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May 2015

Note: This scholarly project reflects individualized, original research conducted in partial fulfillment of the requirements for the Occupational Therapy Doctoral Program, The University of Toledo.

Abstract

Eighty-four healthy females and males participated in a study to examine the inter-instrument reliability of two Baseline digital dynamometers. A cross-sectional, randomized, repeated measures design was chosen to control for extraneous variables and individual differences. Thirty-nine females and 45 males, aged 20-50 years, were tested for grip strength using the American Hand Therapists' standardized protocol for positioning and instructions. The two Baseline digital dynamometers were differentiated from each other by colored stickers: green and yellow. Data was analyzed using paired t-tests for repeated measures and a Bland-Altman analysis. There was a statistically significant difference between the two Baseline digital dynamometers with the green Baseline digital dynamometer measuring higher on average. T-tests for paired data revealed a statistically significant difference between the grip measurements of the two Baseline digital dynamometers (t=3.392; p=.001). The Bland-Altman analysis revealed a bias of 2.4 lbs. The 95% limits of agreement ranged between -10.32 and +15.13 lbs. Results demonstrated that grip strength measurements taken with the Baseline digital dynamometer cannot be considered interchangeable. Therefore the Baseline digital dynamometer cannot be used interchangeably with other Baseline digital dynamometers when retesting patients' grip strength.

A Study of Inter-Instrument Reliability Between two Baseline® Digital Dynamometers

Grip strength is integral for functional hand use (Rice, Leonard, & Carter, 1998). Persons need it to perform almost all types of occupations of daily living and to maintain a certain level of independence (Rice et al., 1998). In a systematic review of 45 peer-reviewed journal articles that identified grip strength as a predictor for health outcomes, the results revealed that low grip strength was associated with decreased functional abilities and increased chances of mortality and disability (Bohannon, 2008). A 25-year prospective cohort study on 6,089 Japanese American men aged 45-68 year olds, revealed that grip strength was a good indicator of future disability and functional limitations (Rantanen et al., 1999). Because grip strength is needed for the execution of a variety of functional tasks, it provides inferable information about a person's level of disability and health status, and is a viable evaluative tool for occupational and physical therapists. At present, there is no published empirical evidence fully documenting the psychometric properties of the Baseline digital dynamometer. For that reason, this study intends to examine the inter-instrument reliability of the Baseline digital dynamometer.

Grip Strength

Grip strength is an assessment commonly used by clinicians to measure the strength of the finger flexors, hypothenar, thenar, and intrinsic muscles of the hand when they are isometrically contracting (Amaral, Mancini, & Novo Junior, 2012). This assessment is important because it provides information about the patient's overall health status and functional abilities (Amaral et al., 2012). Grip strength helps practitioners determine if patients need therapy, and, if so, can help guide occupational therapists to interventions that would be most beneficial (Hamilton, Balnave, & Adams, 1994). Assessing grip strength can establish a baseline to compare with normative data (Poole, 2009). It can also determine the effectiveness of a treatment program and provide an ongoing measure of a patient's progress in treatment (Poole, 2009).

Instruments Used to Measure Grip Strength

There are a variety of instruments used to measure grip strength. The most common of these instruments are hydraulic and digital dynamometers. Hydraulic dynamometers are closed systems with adjustable handles that measure grip strength in pounds and kilograms (Innes, 1999). They have a peak-hold needle that automatically retains the maximum grip strength measurement until it is reset (Sammons Preston Rolyan, 2003). The Jamar hydraulic dynamometer is considered the criterion standard for measuring grip strength because it has been shown to be highly reliable (Fess, 1987; Mathiowetz, 2002; Peolsson, Hedlund, & Oberg, 2001).

Digital dynamometers can be divided into two separate categories: digital and computerized digital. Digital dynamometers have a digital output display within the instrument itself. Computerized digital dynamometers have an output display via a computer. This means the dynamometer's output goes directly to a computer which records and displays the data (Talsania & Kozin, 1998). The benefits of using digital instruments, as opposed to hydraulic dynamometers, are that clinicians can take grip strength measurements anywhere because the digital dynamometers can store and retrieve information (Shechtman, Gestewitz, & Kimble, 2005). Other beneficial features of digital dynamometers are that they can automatically calculate the means, standard deviations, and coefficients of variations, which saves clinicians time, promotes inter-rater reliability, and prevents measurement and mathematical errors (Shechtman et al., 2005; SI Instruments Pty Ltd, 2013).

Although there are distinctive benefits to using a digital dynamometer, there is not a sufficient amount of research showing that they are reliable and valid instruments, especially the digital dynamometers with the digital output. For example, out of 12 identified digital dynamometers, only 5 were noted as having established levels of evidence supporting concurrent validity with the Jamar hydraulic dynamometer (Weinstock-Zlotnick, Bear-Lehman, & Yu, 2011). Measurements have a direct impact on patient treatment and evaluation of patient progress (Amaral et al., 2012). Therefore it is essential that instruments be tested for reliability and inter- and intra-instrument reliability.

