Proceedings of The National Conference
On Undergraduate Research (NCUR) 2013
University of La Crosse, WI
April 11-13 2013

Assessing Changes In Scores For Reaching and Dexterity Using A Functional Capacity Evaluation Over A Four-Day Testing Period

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Abstract

Purpose: To provide evidence that Metriks FCE protocol for reaching and dexterity can be performed in one day of testing, providing an inexpensive and short measure.
Methods: Reaching and dexterity time scores of 19 participants with a mean (±SD) age of 22.2 ± 1.7 were evaluated. Scores were obtained from 10 tests from the Metriks FCE protocol. Tests evaluated were occasional overhead reach left and right, occasional shoulder reach left and right, occasional gross dexterity left and right, occasional fine dexterity left and right, frequent waist reaching, and frequent shoulder reaching. Scores were compared using a one-way repeated measures (within participants) ANOVA
Results: A significant difference between days of testing was found within all 10 testing protocols. The presence of a learning curve was observed for all ten testing protocols. The average scores on all four days and for all 10 protocols were within the “above competitive” and “exceeds above competitive” ranges of the Methods-Time Measurement, indicating the need for only one day of testing.
Practical applications: When testing an individual within the representative population, reaching and dexterity capabilities can be measured using one-day of testing, which allows for a smaller financial burden, a smaller time commitment, and less stress on the participants musculature.

Key Words: Functional Capacity Evaluation, Reaching, Dexterity

1. Introduction

A functional capacity evaluation is a systematic, comprehensive, objective series of dynamic tests designed to measure an individual's abilities or performance in work-related tasks (1). Functional capacity protocols are supposed to define an individual's functional abilities or limitations in the context of safe, productive work tasks (2). Occupational therapists began to develop and use physical capacity evaluations in the late 1940's and early 1950's to assess the patient's capacity to meet the physical demands of work (2). Over the past several decades, FCE's have begun to develop into more complex procedures, and the usage of FCE's has expanded greatly. As stated by King et al. (3), the role of functional capacity evaluation appears to be increasing as employers and insurers rely more heavily on them for decision making (3). Today, FCEs have numerous functions including; assisting insurance companies in settling claims for personal injury, assisting judges and juries in awarding amicable damages in personal injury litigation, and assisting administrative boards in determining whether a person who is ill or injured meets a governmental agency's particular criteria of eligibility to be awarded benefits based on his or her claim (2). Gross et al. states that FCEs are commonly used internationally for return-to work decisions for injured workers (4). As the usage of FCE's has increased, the number of available protocols has increased accordingly. Currently there are several controversies surrounding the use of FCE's. Branton et al. (5) states, that while varying in design, most available FCE protocols are lengthy and expensive to administer, which creates a burden on clients, insurers, and administering therapists (5). The length of time to administer an FCE varies among designers. Some FCEs require less than two hours to administer, whereas other FCEs require 3 to 4 hours or multiple days to administer (3). Rodgers adds, that a rapidly fatiguing muscle is more susceptible to injury and inflammation; therefore a longer testing period could cause more damage or discomfort for test participants (6). Gross et al. (4) explain that because FCEs typically take hours to complete over multiple occasions and cost as much as advanced diagnostic imaging studies, any potential reductions in test burden would be beneficial (4). For the purposes of this study, the reaching and dexterity components of a specificindustry commercial (Metriks) FCE will be evaluated.

Reaching and dexterity are important components of an FCE that are not widely studied**.** Reaching in particular is often overlooked in an FCE, and few studies focus on the shoulder, or assessment of the upper limbs. Gouttebarge et al. (7) described that injuries and limitations can occur any where in the body including the upper extremities (shoulder, forearm, wrist, hand). In a comprehensive assessment of upper extremity function, dexterity is an important component that must be considered (8). Poole et al. explain, dexterity has been defined as 'the fine, voluntary movements, used to manipulate small objects during a specific task, as measured by the time to complete the task' (9). A large difference in reaching and dexterity is that the gross motor, posture stabilizing actions of the upper body and arm in the reach involve different neural pathways and brain centers than those for fine motor, isolated control of the hand and fingers in the grasp and manipulation (10). A protocol that includes assessment for reaching and dexterity is the Metriks FCE protocol.

The Metriks FCE protocol has undergone little explorative research. Similar to the Isernhagan, The Metriks FCE is comprised of a large battery of tests, including walking, mobility, lifting, grip strength, pinch strength, reaching, and dexterity. The Metriks FCE differs from other protocols is that it uses Methods-Time-Measurement (MTM) to assess an individuals level of ability to work in a competitive workplace. Most functional capacity evaluations (FCE) have diminished validity because the process does not utilize a standardized quantitative assessment (11). Methods-Time Measurement (MTM) FCE systems are criterion-referenced and generalizable to the functions required of a worker in the performance of their work demands. In addition, the MTM system has demonstrated high interval consistency with an 8% standard error of measurement at 95% confidence interval (11).

