The Gerontologist
Cite journal as: The Gerontologist Vol. 53, No. 2, 255–267
doi:10.1093/geront/gns071

Advance Access publication May 20, 2012

Development and Validation of Criterion-Referenced Clinically Relevant Fitness Standards for Maintaining Physical Independence in Later Years

Roberta E. Rikli, PhD*,[1] and C. Jessie Jones, PhD[2]

[1]Department of Kinesiology, College of Health and Human Development, California State University, Fullerton.
[2]Department of Health Science, California State University, Fullerton.

*Address correspondence to Roberta E. Rikli, PhD, College of Health and Human Development, California State University, Fullerton, EC-646, 800 N. State College Blvd., Fullerton, CA 92834. E-mail: rrikli@fullerton.edu

Received February 28, 2012; Accepted April 20, 2012
Decision Editor: Rachel Pruchno, PhD

Purpose: To develop and validate criterion-referenced fitness standards for older adults that predict the level of capacity needed for maintaining physical independence into later life. The proposed standards were developed for use with a previously validated test battery for older adults—the Senior Fitness Test (Rikli, R. E., & Jones, C. J. (2001). Development and validation of a functional fitness test for community-residing older adults. Journal of Aging and Physical Activity, 6, 127–159; Rikli, R. E., & Jones, C. J. (1999a). Senior fitness test manual. Champaign, IL: Human Kinetics.). ***Methods:*** A criterion measure to assess physical independence was identified. Next, scores from a subset of 2,140 "moderate-functioning" older adults from a larger cross-sectional database, together with findings from longitudinal research on physical capacity and aging, were used as the basis for proposing fitness standards (performance cut points) associated with having the ability to function independently. Validity and reliability analyses were conducted to test the standards for their accuracy and consistency as predictors of physical independence. ***Results:*** Performance standards are presented for men and women ages 60–94 indicating the level of fitness associated with remaining physically independent until late in life. Reliability and validity indicators for the standards ranged between .79 and .97. ***Implications:*** The proposed standards provide easy-to-use, previously unavailable methods for evaluating physical capacity in older adults relative to that associated with physical independence. Most importantly, the standards can be used in planning interventions that target specific areas of weakness, thus reducing risk for premature loss of mobility and independence.

Key Words: Assessment, Strength, Aerobic endurance, Agility/dynamic balance, Mobility, Physical fitness

With the projected increase in the number and percentage of older adults throughout much of the world, it is critical for both economic and personal reasons that this large segment of the population remains healthy and independent for as long as possible. A key factor in preserving mobility and independence in later years is maintaining the fitness capacity (e.g., strength, endurance, agility, and balance) needed to perform normal everyday activities—to do simple housework, climb steps, lift and carry objects, get in and out of chairs or transportation vehicles, and walk far enough in and around stores, buildings, and parking lots to do one's own shopping and errands (Macaluso & De Vito, 2004; Morey, Pieper, & Cornoni-Huntley, 1998; Paterson & Warburton, 2010).

Unfortunately, limited information is available regarding the fitness level needed for maintaining physical independence. The few studies published regarding threshold requirements for independent living primarily have involved laboratory-based measures, such as maximum oxygen uptake, peak oxygen consumption, or maximum muscle torque (Cress & Meyer, 2003; Fleg et al., 2005; Goodpaster et al., 2006), measures that provide important information for the scientific community but which are not well understood or easily interpreted by most health professionals, program leaders, or by older adults themselves.

The purpose of this research was to establish reliable and valid criterion fitness standards (performance cut points) for five items in a previously validated easy-to-use field test of functional fitness for older adults—the Senior Fitness Test (SFT; Rikli & Jones, 1999a, 2001, in press), standards that indicate the strength, endurance, agility, and dynamic balance associated with maintaining physical independence into later life. Criterion standards are not being proposed at this time for two flexibility items on the SFT as there is insufficient evidence documenting the relationship between measures of flexibility and improved functional ability (Fiatarone Singh, 2002; Paterson, Jones, & Rice, 2007).

