Running: Aging and UE function

Title: Predicting hand function in older adults: Evaluations of grip strength, arm curl strength, and manual dexterity

Chiung-ju Liu, Deana Schuman, Aaron Fredrick, Jessica Bertram, Kristen Utley, and Elaine Ewing Fess

Indiana University, Indianapolis, Indiana, USA

Department of Occupational Therapy, School of Health and Rehabilitation Sciences, Indiana University, 1140 West Michigan Street, CF 311, Indianapolis, Indiana 46202-5199, USA.

Correspondence concerning this article should be addressed to Chiung-ju Liu

Phone: +1(317)274-8006

Email: liu41@iu.edu

This is the author's manuscript of the article published in final edited form as:

Liu, C., Marie, D., Fredrick, A., Bertram, J., Utley, K., & Fess, E. E. (2016). Predicting hand function in older adults: evaluations of grip strength, arm curl strength, and manual dexterity. Aging Clinical and Experimental Research, 1–8. https://doi.org/10.1007/s40520-016-0628-0

Abstract

**Background:** Hand function is critical for independence in activities of daily living for older adults.

**Aims:** The purpose of this study was to examine how grip strength, arm curl strength, and manual dexterous coordination contributed to timed-based versus self-report assessment of hand function in community-dwelling older adults.

**Methods:** Adults aged $\geq$ 60 years without low vision or neurological disorders were recruited. Purdue Pegboard Test, Jarmar hand dynamometer, 30-Second Arm Curl Test, Jebsen-Taylor Hand Function Test, and the Late-Life Function and Disability Instrument were administered to assess manual dexterous coordination, grip strength, arm curl strength, timed-based hand function, and self-report of hand function, respectively.

**Results:** Eighty-four adults (mean age = 72 years) completed the study. Hierarchical multiple regressions show that older adults with better arm curl strength ($\beta = -.25$, $p < .01$) and manual dexterous coordination ($\beta = -.52$, $p < .01$) performed better on the timed-based hand function test. In comparison, older adults with better grip strength ($\beta = .40$, $p < .01$) arm curl strength ($\beta = .23$, $p < .05$) and manual dexterous coordination ($\beta = .23$, $p < .05$) were associated with better self-report of upper extremity function.

**Conclusions:** The relationship between grip strength and hand function may be test-specific. Grip strength becomes a significant factor when the test requires grip strength to successfully complete the test tasks. Arm curl strength independently contributed to hand function in both timed-based and self-report assessments, indicating that strength of extrinsic muscles of the hand are essential for hand function.

**Keywords:** arm strength, grip strength, hand function, aging, fine motor coordination

## Introduction

Age-related decline in neuromuscular function impedes performance of daily tasks [1,2]. For example, the decline in muscle strength of the lower extremity and gait speed are associated with disability in activities of daily living and mobility limitation for older adults [3,4]. While considerable effort has been directed toward understanding and attenuating age-related functional decline of the lower extremity [5-9], the relationship between aging and functional decline of the upper extremity has received relatively less attention.

Lower extremity and upper extremity roles differ in relation to performing activities of daily living. The major role of the lower extremity is specialized for gross motor actions related to mobility, such as kneeling down, sitting down, standing up, walking, running, and climbing. In contrast, the primary role of upper extremity is geared toward strategic positioning of hands for carrying, lifting, pushing, pulling, handling and manipulating daily objects. Fifteen extrinsic muscles and 11 intrinsic muscles are associated with hand function [1]. Extrinsic muscles directly contribute to the gross motor motion of the upper extremity and gripping force, while intrinsic muscles regulate fine motor coordination of the digits [10]. As with the lower extremity, aging affects muscle strength of the upper extremity [11], with the decline rate of strength being more pronounced in intrinsic muscles than in extrinsic muscles [12,13].

In addition to losing muscle strength with age, older adults have poor force control [14]. Force control includes scaling and calibrating force while picking up, transporting, and unloading objects. Grasp in older adults is characterized by excessive grip force [14] as they generate more force to grasp objects compared to young adults [15]. This characteristic of poor force control could lead to premature fatigue or difficulty in manipulating objects. Force control may be as important as grip strength to older adults because most daily objects require the correct amount of force to maneuver; not maximum force. Moreover, aging has an adverse effect on steadiness [16] with older adults having less control of force output. Steadiness is defined as the ability to exert a constant submaximal force, and it is more strongly associated with fine motor coordination and precision than is grip strength [17]. In summary, the literature suggests that hand function in older adults is influenced by three factors: force generation (muscle strength); force need (force control); and force consistency (steadiness).