Currently there are several widely used tests to assess upper limb functions or disorders, these include the Fugl-Meyer Assessment, Isernhagen Work Systems FCE, Jebsen-Taylor Test of Hand Function, Nine-Hole Peg Test, the Purdue Pegboard Tests, and the Metriks FCE.

The Fugl-Meyer assessment of physical performance is quantitative and lends itself to statistical analysis for both research and clinical work (12). Using a Post Hoc analysis it was determined that the significant differences found using an ANOVA were between tests 3 and 4 and tests 3 and 5 within the testing protocol (12). The implication of these results is that it indicates the possible need for multiple days of testing. Sanford et al. analyzed the Fugl-Meyer assessment and determined there was no significant difference between scores obtained by different raters and the inter-rater reliability was 0.96 (13). The Jebsen-Taylor Test of Hand Function assesses broad aspects of hand function commonly used in activities of daily living using standardized tasks (9). The test uses seven timed subtests to assess both fine and manual finger dexterity. Poole et al. states that the Jebsen-Taylor Test of Hand Function contains inter-rater reliability (ICCS ranging from 0.82-1.00), test-retest reliability (r=0.87-0.99), concurrent validity, and discriminative validity. (9). The construct validity of this test is limited because it does not assess work-related tasks.

The nine-hole peg test has similar characteristics as the Metriks FCE protocol for dexterity and occasional reaching. The Nine-hole peg test is a timed measure of fine dexterity and involves placing and removing nine pegs in a pegboard (14). Croarkin et al. claimed to have established the inter-rater reliability (IRR) and test-retest reliability (TRT) of the nine-hole peg test in 1987 (15), however, the r values found, were not measuring the IRR(inter-rater reliability) or the TRT (test re-test reliability) appropriately and could not be accurately determined (15). Similarly Yancosek et al. (14) reviewed the Nine-hole peg test and found that there was a moderate correlation between the Purdue pegboard and the nine-hole peg test however the retest reliability was found to be too high (ICC=0.99) (14). According to Amirjani et al. (16) the Purdue Pegboard Test is a valid and reliable tool to quantify functional impairment caused by carpal tunnel syndrome as well as other impairments and it can be a useful outcome measure in young and middle-aged patients (16).

According to Gallus et al. the test-retest reliability using a one trial administration has been reported ranging from .037 to 0.92 in healthy populations. Using a three trial administration the test-retest reliability improves to 0.82 to 0.89. It was also noted by Gallus et al. that with the three trial administrations there was no practice effect that modified the outcomes of the tests (17).

Although there are numerous testing protocols available to test reaching and dexterity performance, there has not been a protocol such as the Metriks FCE protocol, that tests dexterity along with numerous levels of reaching, that has been tested to assess changes in scores across numerous days. The purpose of this study is to determine if scores for the Metriks FCE protocol for reaching and dexterity will vary on four separate days of testing. It is hypothesized that there will be no significant difference between testing scores from day 1 through day 4 for reaching and dexterity. This can provide a protocol that is less expensive and requires less stress on clients and less time to complete.

2. Methods

2.1 participants

For this study, 20 healthy males and females were recruited using a convenience sampling method. One participant was removed due to an injury sustained outside of this research study; therefore 19 participants with a mean (±SD) age of 22.2 ± 1.7 years were studied. Participants were recruited from the Sheridan College Davis campus, specifically from the Athletic Therapy and Exercise Science and Health Promotion programs. All participants' underwent a prescreening assessment including a health history questionnaire and ROM assessment if past injuries or conditions were present. Participants with current injuries or disabilities that would keep them from performing in the "normal" ranges (as predetermined in the FCE protocol) were excluded.

2.2 experimental protocol

Participants were e-mailed the client information sheet and a health history questionnaire prior to their test day. Participants then brought the signed forms with them to the Sheridan College Davis campus on the first day of testing and signed an informed consent. The Health History Questionnaire was examined to ensure there are no risks to the participant. Testing commenced on day one after the appropriate forms were completed. Following the completion of the prescreening measures, the participant performed the current Metriks FCE protocol (Metriks Education Inc. 2004, Waterloo, Ontario, Canada). This protocol is comprised of four separate components, which include: lifting tasks, reaching and dexterity tasks, measures of strength, and mobility. Participants were asked to perform the current Metriks protocol for reaching and dexterity on all four days (D1, D2, D3, D4) of testing. For each testing day the same testing procedure was used. Each participant was randomly assigned to begin at one of the above testing areas supervised by a trained assessor. Participants were tested in all four components. On D1 participants started at their randomly assigned station at one of the four components, they then moved to the next component in the room, until testing in all four components was finished. For the following days of testing they completed the tests in the same order. Testing on D2, D3, and D4 followed the same format as D1. Overall testing took approximately 60-120 minutes for all testing components to be completed, and took 20-25 minutes for the reaching and dexterity components.

