changing a light bulb, MnSq = 1.54, *Z* = 5.0; placing an object on a shelf above head, MnSq = 1.93, *Z* =9.9; blow drying hair, MnSq = 1.41, *Z* = 5.0). The remaining item with a high MnSq value involving managing transportation needs (MnSq = 1.75, *Z* = 9.9). (See Table 2). For this study these items were retained because of the deemed clinical importance of these activities and the desire to assess the EWH CAT in its currently administered form. Items with low MnSq values (< .60) are considered less of a threat to validity so these items were retained as well.

Monotonicity

With such a large sample, observed counts for each rating category were well over the minimum of 10 for all items. A rating of one was endorsed 116,947 times, a rating of two 65,298 times, a rating of three 97,505 times, a rating of four 100,799 times, and a rating of five 100,116 times. Increases in ratings were associated with increases in person ability. A rating of one was associated with a mean person ability estimate of -2.52, a rating of two with a mean person ability estimate of -1.18, a rating of three with a mean person ability estimate of -.04, a rating of four with a mean person ability estimate of 1.17, and a rating of five with a mean person ability estimate of 2.60. All outfit MnSq values were less than 2.0, ranging from .92 to 1.17.

Hierarchical order of item difficulty

Since the items were hypothesized to represent a difficulty range, this analysis focused on how logical the difficulty ordering of items appeared. Table 5 presents the items. The most challenging items (i.e. those with higher difficulty calibrations) are located at the top of the table and the least challenging items (i.e. those with lower difficulty calibrations) are located at the bottom of the table. Overall, the hierarchy of difficulty was believable. For example, one of the hardest items was participating in recreational activities requiring arm force such as golf, hammering, or tennis while one of the easiest items was grooming hair. Additionally, among items involving a similar action the hierarchy of difficulty was credible. For example, lifting a bag of groceries above one's head was harder than lifting a bag of groceries to waist level.

Match between the items and the sample

Rasch analysis allows a direct comparison of item difficulty and person ability. Figure 2 presents a graph of item difficulty measures plotted against person measures at each logit value. The items are located at the right on the graph at their average measure of challenge in logits (i.e. the measure when the individual's response is in the middle category of the rating scale). In general, the items were normally distributed about the mean, showing a slight floor effect with 2,899 people out of 72,702 receiving minimum extreme measures (4.0% of the sample) and an even smaller ceiling effect with 1,585 people out of 72,702 receiving maximum extreme measures (2.2% of the sample). The sample mean was .13 logits above the item calibration mean (which was anchored at zero) indicating that the items although slightly easy for the sample were well matched for the sample. There were no statistically significant gaps.

Internal Consistency and Separation

The items showed good internal consistency. The person reliability index, analogous to coefficient α, was .87. The separation ratio indicated that the sample was being separated into 3.73 ability groups.

Table 4. Patient Characteristics

Characteristic	
Mean Age +/- SD (N=72,745)	51.7 +/- 16.0
Number of Visits +/- SD (N=72,691)	10.6 +/- 30.4
Comorbidities (N=72,745)	3.5 +/- 3.1
Gender (N=72,744)	
Male	39.4%
Female	60.6%
Acuity (N=72,700)	
0 to 21 Days	19.3%
22 to 90 Days	39.5%
>91 Days	41.2%
Exercise (N=70,788)	
At Least 3x/Week	40.1%
1-2x/Week	27.0%
Seldom or Never	33.0%
Medication Use (N=72,164)	
Yes	35.8%
No	63.4%

Table 5. Item Statistics

Items	Item difficulty	Error	Infit (MnSq)	ZSTD
Please rate your severity of any weakness in your affected arm?	2.22	.08	1.77	8.2
Are you able to participate in recreational activities in which you take some force or impact through your affected arm?(eg, golf, hammering, tennis, etc.)?	1.93	.02	.77	-9.9
Are you able to open a jar with your affected arm?	1.75	.03	.91	-3.3
Are you able to do your usual hobbies, recreational or sporting activities with your affected arm?	1.71	.02	.84	-7.3
Are you able to carry a heavy object (over 10 lbs.) with your affected arm?	1.55	.02	.87	-5.2
Are you able to participate in recreational activities in which you move your affected arm freely (eg, playing Frisbee, badminton, etc.)?	1.50	.03	.83	-5.3
Are you able to open a tight or new jar with your affected arm?	1.36	.01	.94	-8.6
Are you able to do garden or yard work with your affected arm?	1.36	.03	.74	-9.2
Are you able to lift a bag of groceries above your head with you affected arm?	1.10	.02	.84	-8.0
Are you able to do heavy household chores (eg, washing windows or floors) with your affected arm?	.85	.01	.95	-6.0
To what extent does your arm problem interfere with your normal social activities with family, friends, neighbors or groups?	.55	.05	.91	-2.2

Are you able to participate in recreational activities which require little effort (eg, card playing, knitting, etc.) with your affected arm?	.39	.05	1.02	.4
Are you able to do your usual work, housework, or school activities with your affected arm?	.33	.03	.42	-9.9
Are you able to open heavy doors with your affected arm?	.30	.03	1.15	5.1
Are you able to lift a bag of groceries to waist level with your affected arm?	.27	.03	.55	-9.9
Are you able to vacuum, sweep, or rake with your affected arm?	.23	.03	.49	-9.9
Do you feel less capable, less confident or less useful because of your affected arm?	.20	.02	1.40	9.9
Are you limited in your work or other regular daily activities with your affected arm?	.12	.36	.23	-3.0
Are you able to carry a shopping bag or briefcase with your affected arm?	.10	.01	.79	-9.9
Are you able to wash your back with your affected arm?	.10	.01	1.25	9.9
Are you able to push up on your hands (eg, from bathtub or chair)?	.10	.01	.84	-9.9
Are you able to carry a small suitcase with your affected arm?	.04	.01	.93	-7.6
Are you able to change a light bulb overhead with your affected arm?	.00	.09	1.54	5.0
Are you able to use tools or appliances with your affected arm?	-.03	.03	.45	-9.9
Are you able to use a knife to cut food with your affected arm?	-.18	.25	1.20	.8
Are you able to place an object on a shelf above your head with your affected arm?	-.36	.03	1.93	9.9