Reliability and Inter-instrument Reliability

Instrument reliability is the degree to which an instrument can provide accurate and stable information across different circumstances (Kielhofner, 2006). If an instrument is reliable, variability of measurements are attributed to true differences rather than error (Kielhofner, 2006). Inter-instrument reliability is the extent to which two or more instruments obtain similar results. With a variety of hydraulic and digital hand dynamometers on the market, it is important for clinicians to ensure that the assessment tools they are using will provide accurate and stable measurements (Amaral et al., 2012; Fess, 1986).

Interchangeability of Hydraulic and Digital Hand Dynamometers

Shechtman et al. (2005) examined the reliability of the DynEx digital dynamometer in comparison to the criterion standard, Jamar hydraulic dynamometer. Participants included 50 healthy females and 50 healthy males between the ages of 20 and 40 years old. Results demonstrated that the DynEx digital dynamometer ($r = .9864$) and the Jamar hydraulic dynamometer ($r = .9856$) had good test-retest reliability. Grip strength measurements between the two were significantly different ($p = .014$). This could be due to the fact that the Jamar hydraulic dynamometer showed significantly higher grip strength measurements during calibration with suspended known weights. Grip strength measurements between the right and left hands were not significantly different for either of the DynEx digital dynamometer and the Jamar hydraulic dynamometer. Though DynEx digital dynamometers were found to be reliable and comparable to the hydraulic Jamar dynamometer, they should not be used interchangeably (Shechtman et al., 2005).

Allen and Barnett (2011) compared the reliability of the Biometrics E-LINK EP9 electronic dynamometer to the criterion standard Jamar hydraulic dynamometer in 49 healthy adults. Test-retest reliability of the Biometrics E-LINK EP9 electronic dynamometer was excellent for the left hand ($r = .986$) and the right hand ($r = .996$). However, the right hand grip measurements were not comparable to the Jamar hydraulic dynamometer ($p = .000$). The Biometrics E-LINK EP9 electronic dynamometer was shown to be a reliable instrument that should not be used interchangeably with the Jamar hydraulic dynamometer (Allen & Barnett, 2011).

Amaral et al. (2012) compared the accuracy and precision of measurements of the Takei digital dynamometer and the Force Transducer digital dynamometer to the Jamar hydraulic dynamometer in 18 college-aged students. They found significant differences in grip strength measurements between the instruments ($p<.05$). In this study, the Takei digital dynamometer and Force Transducer digital dynamometer presented strength values that were lower than the Jamar hydraulic dynamometer, but similar to each other. Consequently, the Takei and Force Transducer digital dynamometers should not be used interchangeably with the Jamar hydraulic dynamometer nor with each other (Amaral et al., 2012).

Shechtman, Davenport, Malcolm, and Nabavi (2003) compared the Baltimore Therapeutic Equipment (BTE)-Primus with the Jamar hydraulic dynamometer in 180 healthy adults aged 18 to 49 (Shechtman et al., 2003). This study found that the BTE-Primus electronic dynamometer had high test-retest reliability (r=.97). There were no statistically significant differences in grip strength measurements between the two dynamometers. The BTE-Primus electronic dynamometer, when using the standardized protocol for assessing grip strength, is a reliable and valid tool that can be used by clinicians to document patient grip strengths. However, it should not be used interchangeably with other dynamometers (Shechtman et al., 2003).

Bohannon (2006) tested the MicroFET 4 electronic dynamometer for reliability with a sample of 30 healthy adults aged 30-76. Grip strength measurements verified that the electronic dynamometer had high test-retest reliability. Bohannon concluded that the instrument was reliable and could be used by clinicians to document patient measurements, however, it should not be used interchangeably with the Jamar hydraulic dynamometer. Two limitations of this study were that the MicroFET 4 was not compared to a criterion standard, and the sample size (n=30) was small (Bohannon, 2006).

Deaton (2013), a student in the Occupational Therapy Doctorate program at The University of Toledo, conducted a study on the inter-instrument reliability between the Baseline digital dynamometer and the Jamar hydraulic dynamometer. Deaton found that there were statistically significant differences between the Baseline digital dynamometer and the Jamar hydraulic dynamometer grip strength measurements. Deaton reported that the Jamar hydraulic dynamometer –on average- measured higher than the Baseline digital dynamometer. As well, the Baseline digital dynamometer did not show strong concurrent validity. Based on these results, Deaton cautioned clinicians not to compare Baseline digital dynamometers with normative data or to use the Baseline digital dynamometer interchangeably with other dynamometers (Deaton, 2013).

Lack of Empirical Evidence and Current Study

The research evidence discussed above shows that the reliability of specific digital dynamometers is not well documented. All of the digital and electronic dynamometers noted should not be used interchangeably with other dynamometers, specifically with the Jamar hydraulic dynamometer. None of the reviewed studies examined inter-instrument reliability of instruments from the same brand and type, such as all Baseline or Jamar digital hand dynamometers. Many of the studies discussed above recommended that clinicians use the same instrument throughout a patient's treatment program to ensure the reliability of measurements. Instrument effectiveness is determined by instrument reliability (Fess, 1986). An instrument is not valid, unless it produces accurate and stable results (Fess, 1986). The purpose of this study will be to examine the inter-instrument reliability of two Baseline digital dynamometers of the same model to determine if they can be used interchangeably with other Baseline digital dynamometers. This study will investigate whether the Baseline digital dynamometers are reliable instruments that produce stable and accurate measurements and whether there will be a difference in grip strength measurements between the two Baseline digital dynamometers. Results of this study will have implications for occupational and physical therapists who use Baseline digital dynamometers. If Baseline digital dynamometers are interchangeable, future researchers can establish normative data for the instruments.