Both cross-sectional and longitudinal data indicate that hand function declines with age [18,19]. Timed-based assessments are often used in these studies to measure how long it takes for older adults to complete tasks such as opening and closing various fasteners; or to turn over index cards. Specifically, older adults with lower socioeconomic status, advanced age, more joint impairments, and lower grip strength tend to have poor hand function [20]. In other words, they took longer to complete these tasks. While the contribution of grip strength to hand function is statistically significant, it only explains a small portion of the variance compared to socioeconomic status [20]. A more recent study has found that grip strength explains more variance than age in aiming and tapping dexterity tasks [21]. These findings indicate that hand grip strength is associated directly with fast and precise coordinated hand and upper extremity movements. Additionally, factors other than physical attributes may affect hand function.

Similar to the decline in mobility, the decline in hand function relates to dependency in activities of daily living in older adults [22,23]. Therefore, hand function has the potential to serve as an alternative marker of disability in activities of daily living for older adults, in addition to mobility limitation. Further, examining factors related to the decline in hand function in the older adult population may yield useful information to reduce age-related disability.

Interestingly, self-report hand function has rarely been included in the literature on muscle strength and hand function. Self-report hand function measures the degree to which older adults perceive use of their hands, which may offer a different dimension of hand function than timed-based assessments. The purpose of this study was to add to current research knowledge regarding muscle strength and hand function in geriatric populations through analysis of self-report of hand function in addition to traditionally utilized grip and dexterity assessments. Specifically, this study investigated how muscle strength and manual dexterous coordination would contribute to timed-based assessment of hand function versus self-report hand function.

## Methods

A cross-sectional, correlational research design was used for this study. Indiana University Institutional Review Board approved the study protocol. Participants were recruited from congregate meal services sites of the Area Agencies on Aging or senior affordable housing communities located in the Indianapolis metropolitan area between October 2013 and August 2015. Recruitment methods included face-to-face onsite contact, word of mouth, and flyers.

### Participant eligibility criteria

Participants who were English speaking and 60 years of age and above were eligible for the study. Participants were excluded if they could not provide consent, had low vision, or had major neurological diseases (e.g., Parkinson's disease and stroke) that could affect hand movements. Exclusion criteria were based on self-reported information.

### Study procedure

The study was conducted in a common room at the meal services site or housing community. A trained research assistant obtained consent information from all participants before data collection. A brief interview was conducted first to gather demographic information and the Body Mass Index. Next, a series of tests using the Purdue Pegboard Test, Jebsen-Taylor Hand Function Test, Jamar hand dynamometer, Late-Life Function and Disability Instrument, and 30-Second Arm Curl Test were conducted to measure participants' hand dexterity and coordination, timed-based hand function performance, grip strength, self-report hand function, and arm curl strength, respectively. Data collection lasted about 25 to 30 minutes for each participant. Upon completion, each participant received a $5 gift card as compensation for the time in the study.

## Assessments

### Independent variables.

***Grip strength.*** A Jamar® hydraulic hand dynamometer (Lafayette Instrument Company) was used to measure grip strength of the dominant hand. The dynamometer was calibrated using Fess' method [24]. The participant was tested in the seated position with elbow flexed at 90 degrees. The handle position was adjusted to fit the participant's hand. The participant was asked to squeeze the dynamometer at maximal effort for three trials, with a 30-second break between each trial. The average of three trials was calculated for data analysis.

***30-Second Arm Curl Test.*** The 30-Second Arm Curl Test, part of the Senior Fitness Test [25], was used to measure muscle strength of the upper extremity. Criterion validity using integrated upper extremity muscles has been established [26]. A 5-pound dumbbell was used for women and an 8-pound dumbbell for men. The participant was tested in the seated positon. Following a brief demonstration and practice, the participant was asked to hold the dumbbell in the dominant hand and perform arm curl movements as quickly as he/she could in 30 seconds. The number of completed movements was recorded.