2.3 experimental measures

This study is a component of a study looking at a full FCE protocol where participants underwent a complete and comprehensive FCE testing battery that lasted for 60-120 minutes, which included the tests for lifting, mobility, grip and pinch strength, and dexterity and reaching. This specific study includes the manual dexterity and reaching components. The manual dexterity and reaching components consists of: occasional reaching (shoulder level and overhead), gross dexterity, fine dexterity, and frequent reaching (shoulder level and waist level). Testing for both dexterity and reaching were performed using Metriks FCE equipment and an adjustable shelving unit. The equipment included: 20 rivets (small),12 pegs (large), a dexterity tray that has an upper surface that consists of 24 large holes and 40 small holes, and has 15 holes the left and right side panels of the tray, 3 shapes (circle, square, triangle) with four holes in each shape that correspond with the holes on the dexterity tray, and the two adjustable shelving units (Style Selections 72-in H x 36-in W x 18-in D 5-Tier Plastic Freestanding shelving and the 55"H x 36"W x 18"D Plastic Freestanding Shelving Unit)**.** Two different shelving units were used so that the shelves could be adjusted to be at the appropriate height for participants. The shelves were used to place the dexterity tray on at different heights according to the test being performed. Height of the shelving for each test was adjusted according to the participants height (Table 1). Test results were analyzed using normative data from MTM (methods-time-measurement) work rate as well as a one-way repeated measures ANOVA.

Prior to each test the participants were given a thorough set of instructions, detailing the test to follow. A rating of perceived exertion was taken using a modified Borg Scale and heart rate was recorded using a strapless continuous heart rate monitor (ePulse strapless). There was no motivation or encouragement given to the participants as they completed the tests. The participants were informed prior to reaching and dexterity testing that they may terminate testing at any time and for any reason.

2.4 occasional reaching

Participants performed an occasional reaching test at both an overhead level and at shoulder level. The participant was set up in the starting position, standing in front of the shelving unit with the dexterity tray on it; participants faced the tray with their arms down at their sides. Either 12 pegs or 20 rivets were placed in the tray prior to starting the test. The 20 rivets were used for overhead reaching and 12 pegs were used for shoulder level reaching. The client performed a practice trial by moving one peg from the left side of the tray to the corresponding hole on the right side. During the overhead-reaching test, participants moved the 20 rivets from the left side of the tray to the right side of the tray beginning with their left hand. They then used their right hand to move the rivets across the tray again. This was repeated for three times on each hand. The same protocol was used for the shoulder level reaching test but with the tray was moved to the appropriate shoulder height and the participant moved 12 pegs instead of 20 rivets. The total number of moves and the total time to complete the test was recorded.

2.5 dexterity

Participants underwent testing for both fine dexterity as well as gross dexterity. When completing testing for both fine dexterity and gross dexterity participants started the test with their left hand. The tray was set up at waist level for both fine and gross dexterity testing. Either 12 pegs or 20 rivets were placed in the tray prior to starting the test. The 20 rivets were used for fine dexterity and 12 pegs were used for gross dexterity. The client performed a practice trial by moving one peg from the left side of the tray to the corresponding hole on the right side. During the fine dexterity test, participants moved the 20 rivets from the left side of the tray to the right side of the tray beginning with their left hand. They then used their right hand to move the rivets across the tray again. This was repeated for three times on each hand. The same protocol was used for the gross dexterity test the participant moved 12 pegs instead of 20 rivets. The total number of moves and the total time were recorded (e.g. all 20 of the rivets in 36 seconds).

2.6 frequent reaching

The participants then performed frequent reaching tests at both waist level and shoulder level. Frequent reaching tests consisted of the participant unscrewing 12 pegs from one side of the tray that held three shapes (circle, triangle, square) in place. The participant then transferred all three of the shapes to the other side of the tray and screwed all of the pegs back into the shapes onto the tray. Turning of the pegs was performed with one hand, while the other hand held the nut on the inside of the tray. The client performed a practice trial by removing 1 shape and replacing it on the opposite side of the tray. The test was complete when the participant had assembled the final shape onto the new side. The total number of moves and the total time was recoded. For both waist level and shoulder level reaching, testing consisted of one trial.