Are you able to prepare food (eg, peeling, cutting) with your affected arm?	-.43	.03	.80	-6.1
Are you able to wash or blow dry your hair with your affected arm?	-.50	.07	1.41	5.0
Are you able to open doors with your affected arm?	-.57	.01	1.02	2.4
Are you able to do up buttons with your affected arm?	-.57	.01	1.29	9.9
Are you able to turn a key with your affected arm?	-.65	.01	1.16	9.9
Are you able to clean with your affected arm?	-.82	.03	.80	-5.9
Are you able to prepare a meal with your affected arm	-.94	.02	.90	-5.5
Are you able to groom your hair with your affected arm?	-1.04	.02	.87	-5.7
Are you able to make a bed with your affected arm?	-1.07	.03	.89	-3.2
Are you able to tie or lace shoes with your affected arm?	-1.25	.04	1.08	2.0
Are you able to put on a pullover sweater with your affected arm?	-1.35	.01	1.38	9.9
Are you able to drive with your affected arm?	-1.41	.02	1.09	3.4
Are you able to dress with your affected arm?	-1.95	.02	.71	-9.9
Please rate the severity of any stiffness in your affected arm?	-2.19	.06	1.55	6.9
Are you able to manage transportation needs (eg, getting from one place to another) with your affected arm?	-2.73	.03	1.75	9.9