To our knowledge, this is the first attempt to develop criterion standards for a comprehensive fitness test battery for older adults, standards that address the key physiological variables needed for independent functioning. Although mobility and physical independence can be attained in a variety of ways (through use of assistive technologies, public transportation, etc.) and is influenced by multiple factors—cognitive, psychosocial, physical, environmental, and financial (Webber, Porter, & Menec, 2010), the focus of this research is on physiological capacity. Specifically, physical independence is defined as having the physical capacity needed to perform common everyday activities on one's own without additional assistance, activities such as simple housework, lifting and carrying objects, negotiating steps, and walking far enough to do one's own shopping and errands.

Background Information

Senior Fitness Test

In response to the need for valid field-based (nonlaboratory) measurement tools for assessing fitness parameters in older adults, Rikli and Jones (1999a, 1999b) developed a comprehensive functional fitness test battery that included normative performance standards based on a nation-wide study of 7,183 older Americans aged 60–94 years. Functional fitness was defined as "having the physiologic capacity to perform normal everyday activities safely and independently without undue fatigue" (1999a, p. 133).

As briefly described in Table 1, the test battery includes measures of strength, aerobic endurance, flexibility, and agility/dynamic balance. Each item was developed and validated as a means of assessing the underlying physical attributes that support functional mobility. Test–retest reliability for SFT items ranged from .80 to .98. Validity was established through various types of content and criterion analyses, including comparing SFT scores with other "gold standard" measures, such as treadmill VO_2 testing and one repetition maximum strength testing. The test battery, subsequently published as the SFT (Rikli & Jones, 2001, in press), has been widely used throughout the United States and in numerous other countries, with materials reproduced in several languages including Chinese, Danish, Korean, Japanese, Portuguese, and Spanish.

Because of its strong psychometric properties and ease of use, the SFT seemed especially well suited to serve as the basis for developing criterion standards of performance for older adults. The SFT utilizes continuous-scale scoring protocols that make it possible to assess gradual changes over time (improvement or decline) across a wide range of ability levels. Other popular field test measures, such as the single-item gait speed test and the Short Physical Performance Battery (SPPB) have been highly effective as predictors of disability risk, nursing home admittance, and survival rates in older adults (Cesari, 2011; Guralnik et al., 1994, 2000; Studenski et al., 2011), but they do not provide the kind of detailed information needed for evaluating specific aspects of physical fitness, information that is critical in developing interventions that target isolated areas of weakness. The SPPB, for example, utilizes an ordinal ranking system rather than continuous-scale scoring which limits its ability to detect gradual changes in individual performance. It also contains items that have been found to be too easy (side-by-side balance task) or too difficult (5-times chair stand) to be effective performance discriminators for up to 20%–50% of community-residing older adults (Guralnik et al., 1994; Seeman et al., 1994) and for as much as 75% of assisted living/residential care patients (Giuliani et al., 2008).

Table 1. Brief Descriptions of Senior Fitness Test Items

Assessment category	Test item	Test description
Lower body strength	30-s chair stand	Number of full stands in 30 s with arms folded across chest
Upper body strength	30-s arm curl	Number of bicep curls in 30 s holding hand weight (women 5 lb; men 8 lb)
Aerobic endurance	6-min walk or	Number of yards walked in 6 min around 50-yard course
	2-min step test (alternate aerobic test)	Number of full steps completed in 2 min, raising each knee to point midway between patella and iliac crest (score is number of times right knee reaches target)
Lower body flexibility	Chair sit-and-reach	From sitting position at front of chair, with leg extended and hands reaching toward toes, number of inches (+or −) from extended fingers to tip of toe
Upper body flexibility	Back scratch	With one hand reaching over shoulder and one up middle of back, number of inches between extended middle fingers (+ or −)
Agility/dynamic balance	8-foot up-and-go	Number of seconds required to get up from seated position, walk 8 foot, turn, and return to seated position on chair

Note: Full description of Senior Fitness Test items, formerly described as the Fullerton Functional Fitness Test, can be found in Rikli and Jones (1999a, 2001, in press).