***Purdue Pegboard Test.*** The single hand test was selected from the Purdue Pegboard Test to measure hand dexterity and coordination [27]. Psychometric properties of this test have been established in adults and older adults [28,27]. The test was administered on a rectangular board. Twenty-five holes aligned vertically on each side. Small metal pegs were placed in a concave cup at the top of the board on the side of the hand being tested, which was the participant's dominant hand. The participant was asked to pick up pegs one at time from the concave cup and place the pegs in the holes aligning on the same side of the cup. A 15-second practice trial was provided prior to formal testing. The number of pegs placed in 30 seconds was recorded for three 30-second trials. The average of three trials was calculated for data analysis.

**Dependent variables.**

***Jebsen-Taylor Hand Function Test.*** The Jebsen-Taylor Hand Function Test is a standardized, performance-based measure assessing daily function of the upper extremities [29]. The participant performed the following seven subtests in the seated position: 1) writing, 2) card turning, 3) moving small common objects, 4) simulated feeding, 5) stacking checkers, 6) moving light objects, and 7) moving heavy objects. In the writing subtest, the participant was asked to write down a sentence which was presented to him/her. In the subtest of card turning, the participant was asked to turn over five 3x5" index cards. In the subtest of moving small common objects, the participant was asked to pick up two pennies, two bottle caps, and two paper clips one at a time and place them in a can. In the subtest of simulated feeding, the participant was asked to use a spoon to pick up five kidney beans one at a time and place the bean in a can. In the subtest of stacking checkers, the participant was asked to stack four checkers, one on top of the other. In the subtest of moving light objects, the participant was asked to move five empty cans one at a time upon to a ¾-inch board. In the subtest of moving heavy objects, the participant was asked to move five full cans one at a time upon to the same ¾-inch board. Each participant was instructed to perform each subtest as quickly as he or she could using the dominant hand. Time to complete each subtest was recorded. The psychometric properties of the Jebsen-Taylor Hand Function Test have been established in the adult and older adult populations [19,29].

***Late-Life Function and Disability Instrument.*** Seven items measuring self-report of upper extremity function were selected from the Late-Life Function and Disability Instrument [30,31]. These seven items assess how much difficulty that the participant had while: 1) unscrewing the lid off a previously unopened jar without using any devices; 2) putting on and taking off long pants, including managing fasteners; 3) using common utensils for preparing meals, such as can opener, potato peeler, or sharp knife; 4) holding a glass full of water in one hand; 5) reaching behind his/her back as if to put a belt through a belt loop; 6) ripping open a package of snack food, such as cellophane wrapping on crackers, using only his/her hands; and 7) pouring from a large pitcher. The participant answered each question with five response choices: "none," "a little," "some," "quite a lot," or "cannot do." The total raw scores were transformed to 0 to 100 scaled scores, with a higher score indicating better hand function.

## Results

Eighty-four participants completed the study. IBM SPSS Statistics 23 was used to analyze the data. Table 1 shows the descriptive information on demographics and measurement results. Thirty-seven participants were between 61 and 69 years old; 31 were between 70 and 79 years old; and 16 were 80 years old or above. Seventy-six participants (91%) reported that they were right handed, and the rest were left handed. Among the 52 participants with arthritis, 25 indicated that arthritis affected their hand movements. Participants with arthritis who reported that their hand movements were not affected by the condition were similar to those who were affected in age, the Purdue Pegboard single hand test, the 30-Second Arm Curl Test, and the Jebsen-Taylor Hand Function Test. The only exception was the self-report of upper extremity function from the Late-Life Function and Disability Instrument, ($M_{\text{not affected}} = 74.66$, $M_{\text{affected}} = 64.54$), $t(50) = - 2.96$, $p < .01$.

Table 2 shows the correlation matrix among continuous variables. A better performance on the Jebsen-Taylor Hand Function Test (i.e. less in total time) was associated with higher educational attainment, $r = -.35$, $p < .01$, stronger grip strength, $r = -.25$, $p < .05$, more arm curls completed in 30 seconds, $r = -.37$, $p < .01$, and more pegs completed in the Purdue Pegboard single hand test, $r = -.60$, $p < .01$. Similarly, a better self-report of upper extremity function of the Late-Life Function and Disability Instrument was associated with stronger grip strength, $r = .58$, $p < .01$, more arm curls completed in 30 seconds, $r = .40$, $p < .01$, and more pegs completed in the Purdue Pegboard single hand, $r = .24$, $p < .05$.