Methods

Participants

This study recruited a total of 84 healthy females and males between the ages of 20 and 50 years. According to Mathiowetz et al. (1985), grip strength peaks between the ages of 25 to 39 and declines around 59 years (Mathiowetz et al., 1985). Our study recruited participants between the ages of 20-50 because individuals experiencing decline may fatigue more quickly, thus affecting grip strength measurements and inter-instrument reliability measurements. We recruited a fairly even number of male (n=45) and female (n=39) participants to prevent gender disparity.

Inclusion criteria for participants included: self-reported healthy individuals who are able to read, speak, and understand English, with either right- or left-handed dominances. Exclusion criteria included: individuals with neuromuscular and physical conditions that affect hand strength or cause pain when gripping, cognitive impairments that affect comprehension abilities, and individuals who do not speak, read, or understand English. Participants were recruited through a sample of convenience from the University of Toledo, surrounding cities and states. We used fliers, poster displays, e-mail invitations, and word of mouth to advertise study participation. The primary means of recruitment was word of mouth.

Instruments

The Baseline digital dynamometer has a digital readout. This means that the output display is within the instrument itself. This brand of dynamometer can automatically calculate and store grip strength measurements in kilograms and pounds. It has a maximum measurement capacity of 300 lbs. and features an electronic zero calibration system (Fabrication Enterprises Inc., 2015). Additionally, the Baseline digital dynamometer was found to have low inter-instrument reliability when compared with the criterion standard, Jamar hydraulic dynamometer (Deaton, 2013). Currently there is no published empirical evidence fully documenting the psychometric properties of this dynamometer.

For this study, two Baseline digital dynamometers were used to measure grip strength of each participant. These instruments were purchased new, which means that the Baseline digital dynamometers were calibrated and determined to be compliant with design specification by the manufacturer before the study began. Halfway through data collection the instruments were returned to the manufacturer, Fabrication Enterprises, for calibration accuracy. Fabrication Enterprises provided documentation to certify that calibration testing was accomplished using testing weights. This documentation confirmed that the two Baseline digital dynamometers met applicable performance specifications.

Research design

This study used a cross-sectional, randomized, repeated measures design to control for extraneous variables and individual differences. Data consisted of interval level data and was analyzed using descriptive and parametric statistics. All participants were tested with both Baseline digital dynamometers. The order of administration for grip strength testing was randomized to control for extraneous variables and to lower the probability of making a type I error due to fatigue.

Procedure

Prior to the start of data collection, the study was reviewed and approved by the UT Institutional Review Board for human subjects. The participant was interviewed on demographic information and inclusion criteria. This information included the participant's age (not birthdate), ethnicity, hand dominance, and if she/he had any diseases, or neuromuscular or orthopedic injuries that effect hand strength. Participants meeting inclusion criteria were given an informed consent form to review. The test administrator reviewed the consent form with participants; this included stating the purpose of the study and explaining the risks involved with participating. The test administrator informed participants that they could decline participation at any stage of the research project. The participant then either agreed or declined to participate. When the participant agreed to participate, she/he was asked to sign the informed consent form. Data collection began after the participant signed the form.

We used a computer program for randomization and data collection. The dynamometers were differentiated from each other by colored stickers: green and yellow. Each participant was assigned a unique number that was used on all forms and in the data collection program. Similarly, the demographic information of all participants was recorded under the participant numbers.

We used the American Society of Hand Therapist's standardized protocols for administering grip strength: Participant was seated in a chair of standard height with no arm rests, the shoulder of the hand being tested was adducted, the elbow was flexed at 90 degrees, and the wrist and forearm was in neutral position (Fess, 1992). Grip strength was only measured on the right hand. The reasoning behind this decision was based on a study that found that left-hand dominant individuals had similar grip strength measurements on their left and right hands (Petersen, Petrick, Connor, & Conklin, 1989). Petersen et al. tested the practicality of the 10% rule in hand rehabilitation in 310 volunteers between the ages of 17 and 50 years, by recording grip strength measurements for both the right and left hands. The 10% rule states that the dominant hand is 10% stronger than the non-dominant hand. Study results showed that there was a 12.72% strength difference in right-handed individuals and a 0.08% strength difference in left-handed individuals. Because of this, Petersen et al. recommended that practitioners consider hand strength to be equivalent in left-handed individuals (Petersen et al., 1989).

The Baseline digital dynamometers were set to the second handle position. The test administrator provided the same verbal instructions Mathiowetz, Weber, Volland, and Kashman (1984) used when investigating the reliability and validity of four hand strength instruments.