Normative Versus Criterion-Referenced Performance Standards

The normative fitness standards (percentile tables) previously developed for the SFT make it possible for individuals to compare their performance with peers of their same age and gender. A 75-year-old male, for example, who receives a score of 15 on a particular test item, such as the chair stand test for lower body strength, could look at the percentile tables and see how he compared with others in his age group and know whether he had scored better or worse than any given percentage of his peers. What is not possible to determine, though, from normative standards is the level of fitness needed on an attribute (such as lower body strength) to maintain sufficient physical capacity to avoid being "at risk" for losing independence in later years. Although normative standards can be of personal interest to older adults, criterion standards are those of most use in providing researchers and practitioners with the kind of clinical information they need to evaluate fitness level relative to that required for maintaining physical independence.

Per Safrit and Wood (1995), "A criterion-referenced test is defined as a test with a predetermined standard of performance, with the standard tied to a specified domain of behavior" (p. 175). More specifically, criterion-referenced standards, which are typically more subjective and more complex to develop than norm-referenced standards, are those that connect a specific attribute such as lower body strength to that which is required to meet a particular performance goal, such as remaining physically independent (i.e., being able to perform normal everyday activities).

Because of the complexity involved with establishing criterion-referenced standards for performance tests, as becomes evident when reviewing the published work in this area much of which has centered on the nation's youth fitness testing programs (Cureton & Warren, 1990; Mahar & Rowe, 2008; Welk & Meredith, 2008), the process is usually an evolving one that extends over time. Once an initial set of standards are proposed, typically based on a combination of data-based statistics, literature review, and subjective reasoning, additional studies are needed to further confirm and refine the accuracy and appropriateness of the original standards.

Methods

The processes followed in establishing criterion-referenced fitness standards for older adults are consistent with previously published well-defined procedures (Baumgartner, Jackson, Mahar, & Rowe, 2007; Cureton & Warren, 1990; Mahar & Rowe, 2008; Morrow, Jackson, Disch, & Mood, 2011; Safrit & Wood, 1995), procedures that involve three major steps—(a) identifying an appropriate criterion measure to asses the goal of interest (physical independence, in this case), (b) setting the performance standards (fitness cut-point scores), and (c) testing the validity and reliability of the standards as predictors of the criterion goal (physical independence).

Step 1—Identifying an Appropriate Criterion Measure to Assess Physical Independence

In establishing criterion-referenced fitness standards for older adults, it is important to have a suitable method for assessing not only fitness level (which is the purpose of the SFT) but also the ultimate behavioral goal—ability to perform the everyday activities needed for maintaining physical independence. In this study, having the physical ability needed to live independently was assessed through self-report using the Composite Physical Function (CPF) scale, one that was developed based on an adaptation and extension of other previously published scales by Siu, Reuben, and Hays (1990), by Rosow and Breslau (1966), and with items also taken from the National Health Interview Survey (National Center for Health Statistics, 1991). The resulting 12-item CPF scale described in Table 2 is capable of assessing physical function across a wide range of abilities—from those associated with basic activities of daily living (ADLs such as dressing and bathing oneself) to instrumental or intermediate ADLs (such as housework and shopping) to

Table 2. Composite Physical Function (CPF) Scale

Instructions: Indicate your ability to do each of the following by circling appropriate response. Your response should indicate whether you "can do" these activities, not if you actually "do" the activities

	Can do on own without help	Can do with help	Cannot do
a. Take care of own personal needs—like dressing yourself	2	1	0
b. Bathe yourself, using tub or shower	2	1	0
c. Walk outside (1–2 blocks)	2	1	0
d. Do light household chores—like cooking, dusting, washing dishes, and sweeping a walkway	2	1	0
e. Climb up and down a flight of stairs	2	1	0
f. Do own shopping/errands (walk approximately 3–4 blocks; 400 yards)	2	1	0
g. Lift and carry 10 pounds (bag of groceries)	2	1	0
h. Walk 1/2 mile (6–7 blocks)	2	1	0
i. Walk 1 mile (12–14 blocks)	2	1	0
j. Lift and carry 25 pounds (medium to large suitcase)	2	1	0
k. Do heavy household activities—like scrubbing, floors, vacuuming, and raking leaves	2	1	0
l. Do strenuous activities—like hiking, digging in garden, moving heavy objects, bicycling, aerobic dance activities, strenuous calisthenics, etc.	2	1	0