Figure 2. Relationship of Person Ability and Item Difficulty

```
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   -1      .##########################  +  XXX                             -1
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   -6            .####################  +                                  -6
  <less> --------------------- PERSON  -+- ITEM    ----------------- <freq>
 EACH "#" IN THE PERSON COLUMN IS 144 PERSON: EACH "." IS 1 TO 143; Each “X” is
an item.
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Discussion

The purpose of this study was to evaluate the psychometrics of a self-report elbow, wrist, and hand computer adaptive test. Investigations of monotonicity and local independence were conducted and showed satisfactory results. Principal components and fit analyses suggested that a one-factor solution was plausible. In general, the order of item difficulty within each construct was believable. The match between person ability and item difficulty suggested that the items although slightly easy for the sample were well matched for the sample. The items showed good internal consistency and person separation.

There are various reasons why six items misfit. Items related more to symptoms (weakness and stiffness) represent something slightly different than the other more task related items. Lifting items above one's head may also require distinct muscle groups from the other items. Finally, it is likely that the item, "*Are you able to manage transportation needs (e.g. getting from one place to another) with your affected arm*?" was construed to mean something different to different individuals.

Another important characteristic of a measure involves having items that define a difficulty hierarchy. The items appear to be of plausible difficulty across the dimension of lifting distance. For example, lifting a bag of groceries above one's head was harder than lifting a bag of groceries to waist level. Additionally, items requiring more strength calibrated as more difficult items. For instance, recreational activities requiring arm force such as golf, hammering, or tennis were harder than grooming one's hair. Future studies identifying differential item functioning may be necessary to determine whether the item calibrations are stable across different samples.

A unique feature of Rasch analysis is its ability to plot person ability and item difficulty on the same continuum. This feature has advantages in instrument and item bank development, especially when items are designed according to a hypothesized difficulty hierarchy. In the present study 4.0% of the sample grouped at the lowest ability level. This “floor effect” is attributable to a large number of challenging items (i.e. participants performing below the level of the easiest item). This may be due in part to the complexity of the problems experienced by the sample. The hierarchical structure of the EWH CAT item bank makes it apparent that the floor effect could be reduced or eliminated through the inclusion of easier items. For example, the following items might be added to the item bank: using a computer mouse, wiping off a desk, and picking up a pencil.

There was also a considerable number of individuals for whom the items were relatively easy. In the present study 2.2% of the sample grouped at the highest ability level. This “ceiling effect” is attributable to a large number of easy items (i.e. participants performing above the level of the hardest item). This may be due in part to a wide range of ability and problems experienced by the sample. The hierarchical structure of the EWH CAT item bank makes it apparent that the ceiling effect could be reduced or eliminated through the inclusion of harder items. For example, the following items: lifting 25 lbs above one’s head and rearranging furniture.

The present study had a number of limitations. Previous studies have noted the inherent limitations associated with the use of retrospective data from a commercial database (Childs et al., 2014; Resnik & Hart, 2003). Our sample was comprised of patient information extracted from a commercial database. The use of such a database presents threats to both internal and external validity. With such a large database, unknown extraneous variables (e.g. process of test administration, etc.) may compete with the independent variables selected to help explain the outcome of the study causing threats to internal validity. Unidentified selection bias may contribute to threats to external validity (i.e. generalizability to locations outside of the United States). Furthermore, several items misfit. A better item bank might be created by eliminating these items. There were several individuals for whom the items were all easy and a group within the sample for which the items were all difficult. The addition of easier items such as using a computer mouse, wiping off a desk, and picking up a pencil might be added to improve the match between the items and the less able part of the sample. The addition of harder items such as lifting 25 lbs above one's head and rearranging furniture might be added to improve the match between the items and the more able part of the sample.

Future studies might modify the bank by eliminating misfitting items, adding a wider range of difficulty of items, and more selectively choosing the sample (potentially based on impairment). These improvements might help to further clarify tasks that patients are finding difficult and thus, enhance the ease of goal setting and treatment planning. Also, differential item functioning might be addressed. Differential item functioning could potentially reveal questions that might need modification/clarification when used with certain subsets of individuals.

2. Creating a Clinically Useful Data Collection Form for the Elbow, Wrist and Hand Computer Adaptive Test (EWH CAT)

INTRODUCTION

Occupational therapists can evaluate upper extremity function using various types of assessments. These include performance measures, self-report measures, and impairment level measures (Badalamente et al., 2013a). Performance measures, those that evaluate basic movements such as elbow flexion and extension, may be used. Examples of this type of assessment include the Motor Assessment Scale (Carr, Shepherd, Nordholm, & Lynne, 1985), Fugl-Meyer Assessment (Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975), and Wolf Motor Function Test (Wolf et al., 2001). Alternatively, self-reports of function, such as the Disabilities of the Arm, Shoulder, and Hand (DASH) outcome questionnaire (Beaton et al., 2001) may be used. Finally, upper-extremity function may be assessed at the impairment level (i.e. level of anatomical structure or function). These measures include the Minnesota Rate of Manipulation Test or Purdue Pegboard Test (Tiffin & Asher, 1948).

Although all three types of assessments (i.e. performance, self-report, and impairment level) are commonplace in clinical arenas (de Boer et al., 2001), they fail to directly guide therapy sessions in terms of what skills the patient can and can’t do and what the patient’s next goals might include. Despite the fact that reliability and validity have been demonstrated for many assessments, including those assessing upper extremity impairment (Lehman, Sindhu, et al., 2011; Schulzer et al., 2003; Van der Lee et al., 2001), these assessments are underutilized in therapy clinics because they lack the ability to clearly guide clinicians in evaluating specific functional ability, developing patient-centered goals and guiding treatment planning (de Boer et al., 1999; Woodbury & Velozo, 2005). Clinicians may view assessment administration as cumbersome, taking time away from interventions. Often therapists only use assessments to adhere to requirements set forth by clinic management, accrediting agencies, or reimbursement parties (Velozo & Woodbury, 2011; Woodbury & Velozo, 2005). For an assessment to be beneficial in directing clinical practice, it must illustrate the skills of a patient and identify the tasks that are the best next goals for a patient (Lehman, Sindhu, et al., 2011; Woodbury & Velozo, 2005). Many assessments report the results as an overall, total score. Total scores are not easily understood as they disguise the tasks the patient is not able to complete (Lehman, Sindhu, et al., 2011).

To highlight a way in which assessment total scores are unclear about actual ability, imagine a patient with a score of 2.45 (out of a possible 5) on the Functional Status Scale of the Boston Carpal Tunnel Syndrome Questionnaire (BCTQ), one of the most commonly used assessments for this condition (Badalamente et al., 2013b). The score of 2.45 does not highlight the difficulties the patient is experiencing and what goals should be made to help overcome the obstacles they face. A host of problems could attribute to the overall, total score of 2.45/5, such as fine motor difficulties with items such as buttoning one’s shirt or more gross motor problems needed for bathing. Furthermore, a total score does not elucidate for the clinician how challenges with a particular joint motion should contribute to determining treatment goals for the client (Lehman, Sindhu, et al., 2011; Woodbury & Velozo, 2005). Musculoskeletal disorders come with a complicated set of problems including pain, dysfunction in daily tasks, and reduced strength/range of motion necessitating more defined measurement of ability than one single total score allows.

A possible solution to the problem that assessments do not do enough to inform clinical practice involves redesigning assessments using item response theory (IRT) methodologies. The one-parameter IRT model, the Rasch model, can provide a recognizable illustration of what items on an assessment provide the just right challenge for the patient (Kielhofner, Dobra, Forsyth, & Basu, 2005). Instantaneous evaluation of what a patient is able and unable to do can be made by placing his or her ability measure and item difficulty on the same continuum (Linacre, 1997). The output from this analysis has been called a *keyform* (Linacre, 1997). A keyform provides a visual display of the expected response patterns for items on a measure (Linacre, 1997).