Before administering the grip strength assessment, the test administrator stated, “I want you to hold the handle like this and squeeze as hard as you can” (Mathiowetz et al., 1984, pp. 224). The test administrator then demonstrated how to grip the instrument. After the demonstration, the participant was positioned into the correct posture. The test administrator then stated the following, “Are you ready? Squeeze as hard as you can” (Mathiowetz et al., 1984, pp. 224). When the participant squeezed the grip instrument, the test administrator stated, “Harder!...Harder!...Relax” (Mathiowetz et al., 1984, pp. 224). The same instructions were provided for each trial. After each trial, a grip measurement was recorded. After 3 consecutive trials, a mean of the grip strength measurements was calculated. Each Baseline digital dynamometer had 3 trials totaling 6 trials for the right hand. Participants were given 15-20 second rest periods between each trial. They were also given a two-minute break between the administration of the first and second Baseline digital dynamometers. Overall, the data collection took approximately 20 minutes to complete (Mathiowetz et al., 1984).

Data analysis

Interval data were collected from two Baseline digital dynamometers. The average of the three trials on each dynamometer was used to determine grip strength measurements for each participant. All grip strength measurements were recorded in pounds (lbs.). Before we compared the measurements we calculated the mean, standard deviation, and range from the three trials. We used Excel and SPSS for computations. We then compared the means with the paired t-tests. The Bland-Altman analysis was computed to indicate the level of agreement between the dynamometers (Elliott & Woodward, 2007). This type of analysis assesses the agreement between two methods of measurement by computing the bias, or mean difference, across data sets (Elliott & Woodward, 2007). The one-way repeated measure analysis of variance (ANOVA) was used to test for order effects. The effect size was calculated to quantify the magnitude of difference between the instrument means (Borenstein, 2012). The significance level was set at $p<0.05$.

Results

Participants

Eighty-four self-reported healthy adults were recruited for the study. The ages of participants ranged from 20 to 50 years. Fifty-two participants were between the ages of 20 and 30 years with 26% (n=22) of the entire sample size aged 23-24 years. Females made up 46.4% (n=39) of the participants and males made up 53.6% (n=45). The ethnic demographics of the sample included 85.7% (n=72) Caucasian, 8.3% (n=7) African American, 4.8% (n=4) Asian descent, and 1.2% (n=1) American Indian or Alaskan Native (see Figure 1). Seventy (83.3%) participants stated they were right hand dominant, 9 (10.7%) stated they were left hand dominant, and 5 (6%) stated they were ambidextrous.

Statistical Analyses

Descriptive statistics for skewness were below one. The one-way repeated measure ANOVA showed no significant differences (p=.148) between grip strength measurements based on the order of presentation of the dynamometers. The mean, SD, and range of grip strength measurements for the two dynamometers are presented in Table 1. The overall mean of the green Baseline digital dynamometer (82.88 lbs.) was 2.4 lbs. greater than the overall mean of the yellow Baseline digital dynamometer (80.47 lbs.) (see Figure 2). The average minimum forces for the green and yellow Baseline digital dynamometers are 42 lbs. and 39.66 lbs., respectively. The average maximum forces for the green and yellow Baseline dynamometers are 134.33 lbs. and 142.33 lbs., respectively. T-tests for paired data revealed a statistically significant difference between the grip strength measurements of the two Baseline digital dynamometers (t=3.392; p=.001). The Cohen's D test revealed the effect size to be small (d=.105).

Overall, results showed the green Baseline dynamometer measured forces at a slightly greater range than the yellow Baseline dynamometer. However, both dynamometers have similar standard deviations for mean values (see Table 1).

The Bland-Altman analysis revealed a bias of 2.4 lbs. (see Figure 3). Sixty-six percent of the paired grip strength measurements were higher with the green dynamometer. In 95% of the subjects, the difference between the means could lie between -10.32 and +15.13 lbs.

Discussion

The purpose of this study was to examine the inter-instrument reliability of two Baseline digital dynamometers of the same model, to determine if they can be used interchangeably with other Baseline digital dynamometers. This study investigated whether the Baseline digital dynamometers were reliable instruments that produce stable and accurate measurements and whether there was a difference in grip strength measurements between the two Baseline digital dynamometers.

The analysis of instrument reliability is necessary to validate the collection and evaluation of clinical data (Fess, 1986; MacDermid, Evenhuis, & Louzon, 2001). The Jamar hydraulic dynamometer is recognized as the gold standard instrument for measuring grip strength because it demonstrates the highest calibration accuracy, strong reliability, and intra- and inter-tester reliability (Fess, 1987; Mathiowetz et al., 1984; Mathiowetz et al., 1985; Mathiowetz, 2002; Peolsson et al., 2001). However, the empirical evidence for reliability of digital and electronic dynamometers is not well documented. This study provided the inter-instrument reliability values of the Baseline digital dynamometer based on data collected from human subjects without disabilities. Results demonstrated that grip strength measurements taken with different Baseline digital dynamometers should not be considered interchangeable. Therefore the Baseline digital dynamometer should not be used interchangeably with other Baseline digital dynamometers.