Two sets of hierarchical multiple regression models were conducted to predict performance on the: 1) Jebsen-Tylor Hand Function Test, and 2) self-report upper extremity function of the Late-Life Function and Disability Instrument. Predictors were entered into the model as blocks in the following order: 1) the first block included variables of the demographic information of age, years of education, race (White versus non-White), and gender (male versus female); 2) the second block included the information on impaired hand movements (affected or not affected by arthritis); 3) the third block included the variable of grip strength; 4) the fourth block included the variable of 30-Second Arm Curl Test; and 5) the fifth block included the variable of the Purdue Pegboard single hand test. Blocks 3 and 4 were entered first to account for the variance from muscle strength (grip strength and arm curl strength) before entering the final block of hand dexterity and coordination. Table 3 shows results of the hierarchical multiple regressions including R-squared values and standardized coefficients. Scatterplots of the standardized residuals and predicted values support that the assumptions of linearity and homogeneity of variance were met. Collinearity diagnoses showed the predictor variables were moderately independent among each other for all different performance indices.

The final saturated model of predicting performance of the Jebsen-Taylor Hand Function Test was significant, $F(8,69) = 9.67$, $p < .01$. Higher educational attainment, $t = -2.01$, $p < .05$, or having hand movements affected by arthritis, $t = -2.19$, $p < .05$, was associated with less time on the Jebsen-Taylor Hand Function Test. After controlling for the variance of demographic information and whether hand movements were affected by arthritis, participants with better performance on the 30-Second Arm Curl Test, $R^2$ change = .10, and Purdue Pegboard single hand test, $R^2$ change = .23, were associated with better Jebsen-Tylor Hand Function results.

The final saturated model of predicting performance of the self-report upper extremity function of the Late-Life Function and Disability Instrument was significant, $F(8,69) = 7.79$, $p < .01$. Having hand movements affected by arthritis, $t = -2.21$, $p < .05$, was associated with poor self-report upper extremity function of the Late-Life Function and Disability Instrument. After controlling for the variance of demographic information and whether hand movements were affected by arthritis, participants with better grip strength, $R^2$ change = .16, 30-Second Arm Curl, $R^2$ change = .06, and Purdue Pegboard single hand test, $R^2$ change = .04, were associated with better self-report of upper extremity function.

## Discussion

The current study examined predictors of timed-based and self-report hand function assessments measured by the Jebsen-Taylor Hand Function Test and Late-Life Function and Disability Instrument respectively. Grip strength, arm curl strength, and manual dexterous coordination were examined as predictors in addition to demographics and hand movement impairments. Key findings include that grip strength was related to self-report hand function but not timed-based. Moreover, arm curl strength and manual dexterous coordination were related to both types of hand function assessments.

Prior research has shown that socioeconomic status contributes to differences in hand function in older adults more than physical attributes [20]. Despite socioeconomic homogeneity of our current study participants, we found that educational attainment was related to timed-based hand function performance. Participants with fewer years of education were slower to complete the Jebsen-Taylor Hand Function Test than those with more years of education. Among the seven subtests of Jebsen-Taylor Hand Function Test, the writing task seems to be the most relevant factor to educational attainment. A post-hoc analysis of correlation supports this concept. A Spearman's rho correlation between the educational attainment and the writing subtest was -.46 ($p < .01$), while the relationships between the educational attainment and other subtests were not significant (all $p_s > .05$).

Grip strength, arm curl strength, and manual dexterous coordination predict self-report hand function as measured by the Late-Life Function and Disability Instrument. Among the three predictors, grip strength accounted for the most variance of the outcome. Grip strength has been used as an indicator for global functional deterioration in older adults [32-34]. Weak grip strength signifies risk of late-life disability for activities of daily living. Surprisingly, grip strength did not predict the timed-based hand function assessment as measured by the Jebsen-Taylor Hand Function Test. These findings may suggest that the significance of grip strength may be test-specific. Four out of seven questions in the Late-Life Function and Disability Instrument (open a new jar, hold a glass full of water, rip open a snack package, pouring from a large pitcher) involve functional use of maximum grip strength. In contrast, only one out of seven subtests in the Jebsen-Taylor Hand Function Test (moving heavy objects which are five 15-ounce cans) measures the functional use of maximum grip strength.