2.7 data analysis

For the data recorded from dexterity testing and occasional reaching testing, the results from the three trials of each participant's scores was recorded for each hand individually. For the frequent reaching tests, scores from the one trial completed was used. The information was then used in a one-way repeated measures (within subjects) ANOVA. An alpha value of 0.05 was used. Mauchly's Test of Sphericity was used to determine if the assumption of sphericity had been violated. If the test revealed sphericity had been violated an adjustment was made to correct the degrees of freedom for the *F*-distribution.

Overall there were10 statistical analyses completed, this included: left hand occasional reaching overhead, right hand occasional reaching overhead, left hand occasional reaching at shoulder level, right hand occasional reaching at shoulder level, left hand gross dexterity, right hand gross dexterity, left hand fine dexterity, right hand fine dexterity, frequent reaching at waist level, and frequent reaching at shoulder level. Each statistical analyses indicated whether or not there was an effect of test day on test scores and a significant difference between days of testing. Where the data analysis has shown the presence of a significant difference, a Bon Ferrerri Post Hoc analysis was used to determine were the difference lies within the data.

MTM scores were also used when analyzing the data obtained from all ten testing procedures. MTM based Functional Capacity Evaluations are criterion-referenced, generalizable to the functions required of a worker in the performance of their work demands (11). Methods-Time measurement work rate ranges are; 141% and more is exceeding above competitive, 101%-140% is above competitive, 80%-100% is competitive, 70%-79% is entry-level, and 69% is non-competitive. The scores were used to determine the category of work abilities that the participant could be classified in.

3. Results

The data gathered for all ten protocols were each analyzed using a one-way repeated measures ANOVA. Repeated measure's ANOVAs tend to have an increase in type 1 error when a violation of sphericity is present. A type I error occurs when one rejects the null hypothesis when it is true (19). Using Mauchly's sphericity enabled us to decrease the risk of type 1 error by producing a more valid critical F-value. Several of the tests completed did violate the assumption of sphericity. Using the Greenhouse-Geisser correction, the degrees of freedom were corrected to decrease the rate of type 1 error.

The MTM work rate norms revealed that all scores were in the “Above competitive” and “exceeds above competitive” ranges. The MTM work rate norm for occasional overhead reaching and fine dexterity is 36 seconds, for occasional shoulder level reaching and gross dexterity is 20 seconds and for frequent reaching at both waist and shoulder level is the MTM work rate norm is 300 seconds (5 minutes)

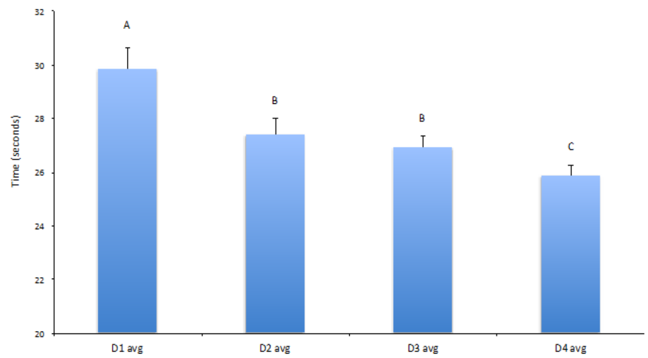


Figure 1. **Occasional Overhead Reach- left hand.** There was a significant Time main effect: F (1, 19) = 14.907, p < .0001. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D2 (p = .027), D1 and D3 (p = .005), D1 and D4 (p = .001), D2 and D4 (p = .046), D3 and D4 (p = .014). Differences shown by different letters, data with the same letter did not have a significant difference.

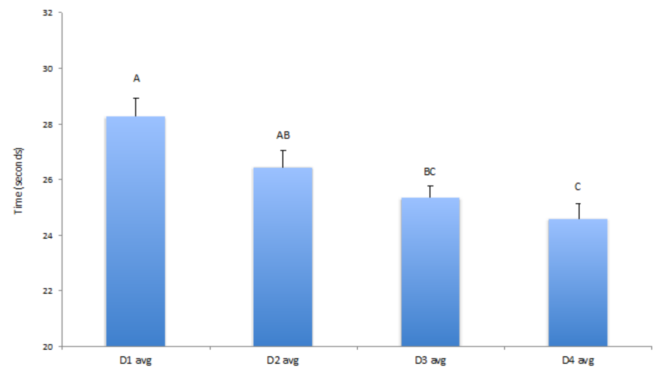


Figure 2. **Occasional Overhead Reach- right hand**. There was a significant Time main effect: F (1,19) = 12.021, p < .0001. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D3 (p = .003), D1 and D4 (p= .003), D2 and D4 (p = .016). Differences shown by different letters, data with the same letter did not have a significant difference.