Descriptive statistics for skewness showed that the data were sufficiently normally distributed for use of parametric analyses. The one-way repeated measure ANOVA (p=.148) showed no order effects. One reason for this may be because this study used a relatively narrow age range to protect against order effects due to age-related fatigue.

The t-tests for paired data revealed a statistically significant difference between the grip strength measurements of the two Baseline digital dynamometers (t=3.392; p=.001). However, the Cohen's D effect size value (d=.105) suggests low practical significance. Based solely on the t-test, the effect size means that the difference between the two instruments may not be large enough to have practical meaning.

Even though the results produced a statistically significant difference between the means, one could question the practical significance of a 2.4 pound average difference between the dynamometers. Is this degree of difference meaningful to occupational therapy clinicians? To explore this issue more fully, we completed a Bland Altman analysis. The Bland-Altman method analyzes the mean difference, or bias, between two different instruments measuring the same quantity (Myles & Cui, 2007; Zou, 2013). It includes the 95% limits of agreement, which provide an interval within which 95% of the true mean differences lie (Bland & Altman, 1999). In other words, these limits are expected to contain the mean differences between two instruments of future subjects 95% of the time (Bland & Altman, 1999).

In this study, the Bland and Altman analysis revealed a bias of 2.4 lbs. between the green and yellow dynamometers indicating the instruments were measuring differently. The 95% limits of agreement ranged between -10.32 and +15.13 lbs. The positive differences, with a limit of 15.13 lbs., mean that for 66% of the subjects, the green dynamometer measured higher than the yellow up to a difference of 15.13 lbs. The negative differences, with a limit of 10.34 lbs., mean that for 32% of the subjects the yellow instrument measured higher than the green up to a difference of 10.34 lbs. (percentages did not add up to 100% because the pairs that tied in measurement were not included). This range in differences between the two dynamometers is unacceptable for clinical practice because a difference between the dynamometers of up to 15.13 lbs. can signify a significant difference in functional abilities.

Furthermore, a difference of this size could conceal true improvement or decline in grip strength (Svens & Lee, 2005). Nitschke, McMeeken, Burry, and Matyas (1999) evaluated the size of change required to detect a genuine change in grip strength for accurate clinical interpretation in 42 females: 32 healthy and 10 with non-specific regional pain syndrome with pain-free grip. Results showed that any change less than 13.2 lbs. could occur by chance. So a change greater than 13.2 lbs. is necessary to detect genuine change in grip strength (Nitschke et al., 1999). This is significant for clinical purposes because the measurement differences between the two Baseline digital dynamometers may appear to indicate a significant functional change when in fact there may have been no significant change.

This study is the first study to evaluate inter-instrument reliability of two instruments of the same brand and type: the Baseline digital dynamometer. This study also adds to the current body of research which indicates that digital dynamometers cannot be used interchangeably with other digital dynamometers or with the Jamar hydraulic dynamometer (Allen & Barnett, 2011;

Amaral et al., 2012; Bohannon, 2006; Deaton, 2013; Shechtman et al., 2003; Shechtman et al., 2005). Overall, the strengths of this study include randomization of participants into one of two orders for grip strength testing, one way repeated measure ANOVA showing no order effects, large sample size (n=84), and narrow age range. Likewise, instrument calibration was administered halfway through data collection, which increased the validity of the instruments' grip strength measurements.

Implications for Occupational Therapy

This study found that the grip strength measurements taken with different Baseline digital dynamometers cannot be considered interchangeable. This means that occupational therapy practitioners should not interchange these devices when retesting patients' grip strength. Occupational therapists should label each Baseline digital dynamometer with a separate name or number and then record this name/number in the patient's chart to prevent clinicians from interchanging the devices (King, 2013). Additionally, normative data for the Baseline digital dynamometer is currently not available. This makes interpreting grip strength measurements difficult because there are no expected grip strength levels for sex- and age-matched healthy community dwelling adults with which to compare patients' measurements. Using the norms established for the Jamar is not advisable based on the results of Deaton (Deaton, 2013).

Limitations and Future Research

Even though there was an equal representation of females and males, gender was not stratified in the randomization process. Additionally, the participant population lacked racial and ethnic diversity and an equal distribution of ages within the range of 20-50 years. Because of this, the results should not be generalized to the overall population. Additionally, normative data needs to be established for the Baseline digital dynamometer to facilitate the interpretation of evaluation results and to assist clinicians with setting realistic treatment goals (Mathiowetz et al., 1985). Future research should be conducted to validate current results, enhance the generalizability of findings, and to determine the test-retest reliability in measuring grip strength in persons with disabilities.

Conclusions

This study examined the reliability and interchangeability of the Baseline digital dynamometer. Results show that the Baseline digital dynamometer should not be used interchangeably with other Baseline digital dynamometers. It is recommended that clinicians use the same device when reassessing patients' grip strength. Furthermore, normative data for the Baseline digital dynamometer is not available. Practitioners should not compare the Baseline digital dynamometer grip strength measurements with current available normative data.

References

Allen, D., & Barnett, F. (2011). Reliability and validity of an electronic dynamometer for measuring grip strength. *International Journal of Therapy and Rehabilitation 18*(5), 258-264.