Conversely, the significance of grip strength may depend on whether a hand function measure is timed-based or not. Our finding shows that grip strength accounted for only a small portion of variance predicting timed-based hand function performance. The small variance may indicate that most daily life tasks do not require maximum grip strength. In picking up coins, turning cards, using a spoon or other subtests required by the Jebsen-Taylor Hand Function Test, force control and steadiness (to maintain submaximal force) may be more critical than maximal force. An alternative interpretation is that other predictors share more similar testing characteristics with the timed-based hand function test than does the grip strength test. Assessments used to evaluate arm curl strength (30-Second Arm Curl Test) and manual dexterous coordination (Purdue Pegboard single hand test) in this study are both timed tests. For example, more arm curls completed within a 30-second period indicates better arm curl strength. Consequently, timed-based measurements may detect the common factor of age-related slowing in motor response [35].

Many motor performance assessments record time or speed to indicate the degree of outcome—usually faster is better. The premise of these assessments is that impairments which may interfere with motor performance (e.g., limited range of motion, pain, and deformities) will result in slowness to complete the assessment. While this premise is correct in most cases, our study found an opposite result. Participants whose movements were affected by arthritis reported worse hand function than those who did not; but they were faster in completing the Jebsen-Taylor Hand Function Test than those whose movements are not affected by arthritis. Older adults who experience impaired movements related to arthritis may sacrifice quality in favor of speed since test instructions required them to complete each task as quickly as they could. Some subtests did not emphasize quality of the results. For example, the card turning subtest instruction was "*turn cards over in any way you wish and the cards do not need to be in a neat pattern when finished*." This may be a caveat to using timed-based performance test if the quality aspect of performance is not taken into consideration. In real life, these older adults may also adopt the strategy of "getting it done as quickly as possible," resulting in poor task outcome such as spilling water from a pouring task or tearing paper while turning a page of a book for reading.

Older adults tend to have poor force control or steadiness [14,15,17]. Compared to young adults, older adults readjust their hand position on the grasped object more often and demonstrate greater variations in their prehension patterns, such as tripod pinch or lateral pinch, when retrieving coins from a purse of pouring milk from a container [36]. After controlling the factor of affected movements due to arthritis, participants with stronger arm curl strength and better manual dexterous coordination used less time to complete the subtests of Jebsen-Taylor Hand Function Test than those with weaker arm curl strength and poor manual dexterous coordination. A main function of arm is to provide stability and mobility to position the hand for dexterous tasks. In addition to being slower, older adults with weaker arm curl strength and poor manual dexterous coordination may be clumsier, which may lead to the need for subtle reposition or adjustments, resulting in longer task time.

One limitation of this study is that sensory changes in older adults were not assessed. Sensation deteriorates with age, for example, the distance of two-point discrimination on the index finger tip becomes wider with increasing age [16]. Although sensory input seems essential for small object manipulation, research has found that impairments in tactile sensibility do not adversely affect manual tasks in older adults [37]. Healthy older adults typically do not have severe tactile deficits to the degree to impair manual dexterity. However, disease-related sensory loss such as neuropathy in older adults may affect hand function more drastically.

## Conclusions

In comparison to prior research on aging and hand function, our study identified new information. First, the relationship between grip strength and hand function is test-specific. Grip strength becomes a significant factor when test require grip strength to successfully complete the test tasks. Second, in addition to grip strength, arm curl strength independently contributes to hand function in both timed-based and self-report assessments. Hand function relies on coordinated extrinsic and intrinsic muscles to provide mobility, stability, and dexterity. This finding highlights the important influence of extrinsic muscles, as measured by arm curl strength, on hand function. Lastly, a timed-based assessment measures only one dimension of motor performance, which is speed. Older adults may compensate impaired movements with speed instead of slowing down. Results from timed-based assessments need to be interpreted with caution.

**Acknowledgement**

Portion of the results had been presented in a poster format at [redacted].