Notes: CPF Rating Scale: High (advanced) functioning: those able to perform all 12 activities without assistance (CPF score of 24); Moderate functioning: those with current ability to perform at least seven activities (score of 14) without assistance, thus meeting commonly recognized requirements for physical independence–able to take care of personal needs, do light housework, walk three to four blocks, negotiate steps, do own shopping, etc.; and Low functioning (at risk): those unable to meet requirements for moderate functioning, thus indicating a person may be "at risk" for losing physical independence.

[a]Moderate functioning, "age-adjusted" scoring: Ages 90 and above: CPF score of 14 (able to perform at least seven activities without assistance), Ages 80–89: CPF score of 16 (able to perform at least eight activities without assistance), Ages 70–79: CPF score of 18 (able to perform at least nine activities without assistance), and Ages 60–69: CPF score of 20 (able to perform at least 10 activities without assistance). The age-adjusted (higher) scoring requirements for a moderate rating for those younger than 90 years are to allow for an anticipated decline in functional ability that is similar to the 10–15% commonly reported rate of physiological decline per decade in older adults, thus creating a standard for "moderate" functioning that reflects "projected" ability for independent functioning in later years (90+), rather than current ability to function independently. Table adapted from Rikli and Jones (1998).

advanced activities, such as strenuous sport, household, and exercise activities. Evidence supporting the test–retest reliability (R = .94) and validity of the CPF (Rikli & Jones, 1998) is consistent with other findings suggesting that self-report measures of functional ability generally are reliable and valid (Guralnik, Reuben, Buchner, & Ferrucci, 1995; Hoeymans, Wouters, Feskens, van den Bos, & Kromhout, 1997).

The CPF scale can be used to categorize individuals as "high (advanced) functioning," "moderate functioning," or as "low functioning" and "at risk" for loss of independence. High functioning are those who indicate that they can perform all 12 items on their own without assistance, thus receiving a perfect score of 24. Moderate functioning are those who can do, or depending on their age group, have the projected ability to do in later life a minimum of seven items on the CPF scale without assistance, thus meeting the usual requirements for physical independence (see additional discussion later). Low functioning individuals are those who do not meet the requirements for a rating of moderate, meaning that they have functional limitations in common everyday activities that may put them at risk for a possible loss of the ability to live independently in later life. For the purposes of this study, "later in life" was defined as age 90+, which seemed logical considering that average life expectancy at birth is nearing 80 years of age and close to 84 years for those who reach the age of 65 years (Administration on Aging, 2010).

Defining physical independence as having the ability to perform at least seven CPF activities without assistance is consistent with information reported elsewhere. It is commonly suggested that living independently requires such attributes as being able to dress and bathe oneself, do simple housework, negotiate steps, lift and carry 10 lbs, and walk at least three to four blocks (approximately 400 yards, far enough to walk from a parking area to stores and buildings as needed to do one's own shopping and errands; Cress, Petrella, Moore, & Schenkman, 2005; Siu et al., 1990; U.S. Department of Health and Human Services, 2006), with these being the kinds of activities that would have to be "checked-off" on the CPF scale in order to meet the minimum requirement for independent functioning.