Amaral, J. F., Mancini, M., & Novo Junior, J. M. (2012). Comparison of three hand dynamometers in relation to the accuracy and precision of the measurements. *Brazilian Journal of Physical Therapy*, *16*(3), 216-224.

Bland, J. M., & Altman, D. G. (1999). Measuring agreement in method comparison studies. *Statistical Methods in Medical Research*, *8*(2), 135-160.

Bohannon, R. W. (2006). Test-retest reliability of the MicroFET 4 hand-grip dynamometer. *Physiotherapy Theory and Practice, 22*(4), 219-221. doi: 10.1080/09593980600822875

Bohannon, R. W. (2008). Hand-grip dynamometry predicts future outcomes in aging adults. *Journal of Geriatric Physical Therapy, 31*(1), 3-10.

Borenstein, M. (2012). Statistical hypothesis tests. In Arthur, J., Waring, M., Coe, R., & Hedges, L.V. (Eds.), *Research methods and methodologies in education* (pp. 330-337). Thousand Oaks, California: SAGE Publications Inc.

Deaton, H. (2013). *A study of inter-instrument reliability and concurrent validity between the Baseline digital dynamometer and the Jamar hydraulic dynamometer*. University of Toledo. Unpublished manuscript.

Fabrication Enterprises Inc. (2015). Baseline® hand dynamometer, digital LCD Gauge, ER™ 300 lb. capacity. Retrieved from: http://www.fab-ent.com/product/120241

Elliott, A. C., & Woodward, W. A. (2007). *Statistical analysis quick reference guidebook: With SPSS examples*. Thousand Oaks, Calif: Sage Publications.

Fess, E. E. (1986). The need for reliability and validity in hand assessment instruments. *Journal of Hand Surgery, 11*(5), 621-623.

Fess, E. E. (1987). A method for checking Jamar dynamometer calibration. *Journal of Hand Therapy, 1*(1), 28-32. doi: http://dx.doi.org/10.1016/S0894-1130(87)80009-1

Fess, E. E. (1992). Grip strength. In J. S. Casanova (Ed.), *Clinical assessment recommendations* (2 ed., pp 41-45), Chicago, IL: American Society of Hand Therapists.

Hamilton, A., Balnave, R., & Adams, R. (1994). Grip strength testing reliability. *Journal of Hand Therapy 7*(3), 163-170.

Innes, E. (1999). Handgrip strength testing: a review of the literature. *Australian Occupational Therapy Journal 46*, 120–140.

Kielhofner, G. (2006). Developing and evaluating quantitative data collection instruments. In G. Kielhofner (Ed.), *Research in occupational therapy: Methods of inquiry for enhancing practice* (pp. 155-176). Philadelphia: F. A. Davis

King, T. I., 2nd. (2013). Interinstrument reliability of the Jamar electronic dynamometer and pinch gauge compared with the Jamar hydraulic dynamometer and B&L Engineering mechanical pinch gauge. *American Journal of Occupational Therapy*, *67*(4), 480-483. doi: 10.5014/ajot.2013.007351

Mathiowetz, V., Weber, K., Volland, G., & Kashman, N. (1984). Reliability and validity of grip and pinch strength evaluations. *Journal of Hand Surgery 9*(2), 222-226.

Mathiowetz, V., Kashman, N., Volland, G., Weber, K., Dowe, M., & Rogers, S. (1985). Grip and pinch strength: Normative data for adults. *Archives of Physical Medicine and Rehabilitation, 66*(2), 69-74.

Mathiowetz, V. (2002). Comparison of Rolyan and Jamar dynamometers for measuring grip strength. *Occupational Therapy International, 9*(3), 201-209.

Myles, P. S., & Cui, J. (2007). I. Using the Bland–Altman method to measure agreement with repeated measures. *British Journal of Anaesthesia, 99*(3), 309-311. doi: 10.1093/bja/aem214

Nitschke, J. E., McMeeken, J. M., Burry, H. C., & Matyas, T. A. (1999). When is a change a genuine change? A clinically meaningful interpretation of grip strength measurements in healthy and disabled women. *Journal of Hand Therapy, 12*(1), 25-30.

Peolsson, A., Hedlund, R., & Oberg, B. (2001). Intra- and inter-tester reliability and reference values for hand strength. *Journal of Rehabilitation Medicine*, *33*(1), 36-41.

Petersen, P., Petrick, M., Connor, H., & Conklin, D. (1989). Grip strength and hand dominance: challenging the 10% rule. *American Journal of Occupational Therapy, 43*(7), 444-447.

Poole, J. (2009). Musculoskeletal factors. In E. B. Crepeau, E. S. Cohn & B. A. Boyt Schell (Eds.), *Willard & Spackman's occupational therapy* (11 ed., pp. 658-680). Philadelphia: Lippincott Williams & Wilkins.

Rantanen, T., Guralnik, J. M., Foley, D., Masaki, K., Leveille, S., Curb, J. D., & White, L. (1999). Midlife hand grip strength as a predictor of old age disability. *JAMA, 281*(6), 558-560.