On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Carmeli E, Patish H, Coleman R (2003) The aging hand. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 58 (2):M146-M152. doi:10.1093/gerona/58.2.M146

2. Janssen I, Heymsfield SB, Ross R (2002) Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. Journal of the American Geriatrics Society 50 (5):889-896. doi:10.1046/j.1532-5415.2002.50216.x

3. Vermeulen J, Neyens JC, van Rossum E, Spreeuwenberg MD, de Witte LP (2011) Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. BMC Geriatr 11:33. doi:10.1186/1471-2318-11-33

4. Visser M, Goodpaster BH, Kritchevsky SB, Newman AB, Nevitt M, Rubin SM, Simonsick EM, Harris TB (2005) Muscle mass, muscle strength, and muscle fat infiltration as predictors of incident mobility limitations in well-functioning older persons. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 60 (3):324-333. doi:10.1093/gerona/60.3.324

5. Puthoff ML, Nielsen DH (2007) Relationships among impairments in lower-extremity strength and power, Functional limitations, and disability in older adults. Physical Therapy 87 (10):1334-1347. doi:10.2522/ptj.20060176

6. Purser JL, Weinberger M, Cohen HJ, Pieper CF, Morey MC, Li T, Williams GR, Lapuerta P (2005) Walking speed predicts health status and hospital costs for frail elderly male veterans. Journal of Rehabilitation Research and Development 42:535-546. doi:10.1682/JRRD.2004.07.0087

7. Hirvensalo M, Rantanen T, Heikkinen E (2000) Mobility difficulties and physical activity as predictors of mortality and loss of independence in the community‐living older population. Journal of the American Geriatrics Society 48 (5):493-498. doi:10.1111/j.1532-5415.2000.tb04994.x

8. Rosso AL, Taylor JA, Tabb LP, Michael YL (2013) Mobility, disability, and social engagement in older adults. J Aging Health 25 (4):617-637. doi:10.1177/0898264313482489

9. Pahor M, Guralnik JM, Ambrosius WT, Blair S, Bonds DE, Church TS, Espeland MA, Fielding RA, Gill TM, Groessl EJ, King AC, Kritchevsky SB, Manini TM, McDermott MM, Miller ME, Newman AB, Rejeski WJ, Sink KM, Williamson JD, investigators Ls (2014) Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial. JAMA 311 (23):2387-2396. doi:10.1001/jama.2014.5616

10. Long C, Conrad P, Hall E, Furler S (1970) Intrinsic-extrinsic muscle control of the hand in power grip and precision handling. J Bone Joint Surg Am 52 (5):853-867

11. Metter EJ, Conwit R, Tobin J, Fozard JL (1997) Age-associated loss of power and strength in the upper extremities in women and men. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 52 (5):B267-B276. doi:10.1093/gerona/52A.5.B267

12. Shinohara M, Latash ML, Zatsiorsky VM (2003) Age effects on force produced by intrinsic and extrinsic hand muscles and finger interaction during MVC tasks. J Appl Physiol 95 (4):1361-1369. doi:10.1152/japplphysiol.00070.2003

13. Hsu J (2009) Aging Related Differences in Hand Intrinsic and Extrinsic Muscles for Hand Dexterity: An MRI Investigation. University of Maryland, College Park, MD

14. Diermayr G, McIsaac TL, Gordon AM (2011) Finger force coordination underlying object manipulation in the elderly–a mini-review. Gerontology 57 (3):217-227. doi:10.1159/000295921

15. Galganski ME, Fuglevand AJ, Enoka RM (1993) Reduced control of motor output in a human hand muscle of elderly subjects during submaximal contractions. Journal of Neurophysiology 69 (6):2108-2115

16. Ranganathan VK, Siemionow V, Sahgal V, Yue GH (2001) Effects of aging on hand function. Journal of the American Geriatrics Society 49 (11):1478-1484. doi:10.1046/j.1532-5415.2001.4911240.x

17. Marmon AR, Pascoe MA, Schwartz RS, Enoka RM (2011) Associations among strength, steadiness, and hand function across the adult life span. Medicine and science in sports and exercise 43 (4):560-567. doi: 10.1249/MSS.0b013e3181f3f3ab

18. Desrosiers J, Hébert R, Bravo G, Rochette A (1998) Comparison of cross-sectional and longitudinal designs in the study of aging of upper extremity performance. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 53 (5):B362-B368. doi:10.1093/gerona/53A.5.B362

19. Hackel ME, Wolfe GA, Bang SM, Canfield JS (1992) Changes in hand function in the aging adult as determined by the Jebsen Test of Hand Function. Physical Therapy 72 (5):373-377