Several concepts of the Rasch measurement model make possible the creation of keyforms. First, items on an assessment must all represent the same construct or idea. If this is the case, Rasch analysis can be used to turn ordinal data into equal interval data, measured in log-odds units. Thus, items making up an assessment can be seen as markings on a ruler located at their logit measure. Person ability estimates (also calculated in logits based on an individual's responses) can be placed on the same linear continuum (i.e. ruler) allowing for the direct comparison between person ability and item difficulty (Kielhofner et al., 2005). The person ability estimates indicate that a person possesses more or less of the construct of interest. For instance, on the Elbow, Wrist and Hand Computer Adaptive Test (EWH CAT), a person with a logit ability measure of -3 would have less elbow, wrist, and hand ability than a person with a logit ability measure of 3.

The purpose of this study was to demonstrate how Rasch analysis can be used to create a data collection form based on identified item characteristics and how this keyform can be used to guide clinicians in goal setting and treatment planning. The general keyform obtained through Rasch analysis provided the basis for this data collection form. This paper is an effort to: (1) Demonstrate how Rasch analysis can be used to generate a keyform based on the EWH CAT items. (2) Demonstrate how a data collection form designed based on this keyform can guide clinicians in goal setting and treatment planning.

METHODS

Participants

This study involves analysis of survey question data that has been previously collected by the Focus On Therapeutic Outcomes, Inc. (FOTO) (Knoxville, TN, USA). FOTO is a web based patient assessment system that reports functional status measures. It is used nationwide in 3,400 clinics by 15,000 clinicians. FOTO provided us with de-identified data from patients who met our inclusion criteria. Data was selected from the FOTO database if patients a) were 18 years old or older; b) were treated for an orthopedic impairment of the elbow, wrist, and/or hand; c) received outpatient therapy; and d) completed the EWH CAT. Data was analyzed to answer questions related to the purposes of the study. Overall, 72,702 cases were analyzed. Each patient at participating clinics was asked whether they would be willing to submit their data to FOTO. Data only from those who have consented is submitted to FOTO. The institutional review board (IRB) at Augusta University granted a waiver of need for IRB approval for this study since all data was de-identified when obtained by the investigators.

Assessments

A demographic questionnaire was used to collect information on age, number of visits, comorbidities, gender, acuity, exercise status, and medication use. See Table 6 for patient characteristics.

Data from the EWH CAT was analyzed. The EWH CAT is a self-report measure containing items asking about the difficulty of daily tasks such as "*Are you able to open a jar with your affected arm?*" Patients rate these items on a scale from one to five either in regards to the difficulty of the task or the severity of the symptom. There have not been any studies conducted to examine the reliability and validity of the EWH CAT. See Appendix A for all the items included on the EWH CAT.

Data Analysis

Preliminary Analyses – Local Independence and Unidimensionality

Local independence of items

Items that are locally independent are unrelated to each other (i.e., there is not a relationship linking the items). Items are locally dependent if one item's correct response relies on another item or if the knowledge required to correctly answer one item is the same as the knowledge needed for a correct response on another item. We examined residual item correlations to assess local indepence. Pairs having residual correlations > 0.30 were considered to be locally dependent (Smith, 2002). We examined conceptual relevance of items, along with residual correlations, to determine if items were to be removed (Lehman, Woodbury, et al., 2011).

One item-pair had a very strong correlation residual correlation, slightly greater than .90 (r =-.909). The pair consisted of the quesitons*: Are you able to do heavy household* *chores (e.g., washing windows or floors) with your affected arm?* and *Are you able to launder clothes (e.g., wash, iron, fold) with your affected arm?* We decided to keep the item representing a more general task (doing heavy household chores) than the item representing a more specific task (laundering clothes). Thus, laundering clothes was removed for the rest of the analyses, leaving 41 items. All other items were kept based on clinical judgment. For instance the tasks, *Are you able to open a jar with your affected arm?* and *Are you able to open a tight or new jar with your affected arm?* were both saved based on the logic that although they represented similar activities they highlighted differing degrees of difficulty of that task and could be used to assess progress.

Unidimensionality

A requirement of measurement is that the items on a test evaluate the same construct. Meaning, that the items must represent similar tasks. For example, questions relating to wrist movements might not involve hand movement and thus, would be measuring a different ability (i.e. wrist versus hand function). To test whether or not items on the EWH CAT represent one construct or idea, a preliminary analysis, an exploratory factor analysis (EFA) was conducted on the EWH CAT items. Because of the ordinal nature of the data, the EFA was conducted on the polychoric correlation matrix with weighted least square parameter estimates (Muthen & Muthen, 1998-2017). EFA identifies the number of factors (i.e. latent traits) that best explain the pattern of covariance underlying a set of measured variable (e.g. item responses). An oblique rotation method called *promax* was used because factors emerging from the data were expected to be correlated. Winsteps Rasch software program was used to impute data for 50% of the missing responses. Winsteps probabilistically produces data based on anchored parameter estimates. The validity of the data imputation process was confirmed by conducting a series of three simulations and evaluating the agreement between results from the simulated data sets. One factor had eigenvalues (*e*) > 1.0 (31.547). All items had loadings > 0.40 on one factor. Thus, this study treated the items on the EWH CAT as if they represent one construct (i.e. all 41 items were analyzed together).

Generating Rasch Keyforms

A keyform was generated for the EWH CAT admission data in Winsteps Rasch software program. To make the keyform clinically meaningful, UMEAN, USCALE, and MRANGE commands were used (Linacre, 2017). The UMEAN score was calculated to be 48.31 and the USCALE score was calculated to be 8.87. MRANGE was set to be 50. Because each item's difficulty calibration varied from admission to discharge (i.e. as patients' conditions changed, item difficulties changed), alterations in functional ability were made observable by anchoring person measures at discharge by average difficulties and average rating scale step estimates at admission values using the UMEAN command. That is, items were anchored at the moderate difficulty (e.g. "*With moderate difficulty*") to a given item at admission (i.e. item average difficulty at admission). Simultaneously, items were anchored at the estimated value for the transition from one rating scale choice to the next, for example, from "*With mild difficulty*" to "*With moderate difficulty*" using the USCALE command. We ensured that person ability estimates ranged from 0-100 by setting the MRANGE=50.

Creation of Data Collection Forms

The keyform we obtain from Winsteps was used as the basis for creating the EWH CAT data collection form. The Winsteps form was modified by adding patient instructions at the top, moving items to the left of the response choices, and adding descriptions above the response choice numbers. Additionally, a percentage person ability scale ranging from 0-100 was placed at the top and bottom of the form. Areas of the form were shaded to improve readability. Responses of a randomly selected patient were used to illustrate what a completed form would look like and ideas regarding goal setting and treatment planning for this individual are discussed. Please note that not all items were answered by any given individual because the test is administered in a computer adaptive format. Observed responses of the chosen individual were circled. If the observed response was unexpected, a square was placed around the expected response. If the observed response was very unexpected, a triangle was place around the expected response.

RESULTS

Creation of Data Collection Forms

A data collection form was created for the EWH CAT items based on the keyform generated from the Winsteps Rasch analysis program (Linacre, 2017). This form is shown in Figure 3. Instructions were placed at the top to read, "*Please answer the questions below.*" Items are located at the left in the order of their decreasing difficulty. Rating scale choices (1-5) are presented at the right of each item with descriptions of what ratings mean above the number responses. The rating scale choices are placed at a location related to the person ability scale at the bottom. For instance, an individual with a person ability measure of 60 would be most likely to rate all items as a "2" or a "3". Likewise, a person with a person ability of 80 would be most likely to rate items as a "4" or a "5".