Rice, M. S., Leonard, C., & Carter, M. (1998). Grip strengths and required forces in accessing everyday containers in a normal population. *American Journal of Occupational Therapy, 52*(8), 621-626.

Sammons Preston Rolyan. (2003). *Jamar: Hydraulic hand dynamometer owner's manual* (online brochure). Retrieved from http://www.mobilityworld.co.uk/pdf/4_user%20instruction.pdf

Shechtman, O., Davenport, R., Malcolm, M., & Nabavi, D. (2003). Reliability and validity of the BTE-Primus grip tool. *Journal of Hand Therapy, 16*(1), 36-42. doi: http://dx.doi.org/10.1016/S0894-1130(03)80022-4

Shechtman, O., Gestewitz, L., & Kimble, C. (2005). Reliability and validity of the DynEx dynamometer. *Journal of Hand Therapy, 18*(3), 339-347. doi: http://dx.doi.org/10.1197/j.jht.2005.04.002

SI Instruments Pty Ltd. (2013). *Jamar® Plus+ Digital Hand Dynamometer* (online brochure). Retrieved from http://www.si-instruments.com.au/product/show/141/digital-hand-dynamometer/0.html

Svens, B., & Lee, H. (2005). Intra- and inter-instrument reliability of grip-strength measurements: GripTrack™ and Jamar® hand dynamometers. *British Journal of Hand Therapy, 10,* 47-55.

Talsania, J. S., & Kozin, S. H. (1998). Normal digital contribution to grip strength assessed by a computerized digital dynamometer. *The Journal of Hand Surgery: British & European Volume*, *23*(2), 162-166.

Weinstock-Zlotnick, G., Bear-Lehman, J., & Yu, T. Y. (2011). A test case: does the availability of visual feedback impact grip strength measurements when using a digital dynamometer? *Journal of Hand Therapy*, 24(3), 266-276. doi: 10.1016/j.jht.2011.01.004

Zou, G. Y. (2013). Confidence interval estimation for the Bland-Altman limits of agreement with multiple observations per individual. *Statistical Methods in Medical Research*, *22*(6), 630-642. doi: 10.1177/0962280211402548

Table 1

Descriptive Data for Baseline Digital Dynamometers

	M	SD	Minimum	Maximum	Range
Green	82.88	22.74	36	136	100.00
Yellow	80.47	22.85	36	153	117.00