20. Hughes SL, Gibbs J, Edelman P, Singer R, Chang RW (1992) Joint impairment and hand function in the elderly. Journal of the American Geriatrics Society 40 (9):871-877. doi:10.1111/j.1532-5415.1992.tb01982.x

21. Martin JA, Ramsay J, Hughes C, Peters DM, Edwards MG (2015) Age and grip strength predict hand dexterity in adults. PloS one 10 (2). doi:10.1371/journal.pone.0117598

22. Falconer J, Hughes SL, Naughton BJ, Singer R, Chang RW, Sinacore JM (1991) Self report and performance-based hand function tests as correlates of dependency in the elderly. Journal of the American Geriatrics Society 39 (7):695-699. doi:10.1111/j.1532-5415.1991.tb03624.x

23. Incel NA, Sezgin M, As I, Cimen OB, Sahin G (2009) The geriatric hand: correlation of hand-muscle function and activity restriction in elderly. International Journal of Rehabilitation Research 32 (3):213-218. doi:10.1097/MRR.0b013e3283298226

24. Fess EE (1987) A method for checking Jamar dynamometer calibration. Journal of Hand Therapy 1 (1):28-32. doi:10.1016/S0894-1130(87)80009-1

25. Rikli RE, Jones CJ (1999) Development and validation of a functional fitness test for community-residing older adults. Journal of aging and physical activity 7:129-161

26. Rikli RE, Jones CJ (2013) Test validity, reliability, percentile norms, and criterion-referenced standards. In: Senior Fitness Test Manual. 2nd edn. Human Kinetics, Champaign, IL,

27. Tiffin J, Asher EJ (1948) The Purdue Pegboard: norms and studies of reliability and validity. Journal of Applied Psychology 32 (3):234. doi:10.1037/h0061266

28. Desrosiers J, Hebert R, Bravo G, Dutil E (1995) The Purdue Pegboard Test: Normative data for people aged 60 and over. Disability & Rehabilitation 17 (5):217-224. doi:10.3109/09638289509166638

29. Jebsen RH, Taylor N, Trieschmann R, Trotter MJ, Howard LA (1969) An objective and standardized test of hand function. Archives of physical medicine and rehabilitation 50 (6):311-319

30. Beauchamp MK, Schmidt CT, Pedersen MM, Bean JF, Jette AM (2014) Psychometric properties of the Late-Life Function and Disability Instrument: A systematic review. BMC Geriatrics 14 (1):12. doi: 10.1186/1471-2318-14-12

31. Haley SM, Jette AM, Coster WJ, Kooyoomjian JT, Levenson S, Heeren T, Ashba J (2002) Late Life Function and Disability Instrument II. Development and evaluation of the function

component. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 57 (4):M217-M222. doi:10.1093/gerona/57.4.M217

32. McGee CW, Mathiowetz V (2003) The relationship between upper extremity strength and instrumental activities of daily living performance among elderly women. OTJR: Occupation, Participation and Health 23 (4):143-154. doi:10.1177/153944920302300402

33. Al Shin S, Markides KS, Ottenbacher KJ, Raji MA (2004) Hand grip strength and incident ADL disability in elderly Mexican Americans over a seven-year period. Aging Clin Exp Res 16 (6):481-486. doi:10.1007/BF03327406

34. Giampaoli S, Ferrucci L, Cecchi F, Lo Noce C, Poce A, Dima F, Santaquilani A, Vescio MF, Menotti A (1999) Hand-grip strength predicts incident disability in non-disabled older men. Age and Ageing 28 (3):283-288. doi:10.1093/ageing/28.3.283

35. Falkenstein M, Yordanova J, Kolev V (2006) Effects of aging on slowing of motor-response generation. International Journal of Psychophysiology 59 (1):22-29. doi:10.1016/j.ijpsycho.2005.08.004

36. Shiffman LM (1992) Effects of aging on adult hand function. American Journal of Occupational Therapy 46 (9):785-792. doi:10.5014/ajot.46.9.785

37. Cole K, Rotella DL, Harper JG (1998) Tactile impairments cannot explain the effect of age on a grasp and lift task. Exp Brain Res 121 (3):263-269. doi:10.1007/s002210050459

Table 1.