The data collection form of the EWH CAT was filled out according to an individual at admission and discharge. Figure 4 has the admission responses circled, while Figure 5 has discharge responses circled. Also, note that not all items are answered because the test is administered in a computer adaptive format. If the observed response was unexpected, the expected response for that item has a square around it. If the observed response was very unexpected, the expected response has a triangle around it. Areas where goals might be set are evident. Based on unexpected responses and responses on which *With Moderate Difficulty* were selected, this individual seems to have difficulty with tasks that require strength more than tasks requiring dexterity and flexibility. Also, in particular this individual seems challenged with carrying items. Based on the hierarchy of difficulty, goals set might involve activities around where this individual is circling four's or the one unexpected instance of a three. Some improvement in this individual's elbow, wrist, and hand ability is illustrated by discharge. On Figure 5, it is evident that this individual has improved in mobility, dexterity, and flexibility, but is still having challenges with tasks requiring strength such as carrying a suitcase.

Table 6: Patient Characteristics

Characteristic	
Mean Age +/- SD (N=72,745)	51.7 +/- 16.0
Number of Visits +/- SD (N=72,691)	10.6 +/- 30.4
Comorbidities (N=72,745)	3.5 +/- 3.1
Gender (N=72,744)	
Male	39.4%
Female	60.6%
Acuity (N=72,700)	
0 to 21 Days	19.3%
22 to 90 Days	39.5%
>91 Days	41.2%
Exercise (N=70,788)	
At Least 3x/Week	40.1%
1-2x/Week	27.0%
Seldom or Never	33.0%
Medication Use (N=72,164)	
Yes	35.8%
No	63.4%

Figure 3. Elbow, Wrist, and Hand Computer Adaptive Test (EWH CAT) Data Collection Form

Please answer the questions below.

Percentage Ability Measure out of 100	0 20 40 60 80 100
Activity	
	Very Severe Severe Moderate Mild None
Please rate your severity of any weakness in your affected arm?	1 : 2 : 3 : 4 : 5
	Unable Severe Moderate Mild No Difficulty
Are you able to participate in recreational activities in which you take some force or impact through your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open a jar with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do your usual hobbies, recreational or sporting activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to carry a heavy object (over 10 lbs.) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to participate in recreational activities in which you move your affected arm freely (e.g., playing Frisbee, badminton, etc.)?	1 : 2 : 3 : 4 : 5
Are you able to open a tight or new jar with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do garden or yard work with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to lift a bag of groceries above your head with you affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do heavy household chores (e.g., washing windows or floors) with your affected arm?	1 : 2 : 3 : 4 : 5
To what extent does your arm problem interfere with your normal social activities with family, friends, neighbors or groups?	1 : 2 : 3 : 4 : 5
Are you able to participate in recreational activities which require little effort (e.g., card playing, knitting, etc.) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do your usual work, housework, or school activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open heavy doors with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to lift a bag of groceries to waist level with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to vacuum, sweep, or rake with your affected arm?	1 : 2 : 3 : 4 : 5
	Strongly Agree Agree Neither Disagree Strongly Disagree
Do you feel less capable, less confident or less useful because of your affected arm?	1 : 2 : 3 : 4 : 5
	Unable Severe Moderate Mild No Difficulty

Are you limited in your work or other regular daily activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to carry a shopping bag or briefcase with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to wash your back with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to push up on your hands (e.g., from bathtub or chair)?	1 : 2 : 3 : 4 : 5
Are you able to carry a small suitcase with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to change a light bulb overhead with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to use tools or appliances with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to use a knife to cut food with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to place an object on a shelf above your head with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to prepare food (e.g., peeling, cutting) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to wash or blow dry your hair with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open doors with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do up buttons with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to turn a key with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to clean with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to prepare a meal with your affected arm	1 : 2 : 3 : 4 : 5
Are you able to groom your hair with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to make a bed with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to tie or lace shoes with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to put on a pullover sweater with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to drive with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to dress with your affected arm?	1 : 2 : 3 : 4 : 5
	Very Severe Severe Moderate Mild None
Please rate the severity of any stiffness in your affected arm?	1 : 2 : 3 : 4 : 5
	Unable Severe Moderate Mild No Difficulty
Are you able to manage transportation needs (e.g., getting from one place to another) with your affected arm?	1 : 2 : 3 : 4 : 5
Percentage Ability Measure out of 100	0 20 40 60 80 100

Figure 4. Admission Responses for EWH CAT Data Collection Form

(Note: Not all items are answered because the test is administered in a computer adaptive format. Observed responses are circled. If observed response was unexpected, the expected response for that item has a square around it. If the observed response was very unexpected, the expected response has a triangle around it.)

Please answer the questions below.

Percentage Ability Measure out of 100	0 20 40 60 80 100
Activity	
	Very Severe Severe Moderate Mild None
Please rate your severity of any weakness in your affected arm?	1 : 2 : 3 : 4 : [✓ 5]
	Unable Severe Moderate Mild No Difficulty
Are you able to participate in recreational activities in which you take some force or impact through your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open a jar with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do your usual hobbies, recreational or sporting activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to carry a heavy object (over 10 lbs.) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to participate in recreational activities in which you move your affected arm freely (e.g., playing Frisbee, badminton, etc.)?	1 : 2 : 3 : 4 : 5
Are you able to open a tight or new jar with your affected arm?	1 : 2 : 3 : [✓ 4] : 5
Are you able to do garden or yard work with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to lift a bag of groceries above your head with you affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do heavy household chores (e.g., washing windows or floors) with your affected arm?	1 : 2 : 3 : [✓ 4] : 5
To what extent does your arm problem interfere with your normal social activities with family, friends, neighbors or groups?	1 : 2 : 3 : 4 : 5
Are you able to participate in recreational activities which require little effort (e.g., card playing, knitting, etc.) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do your usual work, housework, or school activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open heavy doors with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to lift a bag of groceries to waist level with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to vacuum, sweep, or rake with your affected arm?	1 : 2 : 3 : 4 : 5
	Strongly Agree Agree Neither Disagree Strongly Disagree

Do you feel less capable, less confident or less useful because of your affected arm?	1 : 2 : 3 : 4 : 5
	Unable Severe Moderate Mild No Difficulty
Are you limited in your work or other regular daily activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to carry a shopping bag or briefcase with your affected arm?	1 : 2 : 3 : [✓ 4] : 5
Are you able to wash your back with your affected arm?	1 : 2 : 3 : [✓ 4] : 5
Are you able to push up on your hands (e.g., from bathtub or chair)?	1 : 2 : 3 : 4 : 5
Are you able to carry a small suitcase with your affected arm?	1 : 2 : [✓ 3] : [✓ 4] : 5
Are you able to change a light bulb overhead with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to use tools or appliances with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to use a knife to cut food with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to place an object on a shelf above your head with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to prepare food (e.g., peeling, cutting) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to wash or blow dry your hair with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open doors with your affected arm?	1 : 2 : 3 : [✓ 4] : 5
Are you able to do up buttons with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to turn a key with your affected arm?	1 : 2 : 3 : [✓ 4] : 5
Are you able to clean with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to prepare a meal with your affected arm	1 : 2 : 3 : 4 : 5
Are you able to groom your hair with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to make a bed with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to tie or lace shoes with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to put on a pullover sweater with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to drive with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to dress with your affected arm?	1 : 2 : 3 : 4 : 5
	Very Severe Severe Moderate Mild None
Please rate the severity of any stiffness in your affected arm?	1 : 2 : 3 : 4 : 5