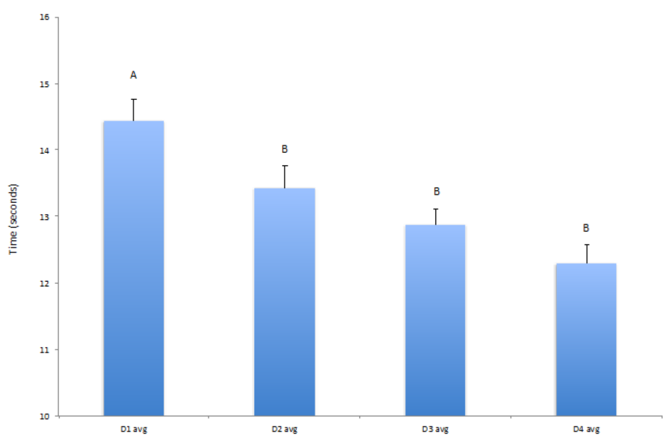


Figure 3. **Occasional Shoulder Reach- left hand.** There was a significant Time main effect: F (1,19) = 14.080, p < .0001. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D2 (p = .018), D1 and D3 (p = .002), D1 and D4 (p < .0001).
Differences shown by different letters, data with the same letter did not have a significant difference.

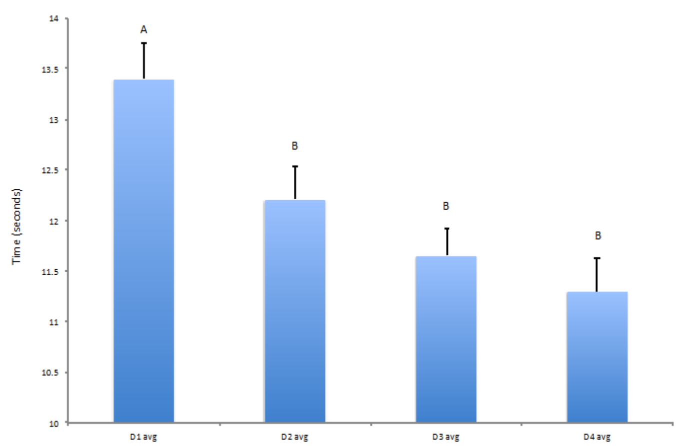
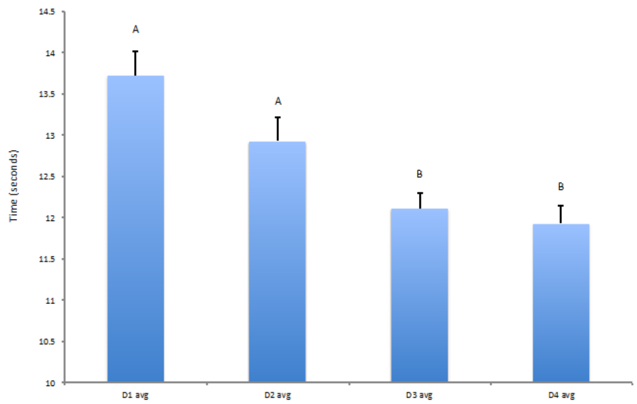


Figure 4. **Occasional Overhead Reach- right hand**. There was a significant Time main effect: F (1,19) = 16.023, p < .0001. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D2 (p = .009), D1 and D3 (p = .002), D1 and D4 (p < .0001).
Differences shown by different letters, data with the same letter did not have a significant difference.



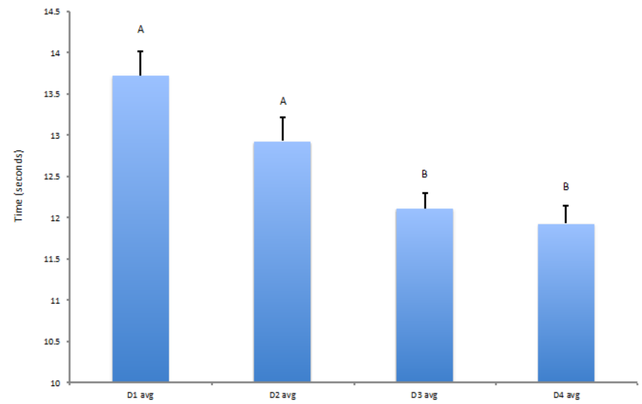
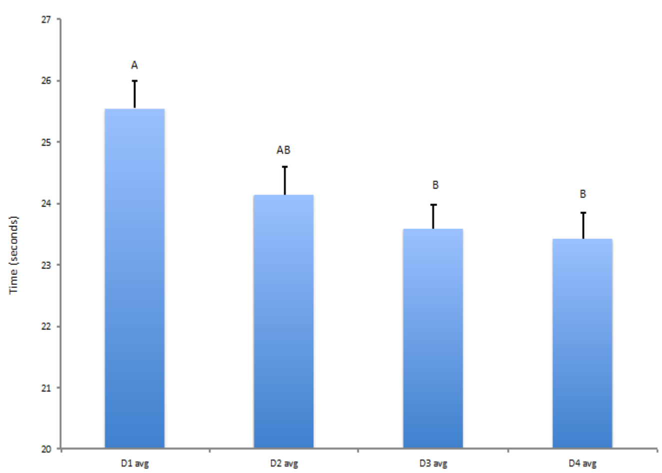