Descriptive Information on the Demographics and Measurements of Upper Extremity and Hand Function.

| Measure | *Mean* or *n* | *SD* or *%* |
|---|---|---|
| Age (year) | 72.01 (mean) | 6.90 (*SD*) |
| Gender | | |
| Female | 69 (*n*) | 82 (*%*) |
| Race | | |
| Caucasian | 34 (*n*) | 41 (*%*) |
| African American | 46 (*n*) | 55 (*%*) |
| Asian or two or more | 4 (*n*) | 5 (*%*) |
| Arthritis | 52 (*n*) | 62 (*%*) |
| Years of education | 13.09 (mean) | 2.53 (*SD*) |
| Body Mass Index | 30.35 (mean) | 6.62 (*SD*) |
| Grip strength (pound) | 20.80 (mean) | 9.22 (*SD*) |
| 30-Second Arm Curl (count)[a] | 13.48 (mean) | 3.69 (*SD*) |
| Purdue Pegboard Test: single hand (second) | 14 (mean) | 10.22 (*SD*) |
| Late-Life Function and Disability Instrument: upper extremity function (score) | 71.26 (mean) | 14.61 (*SD*) |
| Jebsen-Taylor Hand Function Test (second) | | |
| Total | 66.61 (mean) | 14.22 (*SD*) |
| Writing | 20.48 (mean) | 8.63 (*SD*) |
| Card turning | 7.17 (mean) | 2.12 (*SD*) |
| Moving small common objects | 10.45 (mean) | 2.65 (*SD*) |
| Simulated feeding | 10.62 (mean) | 2.32 (*SD*) |
| Stacking checkers | 6.65 (mean) | 1.51 (*SD*) |
| Moving light objects | 5.61 (mean) | 1.24 (*SD*) |
| Moving heavy objects | 5.64 (mean) | 1.34 (*SD*) |

a. $n = 81$.

Table 2.

Intercorrelations for Two Measures of Hand Functions with Age, Years of Education, Body Mass Index, Purdue Pegboard Single Hand, Grip Strength, and 30-Second Arm Curl Test.

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. Jebsen-Taylor Hand Function Test | -- | | | | | | |
| 2. Self-report upper extremity function from the LLFDI | -.33** | -- | | | | | |
| 3. Age | .04 | -.17 | -- | | | | |
| 4. Years of education | -.35** | .11 | -.02 | -- | | | |
| 5. Body mass index | .04 | .03 | -.18 | -.01 | -- | | |
| 6. Grip strength | -.25* | .58** | -.22* | .03 | .05 | -- | |
| 7. 30-Second Arm Curl | -.37** | .40** | -.08 | .16 | -.05 | .22* | -- |
| 8. Purdue Pegboard (single hand) | -.60** | .24* | .09 | .21 | -.11 | .05 | .16 |

*Note.* LLFDI- Late-Life Function and Disability Instrument. *$p < .05$. **$p < .01$.

Table 3.

Hierarchical Regression Analysis Predicting Time-Based Hand Function Test and Self-Reported Upper Extremity Function.

| | Jebsen-Taylor Hand Function Test | | | Self-reported upper extremity function from LLFDI | | |
|---|---|---|---|---|---|---|
| Step and Predicting variable | $R^2$ | $\Delta R^2$ | $\beta$[b] | $R^2$ | $\Delta R^2$ | $\beta$[b] |
| Step 1 | .13* | .13* | | .17** | .17* | |
| Age | | | .08 | | | -.05 |
| Years of education | | | -.19* | | | -.04 |
| Race | | | -.01 | | | -.003 |
| Gender | | | -.12 | | | .11 |
| Step 2 | .15* | .02 | | .21** | .05* | |
| Hand movements affected by arthritis | | | -.19* | | | -.20* |
| Step 3 | .21* | .06* | | .37** | .16** | |
| Grip strength | | | -.11 | | | .40** |
| Step 4 | .30** | .10** | | .43** | .06** | |
| 30-Second Arm Curl | | | -.25** | | | .23* |
| Step 5 | .53** | .23** | | .48** | .04* | |
| Purdue Pegboard single hand | | | -.52** | | | .23* |

*Note.* LLFDI- Late-Life Function and Disability Instrument. [b] Estimations were from the final saturated regression model. *$p$ < .05.

**$p$ < .01.