	Unable Severe Moderate Mild No Difficulty
Are you able to manage transportation needs (e.g., getting from one place to another) with your affected arm?	1 : 2 : 3 : 4 : 5
Percentage Ability Measure out of 100	0 20 40 60 80 100

Based on unexpected responses and responses on which *With Moderate Difficulty* was selected, this individual seems to have difficulty with tasks that require strength more than tasks requiring dexterity. Also, in particular this individual seems challenged with carrying items. Based on the hierarchy of difficulty, goals set might involve activities around where this individual is circling four's or the one unexpected instance of a three.

Figure 5. Discharge Responses for EWH CAT Data Collection Form

(Note: Not all items are answered because the test is administered in a computer adaptive format. Observed responses are circled. If observed response was unexpected, the expected response for that item has a square around it. If the observed response was very unexpected, the expected response has a triangle around it.)

Please answer the questions below.

Percentage Ability Measure out of 100	0 20 40 60 80 100
Activity	
	Very Severe Severe Moderate Mild None
Please rate your severity of any weakness in your affected arm?	1 : 2 : 3 : 4 : [✓ 5]
	Unable Severe Moderate Mild No Difficulty
Are you able to participate in recreational activities in which you take some force or impact through your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open a jar with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do your usual hobbies, recreational or sporting activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to carry a heavy object (over 10 lbs.) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to participate in recreational activities in which you move your affected arm freely (e.g., playing Frisbee, badminton, etc.)?	1 : 2 : 3 : 4 : 5
Are you able to open a tight or new jar with your affected arm?	1 : 2 : 3 $\boxed{4}$: [✓ 5]
Are you able to do garden or yard work with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to lift a bag of groceries above your head with you affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do heavy household chores (e.g., washing windows or floors) with your affected arm?	1 : 2 : 3 : 4 : [✓ 5]
To what extent does your arm problem interfere with your normal social activities with family, friends, neighbors or groups?	1 : 2 : 3 : 4 : 5
Are you able to participate in recreational activities which require little effort (e.g., card playing, knitting, etc.) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to do your usual work, housework, or school activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open heavy doors with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to lift a bag of groceries to waist level with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to vacuum, sweep, or rake with your affected arm?	1 : 2 : 3 : 4 : 5
	Strongly Agree Agree Neither Disagree Strongly Disagree

Do you feel less capable, less confident or less useful because of your affected arm?	1 : 2 : 3 : 4 : 5
	Unable Severe Moderate Mild No Difficulty
Are you limited in your work or other regular daily activities with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to carry a shopping bag or briefcase with your affected arm?	1 : 2 : 3 : [✓ 4] : 5
Are you able to wash your back with your affected arm?	1 : 2 : 3 : 4 : [✓ 5]
Are you able to push up on your hands (e.g., from bathtub or chair)?	1 : 2 : 3 : 4 : 5
Are you able to carry a small suitcase with your affected arm?	1 : 2 : 3 : [✓ 4] : [△ 5]
Are you able to change a light bulb overhead with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to use tools or appliances with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to use a knife to cut food with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to place an object on a shelf above your head with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to prepare food (e.g., peeling, cutting) with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to wash or blow dry your hair with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to open doors with your affected arm?	1 : 2 : 3 : 4 : [✓ 5]
Are you able to do up buttons with your affected arm?	1 : 2 : 3 : 4 : [✓ 5]
Are you able to turn a key with your affected arm?	1 : 2 : 3 : 4 : [✓ 5]
Are you able to clean with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to prepare a meal with your affected arm	1 : 2 : 3 : 4 : 5
Are you able to groom your hair with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to make a bed with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to tie or lace shoes with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to put on a pullover sweater with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to drive with your affected arm?	1 : 2 : 3 : 4 : 5
Are you able to dress with your affected arm?	1 : 2 : 3 : 4 : 5
	Very Severe Severe Moderate Mild None
Please rate the severity of any stiffness in your affected arm?	1 : 2 : 3 : 4 : 5
	Unable Severe Moderate Mild No Difficulty
Are you able to manage transportation needs (e.g., getting from one place to another) with your affected arm?	1 : 2 : 3 : 4 : 5
Percentage Ability Measure out of 100	0 20 40 60 80 100

At discharge, it is clear to see that this individual has improved in mobility and dexterity, but is still having challenges with tasks requiring strength such as carrying a small suitcase.

DISCUSSION

The purposes of this study was to create a clinically useful data collection form for the EWH CAT, to illustrate how patient responses would look on the form at admission and discharge, and to demonstrate how such a form might guide clinicians in goal setting and treatment planning. Keyform output from Winsteps Rasch analysis program (Linacre, 2017) served as the basis for creating the EWH CAT data collection forms. These data collection forms offer several advantages over the forms typically used in the clinic. First, this type of data collection form makes unexpected responses easy to spot (Kielhofner et al., 2005; Linacre, 1997). For example, in Figures 4 and 5, notice that this individual's response to several of the carrying items (e.g. *Are you able to carry a shopping bag or briefcase with your affected arm?*) and items requiring strength (e.g. *Are you able to open a tight or new jar with your affected arm?*) are unexpected. These items seem to be unpredictably more difficult for this individual than items requiring dexterity (e.g. *Are you able to do up buttons with your affected arm?)* and flexibility (e.g. *Are you able to wash your back with your affected arm?*).

Another advantage of this type of data collection form is that it can be used in conjunction with impairment and performance assessments to aid goal setting and treatment planning. The forms illustrated in Figures 4 and 5, with actual patient data, illustrate this benefit. Examining such a form gives a real sense of what activities are most and least difficult for the patient. In particular, this individual seems challenged with carrying items. Based on the hierarchy of difficulty, goals set might involve activities around where this individual is circling four's or the one unexpected instance of a three. For instance, goals set might include being able to push up on your hands (e.g.

from bathtub or chair), carry a small suitcase, change a light bulb overhead, use tools or appliances and other similar activities.

Previous studies have noted the benefits of using keyforms created using Winsteps Rasch analysis program. Linacre (1997) and Kielhofner and colleagues (2005) focused on the keyform as a way of obtaining "instantaneous measurement” without the need for any computer software. A line can be drawn on the keyform to represent a person’s overall person measure. Then the pattern of responses can be used diagnostically. Linacre (1997) created a keyform based on the Functional Independence Measure (FIM) while Kielhofner and colleagues (2005) used data from the Occupational Performance History Interview-2nd Edition.

Another study sought to validate the item structure of the Fugl-Meyer Assessment (Woodbury et al., 2007). Using the keyforms generated by Winsteps Rasch analysis program, the pattern of upper extremity responses were validated across participants. That is, these authors were able to verify that participants with different abilities were scoring higher on easy items and lower on harder items. This provides evidence that the Fugl-Meyer Assessment retains its structure when measuring individuals across the ability range.

With the quickly advancing technology, such a form could easily be transferred to be completed on a tablet with links to protocols for treating individuals with differing responses. Work by Avery, Russell, Raina, Walter, and Rosenbaum as early as 2003 (Avery, Russell, Raina, Walter, & Rosenbaum, 2003) demonstrated how a computer program could generate output similar to the keyform produced by the Winsteps Rasch analysis program. These authors collected data on the Gross Motor Ability Estimator that showed a clear pattern of gross motor development. For example, in a baby, head lifting was an easier item than pulling to a sit.

Very few studies have presented longitudinal data (i.e. data at both admission and discharge) using data collection forms created based on keyforms from Winsteps Rasch analysis program output. One such study (Lehman, Sindhu, et al., 2011) created a data collected form for the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire. These authors showed the utility of such forms to establish short and long term goals and then by examining follow up (i.e. discharge) forms to discern if progress was being made. This study is the first time that a data collection form has been created for the EWH CAT on the basis of keyforms generated through Rasch analysis and longitudinal data has been examined.