Figure 5. **Occasional Gross Dexterity- left hand**. There was a significant Time main effect: $F(1,19) = 18.402$, $p < .0001$. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D3 ($p < .0001$), D1 and D4 ($p < .0001$), D2 and D3 ($p = .005$), D2 and D4 ($p = .031$). Differences shown by different letters, data with the same letter did not have a significant difference.

Figure 6. **Occasional Gross Dexterity- right hand.** There was a significant Time main effect: $F(1,19) =19.288$, $p < .0001$. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D2 ($p = .025$), D1 and D3 ($p < .0001$), D1 and D4 ($p < .0001$), D2 and D3 ($p = .030$), D2 and D4 ($p = .026$).Differences shown by different letters, data with the same letter did not have a significant difference.



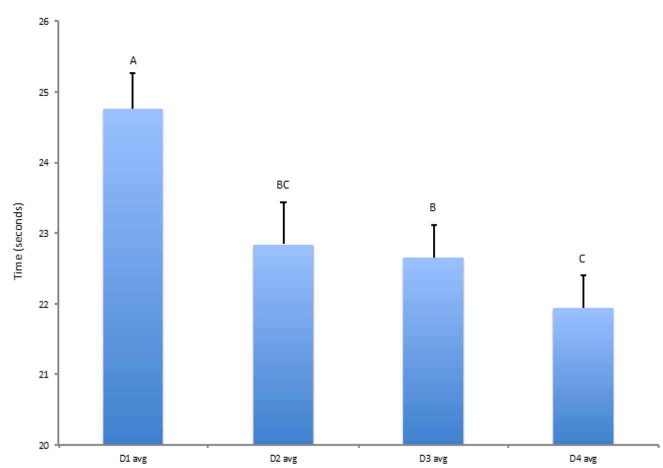


Figure 7. **Occasional Fine Dexterity- left hand**. There was a significant Time main effect: $F(1,19) =10.046$, $p < .0001$. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D3 ($p = .004$), D1 and D4 ($p = .001$).
Differences shown by different letters, data with the same letter did not have a significant difference.

Figure 8. **Occasional Fine Dexterity- right hand**. There was a significant Time main effect: $F(1,19) = 13.625$, $p < .0001$. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D2 ($p = .028$), D1 and D3 ($p = .001$), D1 and D4 ($p < .0001$), D3 and D4 ($p = .047$). Differences shown by different letters, data with the same letter did not have a significant difference.

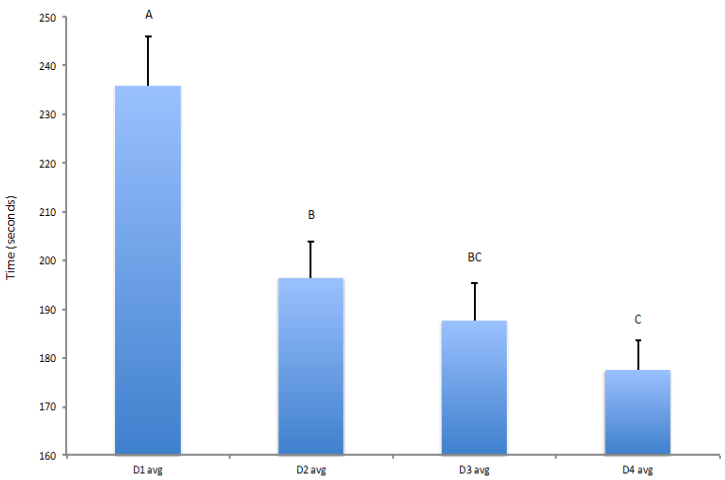


Figure 9**. Frequent Reaching- waist Level.** There was a significant Time main effect: F (1,19) = 29.263, p < .0001. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D2 (p = .002), D1 and D3 (p < .0001), D1 and D4 (p < .0001), D2 and D4 (p = .011). Differences shown by different letters, data with the same letter did not have a significant difference.