Note. n=84; all data are in pounds

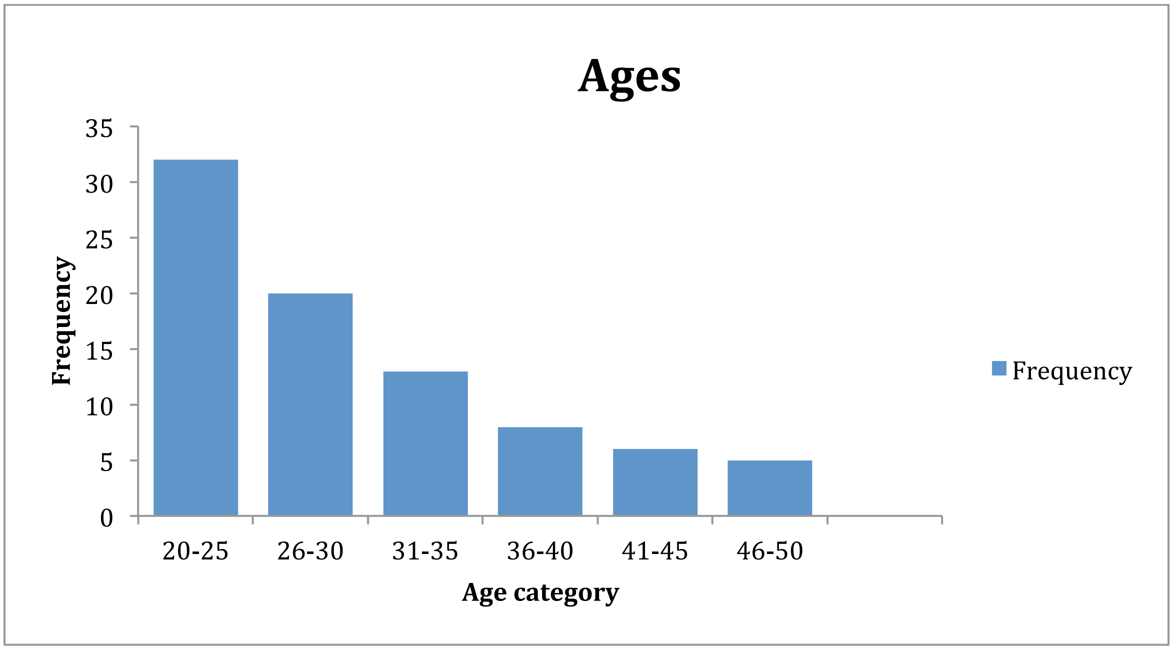

Figure 1. Participant ages in five year increments

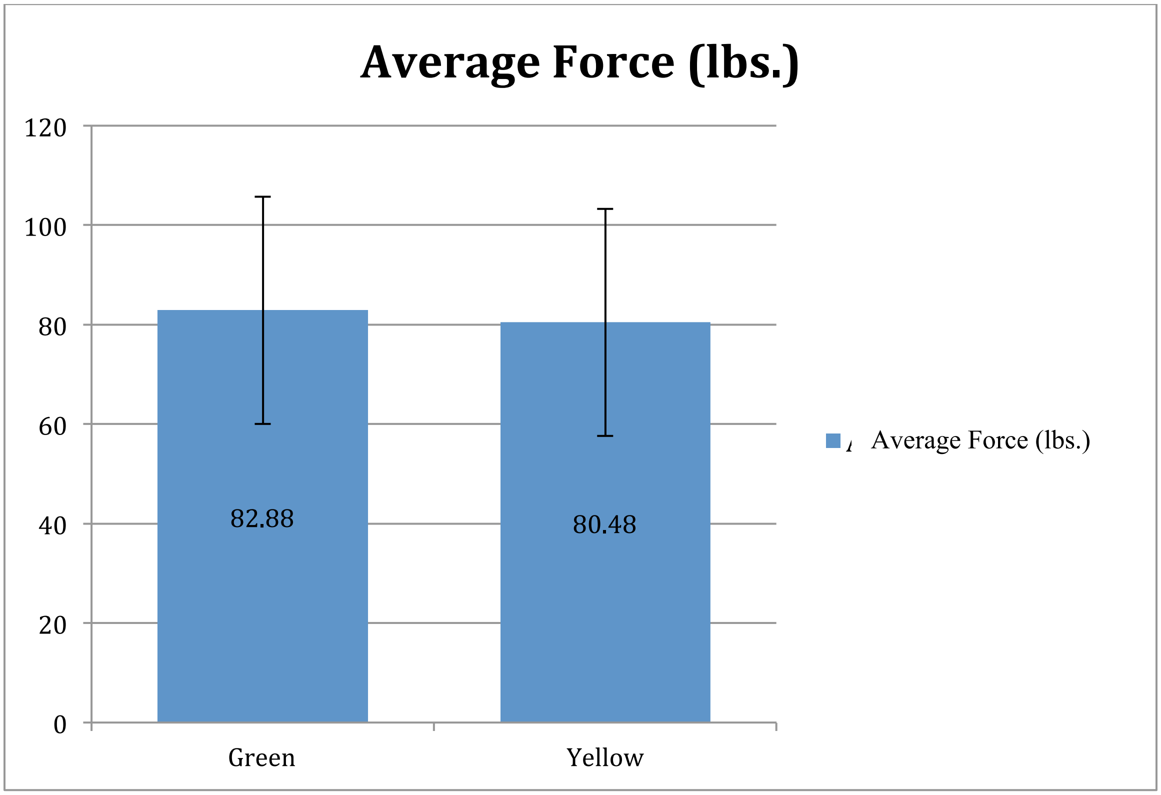

Figure 2. Average force measurements and standard deviations.

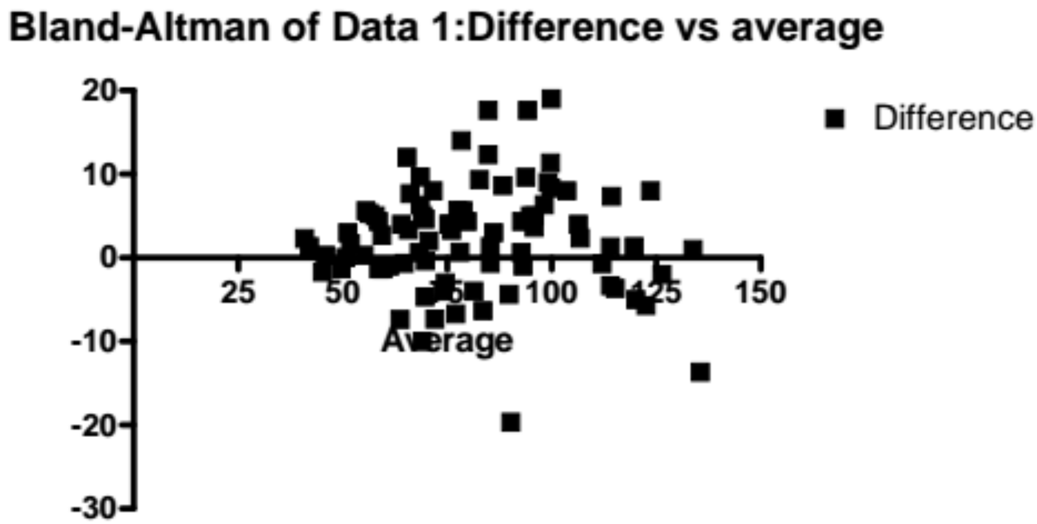

Figure 3. Bland-Altman Plot for grip strength using the green and yellow Baseline digital dynamometers. Differences in grip strength measurements between the two dynamometers were plotted against the mean forces for the 84 participants. The bias is indicated by the middle line (2.4 pounds). Ninety-five percent of participants fell within the limit of agreement: -10.32–15.14 pounds.