This study has several limitations. Of concern is that the ordering of items with the most difficult on top (read first by the patient) and least difficult at the bottom (read last by the patient) might influence the perception of the questions and how individuals respond. If an individual subconsciously recognizes that the questions are getting easier, they may start to respond accordingly without thinking about the actual level of challenge that the activity presents for them.

Additionally, the keyforms produced using Rasch measurement methodologies had slightly different difficulty hierarchies at admission and discharge. If the difficulty of items varies substantially from admission to discharge, this could impact the usefulness and validity of the data collection form in regards to goal setting and treatment planning. In the current study, the concern over differing admission and discharge difficulty estimates was handled by obtaining person measures at discharge after anchoring on the basis of item and step difficulties at admission. Accordingly, the admission keyform was the one used to create the data collection form. This procedure was followed based on the thinking that therapists would want to see how much a patient's ability changes from admission to discharge. However, this method could be problematic if it results in a large majority of the participants having maximum person ability estimates at discharge (not the case in the current study).

In conclusion, a data collection form such as the one presented in this article has multiple advantages. First, it can aid in goal setting and treatment planning. Second, because it clearly illustrates when change has occurred, it could be used to justify reimbursement by insurance companies and to support decisions made by accreditation agencies. Furthermore, such forms could be useful to compare the effectiveness of different treatments.

Future research should endeavor to create a version of this and other forms on a tablet interface. Then reliability and validity should be tested using this method of presentation of the form. Moreover, work should be done to create links on the tablet to useful information based on individuals' determined person measures (i.e. ability levels). Other studies might explore individuals' degree of meaningfulness ascribed to each of the tasks on the EWH CAT. The value an individual places on a task might influence the difficulty of the task for that individual leading to unexpected responses. Qualitative data on therapists' perceptions of the forms would likewise prove invaluable. Clinicians might suggest further modifications that would enhance such forms' ability to guide goal setting and treatment planning.

IV. DISCUSSION

Musculoskeletal disorders (MSDs), including elbow, wrist, and hand impairments, are the second most common disability worldwide and place a large burden on the health care system (Southerst et al., 2015; Walker-Bone & Linaker, 2016). MSDs involving the upper extremity are among the leading work-related health concerns in the United States, accounting for up to 30% of all injuries requiring time away from work (Gardner, Dale, VanDillen, Franzblau, & Evanoff, 2008). For example, the cost of medical care and lost work time associated with lateral and medial epicondylitis is more than $22 billion annually in the United States (Menta et al., 2015). Furthermore, carpal tunnel syndrome with prevalence estimates ranging from 2.7% to 7.8% is one of the most costly work-related upper extremity disorders, accounting for direct and indirect costs in excess of $2 billion per year in the United States (Menta et al., 2015).

Due to the prevalence and cost associated with elbow, wrist, and hand impairments, accurate and precise assessment is critical to ensure that patient treatment is optimal (i.e. efficient and productive) (Badalamente et al., 2013a). Potential benefits of accurate and precise assessments for this population include guiding therapists in goal setting. Additionally, identifying factors that increase the probability of favorable outcomes for patients with elbow, wrist, and hand, diagnoses can assist in treatment planning.

Overall, the purpose of this study was to examine the Elbow, Wrist, and Hand Computer Adaptive Test (EWH CAT) at the item-level and additionally, to establish its predictive value. Using Rasch analysis, we investigated the item-level properties of this assessment and developed a data collection form to aid clinicians in goal setting and treatment planning. Using multiple regression, we identified guiding factors (i.e. different characteristics of individuals) to assist in planning treatment and resource allocation. More specifically, our aims were as follows: (1) To examine the item-level characteristics of the EWH CAT using Rasch analysis, including item difficulty measures, person ability measures, item fit, and item-person match. (2) Based on identified item characteristics, to create a data collection form to guide clinicians in goal setting and treatment planning. (3) To identify the best predictors for high functional recovery based on age, gender, co-morbidities, acuity, surgical history, exercise status, payer source, and medication use.

The introduction provided a background regarding the significance of elbow, wrist, and hand impairment, citing various statistics supporting the cost of these impairments in regards to prevalence, functional ability (i.e. ability to work), and medical expenses. Because of these costs both at the individual and national levels, accurate and precise assessment is critical in the clinic. The role of assessment was discussed along with the difficulties clinicians have wisely choosing from the vast numbers of assessments that are available. Three types of assessments were presented: generic health measures, disease-specific measures, and region-specific measures, along with some problems related to the interpretation of these types of assessments. Importantly, the introduction highlighted that for an assessment to be beneficial in directing clinical practice it must illustrate the activities that an individual is able to perform and identify the tasks that are the best next goals (Lehman, Sindhu, et al., 2011; Woodbury & Velozo, 2005).

Furthermore complicating assessment and treatment, a complex range of physical, psychosocial, and occupational factors interact and influence individual’s response and subsequent rehabilitation and recovery from musculoskeletal disorders (Walker-Bone & Linaker, 2016). The introduction detailed research supporting the need for the identification of prognostic factors related to outcomes for individuals with elbow, wrist, and hand impairments. This introduction concluded that we need accurate and efficient methods of evaluation and assessment for elbow, wrist, and hand diagnoses to better optimize treatment strategies and guide goal setting.

Specific Aim 1 evaluated the psychometrics of the EWH CAT using Rasch analysis, the one parameter item response theory model. Investigations of local independence and monotonicity were conducted and showed satisfactory results. Factor analysis and fit analyses suggested that a one-factor solution was plausible. In general, the order of item difficulty within each construct was believable. The match between person ability and item difficulty suggested that the items were generally well fitting with the sample. The items showed good internal consistency and person separation.

A unique feature of Rasch analysis is its ability to plot person ability and item difficulty on the same continuum. This feature has advantages in instrument and item bank development, especially when items are designed according to a hypothesized difficulty hierarchy. One informative outcome from our analysis for Specific Aim 1 was what additional items might be advantageous. Four percent of the sample grouped at the lowest ability level and 2.2% of the sample grouped at the highest ability level. The “floor effect” observed is attributable to a large number of challenging items (i.e. participants performing below the level of the easiest item). This may be due in part to the complexity of the problems experienced by the sample. For this sample, inclusion of easier items would be advantageous. For example, the following items, might be added to the item bank: using a computer mouse, wiping off a desk, and picking up a pencil. This would allow for more precise measurement of those individuals with lower ability levels.

The “ceiling effect” is attributable to a large number of easy items (i.e. participants performing above the level of the hardest item). This may be due in part to a wide range of ability and problems experienced by the sample. The hierarchical structure of the EWH CAT item bank makes it apparent that the ceiling effect could be reduced or eliminated through the inclusion of harder items. For example, the following items: lifting 25 lbs. above one’s head and rearranging furniture.

The goal of Specific Aim 2 was to describe how to create a clinically useful data collection form for an assessment such as the EWH CAT. Then, to illustrate how patient responses would look on the form at admission and discharge and how such a form might guide clinicians in goal setting and treatment planning. Keyform output from Winsteps Rasch analysis program (Linacre, 2017) served as the basis for creating the EWH CAT data collection forms. These data collection forms offer several advantages over the forms typically used in the clinic. First, this type of data collection form makes unexpected responses easy to spot (Kielhofner et al., 2005; Linacre, 1997). Second, this type of data collection form can be used in conjunction with impairment and performance assessments to aid goal setting and treatment planning. Results for Specific Aim 2 provides example admission and discharge forms filled out with patient data to illustrate these benefits.