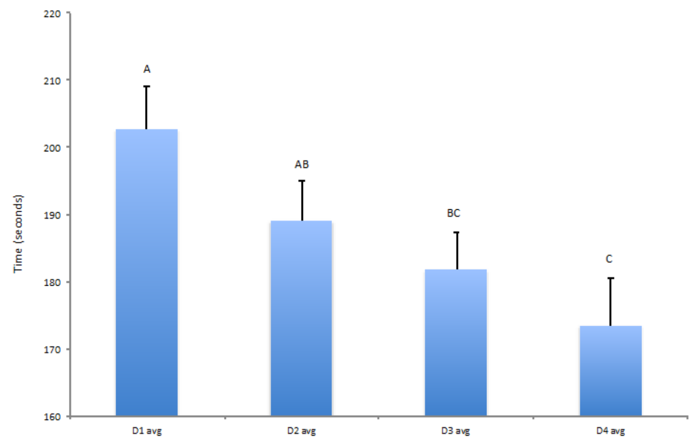


Figure 10. **Frequent Reaching- shoulder level**. There was a significant Time main effect: F (1,19) = 12.799, p < .0001. Using a Bonferrini Post Hoc analysis it was revealed that there are significant differences between: D1 and D3 (p = .001), D1 and D4 (p < .0001), D2 and D4 (p = .049). Differences shown by different letters, data with the same letter did not have a significant difference.

4. Discussion

The purpose of this study was to determine if scores for the Metriks FCE protocol for reaching and dexterity would vary on four separate days of testing. It was hypothesized that there would be no significant difference between testing scores from day 1 through to day 4 for reaching and dexterity indicating that it is only necessary to complete1 day of testing is necessary to complete. The hypothesis that there will be no significant difference between testing scores from day 1 through to day 4 for reaching and dexterity was refuted. The results of this study revealed that day of testing does have a significant effect on scores for reaching and dexterity. However, for the population tested in this study all scores were in the “above competitive range” and “exceeding above competitive range” using the MTM norm. Therefore this indicates the need for only one day of testing. The importance of the significant effect, for this representative population, is that if you do not have a competitive score on day one, the information gathered can show you how many days of testing will be required to obtain a competitive score because scores have been shown to improve across the four days of testing. For individuals from an injured population, the data may present different findings when comparing scores of four days of testing.

Several research studies such have evaluated the test-retest reliability, inter-rater reliability, and validity of short form FCEs. Some examples are; Yancosek et al. (14) studying reviewing the results of previous studies reliability and validity in FCEs, Poole et al. (9) studied the test-retest and validity of the Jesbsen-Taylor Test of Hand Function, Reesnik et al. (13) evaluated the inter-rater reliability of the Fugl-Meyer assessment of physical performance, Grice et al. (8) and Croarkin et al. (15) both studied the inter-rater reliability and test-retest reliability of the Nine-hole Peg test, and Amirjani et al. (16) studied the validity and reliability of the Purdue Peg Board test. This study assessed the main time effect over four days of testing, to obtain an indication of how many days of testing need to be performed. Further studies should aim to provide information on the inter-rater reliability and test-retest reliability of the Metriks FCE protocol.

Gallus et al. tested the test-retest reliability using a one trial administration has been reported ranging from .037 to 0.92 in healthy populations (17). Using a three trial administration the test-retest reliability improves to 0.82 to 0.89. It was also noted by Gallus et al. that with the three trial administrations there was no practice effect that modified the outcomes of the tests (17). This is contradictory to our study, which indicates that a learning effect does impact the outcomes of the test scores.

The improvement of testing scores from D1 through to D4 may be attributed to a learning effect. Flanagan et al. state, 'in a motor learning task involving the manipulation of an object, with novel dynamics, subjects can learn to predict the behavior of the object' (18). The presence of a learning curve can help in predicting future performance in the Metriks FCE for reaching and dexterity. It cannot be concluded that a learning effect was the sole reason for the significant difference between days of testing. Scores may also have been affected by participants' attitude and psychological states on the different days of testing. Participants were tested over the course of several weeks. During this time, some participants were writing exams, completing assignments, or were on reading week. The changes in their stress levels and attitudes could have caused a change in scores over the four days.

A limitation to this study was the type of shelving unit used for adjusting the height of the dexterity tray for the different testing protocols. Using the adjustable shelving unit did allow us to adjust the height of the tray for three different groupings of height; however, a shelving unit that could be adjusted to the specific height of each individual would be ideal.

For this study, one to four participants were being tested in the same room at the same time. Due to time constraints, it was necessary to test individual participants simultaneously. This may have caused distractions to the participants causing a decreased or increased score.

5. Conclusion

In conclusion, the results of this present study indicate that FCE testing can be done with only one day of testing for the representative population. The next steps to research in this area will be to investigate the effects of day of testing on scores for individuals from an injured population. Further testing should also be directed toward the cause of the difference between days of testing, we could determine whether the learning curve is responsible for the differences within all ten testing protocols. Further testing should also aim to provide information on the inter-rater reliability, test-retest reliability and the validity of the Metriks FCE protocol

It is, therefore, propose that FCE testing be performed using Metriks FCE protocol in one day of testing. More days of testing are not needed as the scores are above the competitive range of the MTM norm. Completing further days of testing when the scores are above the MTM norm will not provide additional useful information, but will only be time consuming.

6. Practical Applications

When testing an individual within the representative population, reaching and dexterity capabilities can be measured using one-day of testing. The benefits of a single test session include: a smaller financial burden, a smaller time commitment, and less stress on the participants musculature. Having a smaller financial burden and a smaller time commitment will benefit many parties, including but not limited to; insurance companies, kinesiologist or therapists performing the FCE, and the individual performing the FCE. When testing an individual from an injured population, the data gathered can be used to help in the prediction of days of testing needed to acquire a competitive score.

7. References Cited

(1) Nicholls, A., Gibson, L., McKenna, K., Gray, M., Wieland, T. (2011). Assessment of standing in functional capacity evaluation: an exploration of methods used by a sample of occupational therapists. Work, 38, 145-153.
(2) Smith, S.L., Cunnigham, S., Weinberg, R. (1986). The predictive validity of the functional capacities evaluation. The American Journal of Occupational Therapy, 40(8), 564-567.
(3) King, P.M., Tuckwell, N., Barett, T.E. (1998). A critical review of functional capacity evaluations. *Journal of the American Physical Therapy Association.* 78(8), 852-866
(4) Gross, D.P., Battie, M.C., Asante, A. (2006). Development and validation of a short-form functional capacity evaluation for use in claimants with low back disorders. Journal of Occupational Rehabilitation, 16(1), 53-61.
(5) Branton, E.N., Arnold, K.M., Appelt, S.R., Hodges, M.M., Battie, M.C., Gross, D.P. (2010). A short-form functional capacity evaluation predicts time to recovery but not sustained return-to-work. Journal of Occupational Rehabilitation, 20, 387-393.
(6) Rodgers, S.H. (2006). Rodgers Muscle Fatigue Analysis. Occupational Medicine: State of the art reviews, volume 2.
(7) Gouttebarge, V., Wind, H., Kuijer, P.F.M., Sluiter, J.K., Frings-Dresen, M.H.W. (2010). How assess physical work-ability with functional capacity evaluation methods in a more specific and efficient way. Work, 37, 111-115.
(8) Grice, K.O., Vogel, K.A., Le, V., Mitchell, A., Muniz, S., Vollmer, M.A. (2003). Adult norms for a commercially available nine hole peg test for finger dexterity. American Journal of Occupational History, 57, 570-573.
(9) Poole, J.L. (2003). Measure of adult hand function. Arthritis and Rheumatism, 49(5), 59-66.
(10) Kimmerle, M., Mainwaring, L., Borenstein, M., (2003). The functional repertoire of the hand and its application to assessment. The American Journal of Occupational Therapy, 57, 489-498
(11) Coupland, M. (1998) using methods-time measurement (MTM) in functional capacity evaluation. Matheson, Roy Matheson & Associates, pg. 2-9
(12) Duncan, P.W., Propst, M., Nelson, S.G. (1983). Reliability of the Fugl-Meyer assessment of sensorimotor recovery following cerebrovascular incident. Physical Therapy, 63(10), 1606-1610.
(13) Reesink, D.D., Jorritsma, W., Reneman, M.F. (2007). Basis for a functional capacity evaluation methodology for patients with work-related neck disorders. Journal for Occupational rehabilitation, 17, 436-449.
(14) Yancosek, K.E., Howell, D. (2009). A narrative review of dexterity assessments. Journal of Hand Therapy, 22, 258-270.
(15) Croarkin, E., Danoff, J., Barnes, C. (2004). Evidence-based rating of upper extremity motor function tests used for people following a stroke. Physical Therapy, 84, 62-74.
(16) Amirjani, N., Ashworth, N.L., Olson, J.L, Morhart M., Chan, K.M. (2011). Validity and reliability of the Purdue pegboard test in carpal tunnel syndrome. Muscle Nerve, 43(2), 171-177.
(17) Gallus, J., Mathiowetz, V. (2002). Test-retest reliability of the Purdue Pegboard for persons with multiple sclerosis. American Journal of Occupational Therapy, 57, 108-111.
(18) Flanagan, R.J., Vetter. P., Johansson, R.S., Wolpert, D.M. (2003). Prediction precedes control in motor learning. Current Biology, 13(2), 146-150.
(19) Levin, J., Fox, J.A., Forde, D.R., (2006) Elementary Statistics in social research. Boston, MA: Allyn & Bacon.