In conclusion, that such a data collection form has multiple advantages. First, it can aid in goal setting and treatment planning. Second, because it clearly illustrates when change has occurred, it could be used to justify reimbursement by insurance companies and support decisions made by accreditation agencies. Furthermore, such forms could be useful to compare the effectiveness of different treatments.

Future research should endeavor to create a version of this and other forms on a tablet interface. Then reliability and validity should be tested using this method of presentation of the form. Moreover, work should be done to create links on the tablet to useful information based on individuals' determined person measures (i.e. ability levels). Other studies might explore individuals' degree of meaningfulness ascribed to each of the tasks on the EWH CAT. The value an individual places on a task might influence the difficulty of the task for that individual leading to unexpected responses. Qualitative data on therapists' perceptions of the forms would likewise prove invaluable. Clinicians might suggest further modifications that would enhance such forms' ability to guide goal setting and treatment planning.

Recognizing that forecasting patient outcomes based on time and intervention is such an enormous task, the main objective of Specific Aim 3 was to investigate characteristics of patients with elbow, wrist, and hand diagnoses who were more or less likely to have favorable outcomes. Three immutable variables were found to be associated with the likelihood of a poorer outcome: being female, having greater than three comorbidities, and having a history of surgery. Four mutable variables were found to be associated with the likelihood of a poorer outcome: acuity of 22 days or greater, exercising less than 3 times a week, no medication use, and payer source. Individuals who were at a high risk of a poor outcome were more likely to use worker's compensation, litigation, or automotive compared to having private insurance.

One immutable variable was significantly associated with a low risk of a poor outcome: no history of surgery. Three mutable variables were significantly associated with a low risk of a poor outcome: no medication use, shorter acuity, and payer source.

When compared to private insurance, individuals at low risk of a poor outcome were more likely to use private companies than worker's compensation, litigation, or automotive. Conversely, they were more likely to have Medicare or Medicaid than to use private insurance.

Our analyses for Specific Aim 3 generated significant models that might assist in the identification of patients who would require less rehabilitation (those with low risk of a poor outcome) and others who may respond poorly to extensive rehabilitation (those with high risk of a poor outcome). The group of patients with low risk of a poor outcome achieved significant change in functional status with very few visits. Conversely, the patients categorized as high risk of a poor outcome had limited improvement in functional status despite numerous visits. Identifying the variables predictive of outcomes could be of benefit in guiding the plan of care for individuals at high risk of a poor outcome. This does not in any way suggest that treatment should not be given to individuals with potential for a poor prognosis. However, it does suggest that a treatment approach different from traditional rehabilitation may be required (e.g. longer duration with goals for maintenance) and/or additional consults (e.g. for psychiatry/counseling or medication management) may be necessary.

Due to the increased use of rehabilitation services throughout the nation, efficient and effective medical care is crucial. As previously noted, musculoskeletal disorders, including elbow, wrist, and hand impairments, are the second most common disability worldwide (Southerst et al., 2015; Walker-Bone & Linaker, 2016) and the leading work-related health concerns in the United States (Gardner et al., 2008). The growing financial demand placed on the healthcare system by these disorders should stimulate increased efforts to make care efficient.

V. SUMMARY

In conclusion, an overall aim of this project was to highlight the importance of accurate and efficient assessment for those with elbow, wrist, and hand impairments, which seamlessly guides goal setting and treatment planning. The item characteristics of the EWH CAT were examined using item response theory methodologies. Item characteristics proved to be commendable and thus, a data collection form was created for the EWH CAT that might one day be used on a tablet interface with links to goal suggestions and treatment strategies. Finally, patient characteristics predictive of positive outcomes were identified. Identification of such characteristics might be helpful clues to clinicians about when a treatment approach different from traditional rehabilitation may be required (e.g. longer duration with goals for maintenance) and/or additional consults (e.g. for psychiatry/counseling or medication management) may be necessary.

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APPENDIX A: Elbow, Wrist, and Hand Computer Adaptive Test (EWH CAT) Questions and Response Choices

Questions	Response Choices				
1. Are you able to open a tight or new jar with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
2. Are you able to turn a key with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
3. Are you able to prepare a meal with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
4. Are you able to push open a heavy door with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
5. Are you able to place an object on a shelf above your head with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
6. Are you able to do heavy household chores (e.g. washing windows or floors) with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
7. Are you able to do garden or yard work with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
8. Are you able to make a bed with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
9. Are you able to carry a shopping bag or briefcase with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
10. Are you able to carry a heavy object (over 10 lbs.) with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
11. Are you able to change a light bulb overhead with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
12. Are you able to wash or blow dry your hair with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
13. Are you able to wash your back with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
14. Are you able to put on a pullover sweater with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
15. Are you able to use a knife to cut food with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
16. Are you able to participate in recreational activities which require little effort (e.g. card playing, knitting, etc.) with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
17. Are you able to participate in recreational activities in which you take some force or impact through your affected arm? (e.g. golf, hammering, tennis, etc.)?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
18. Are you able to participate in recreational activities in which you move your affected arm freely (e.g. playing Frisbee, badminton, etc.)?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
19. Are you able to manage transportation needs (e.g. getting from one place to another) with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty

20. To what extent does your arm problem interfere with your normal social activities with family, friends, neighbors or groups?	Unable to do	Severely	Moderately	Mildly	Not at all
21. Are you limited in your work or other regular daily activities with your affected arm?	Unable to do	Severely limited	Moderately limited	Mildly limited	Not limited at all
22. Please rate the severity of any weakness in your affected arm?	Very severe	Severe	Moderate	Mild	None
23. Please rate the severity of any stiffness in your affected arm?	Very severe	Severe	Moderate	Mild	None
24. Do you feel less capable, less confident or less useful because of your affected arm?	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
25. Are you able to do your usual work, housework, or school activities with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
26. Are you able to do your usual hobbies, recreational or sporting activities with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
27. Are you able to lift a bag of groceries to waist level with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
28. Are you able to lift a bag groceries above your head with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
29. Are you able to groom your hair with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
30. Are you able to push up on your hands (e.g. from bathtub or chair)?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
31. Are you able to prepare food (e.g. peeling, cutting) with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
32. Are you able to drive with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
33. Are you able to vacuum, sweep, or rake with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
34. Are you able to dress with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
35. Are you able to do up buttons with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
36. Are you able to use tools or appliances with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
37. Are you able to open doors with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
38. Are you able to clean with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
39. Are you able to tie or lace shoes with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
40. Are you able to launder clothes (e.g. wash, iron, fold) with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
41. Are you able to open a jar with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty
42. Are you able to carry a small suitcase with your affected arm?	Unable to do	With severe difficulty	With moderate difficulty	With mild difficulty	With no difficulty