However, with the goal being to develop criterion fitness standards that project one's ability to live independently until later life (age 90+), it is important that younger age groups (those in their 60s, 70s, and even 80s) have more stringent criteria than those in their 90s for being assessed as "moderate" functioning, criteria that are set high enough to allow younger older adults to experience normal age-related declines and not progress below the functional ability requirements for independent living at age 90. Therefore, knowing that age-related declines in physical capacity after the age of 50 or 60 are commonly reported to be at least 10%–15% per decade and that declines in physical capacity are associated with declines in functional ability (Macaluso & De Vito, 2004; Morey et al., 1998; Paterson et al., 2007; Vandervoort, 2002), it may be reasonable to assume (in the absence of better data) that performance on the CPF scale could likely decline at a somewhat similar 10%–15% rate per decade rate as does physical capacity. Based on this assumption, the age-adjusted scoring option for defining moderate functioning, as described in Table 2, was used in this study. Whereas a score of 14 (ability to perform a minimum of seven CPF activities without assistance) is required for a rating of moderate for those aged 90 years and older, higher scores of 20, 18, and 16, respectively, are needed in order for those in their 60s, 70s, and 80s to be rated as moderate functioning. Thus, both the definition of moderate functioning and its interpretation are adjusted for age. For those under the age of 90 years, a rating of moderate reflects *projected ability* for physical independence at age 90 rather than *current ability* to function independently. Those in their 60s, 70s, and 80s, then, who fail to achieve the appropriate age-adjusted requirement for a rating of moderate would be rated as "low functioning" for their age and may be at risk for loss of mobility and independence prior to age 90.

Step 2—Setting the Criterion Performance Standards (Cut-Point Scores) for SFT Test Items

As is typical in initially establishing criterion-based standards, a combination of processes involving subjective reasoning, data-based statistics, and literature review were utilized in arriving at the recommended fitness standards (cut-point scores) for the SFT test items, that is, fitness scores that would predict ability to function independently in later years. Stage 1 of the process involved making the decision to use scores from the previously published SFT normative data set as the initial starting point for setting the standards, particularly the fitness scores obtained by the 2,140 participants who met the age-adjusted criteria for having moderate functional ability as defined by the CPF. The normative SFT data set seemed especially appropriate for use in developing criterion performance standards for this population because it is, to our knowledge, the largest data set of its kind reflecting comprehensive measures of fitness for older adults and because it is based on a well-defined population of community-residing older adults. Demographic characteristics and SFT scores for normative study participants are described in Rikli and Jones (1999b). Table 3 presents the average fitness scores achieved by the 2,140 subset of moderate-functioning participants, scores that served as the initial basis for the ultimately proposed criterion performance standards.

Stage 2 of the standards-setting process involved converting the obtained scores from the normative database described earlier to recommended fitness standards, with adjustments made as appropriate to reflect other relevant information from the literature such as data indicating that a faster rate of physical decline is observed when performance is tracked over time from one age period to the next (i.e., measured longitudinally) versus when data are collected cross-sectionally (on different age groups at the same time). Thus, with the normative study data having been collected from cross-sectional age groups, adjustments were needed in converting these scores to recommended fitness standards, standards that would be set high enough to take into account the greater rate of decline expected when performance is tracked over time.

In past studies where both cross-sectional fitness data (baseline comparisons across age groups) and longitudinal data (scores collected over a period of time) were available on the same participants using the same measurement protocols, it was found that the average rate of physical decline measured longitudinally was approximately 1.25 times as great as when measured cross-sectionally (Bassey & Harries, 1993; Goodpaster et al., 2006; Hollenberg, Yang, Haight, & Tager, 2006; Jackson, Sui, Bebert, Church, & Blair, 2009; Kallman, Plato, & Tobin, 1990; Rantanen et al., 1998; Stathokostas, Jacob-Johnson, Petrella, & Paterson, 2004; Winegard, Hicks, Sale, & Vandervoort, 1996). Thus, in utilizing data from the SFT normative study to propose recommended fitness standards for various age groups, it was important to make adjustments that reflected the approximate 1.25 times greater rate of decline expected when performance is to be tracked over time. Because, in the studies reviewed, there was no evidence that the type of fitness measure (e.g., strength vs. aerobic) or gender (women vs. men) were factors in influencing the rate of decline when performance was measured longitudinally versus cross-sectionally, 1.25 was considered an appropriate conversion factor on all test items for both men and women. Again, it was important that fitness standards be set sufficiently high for younger older adults so that the normal age-related declines will not cause them to progress below the level of fitness needed for independent functioning at age 90.

As such, the ultimately "proposed fitness standards" presented in Table 4 reflect an average anticipated decline in performance of 40.1% over the 30-year period from 60–64 to 90–94 compared with the average 32.2% decline seen in the normative scores presented in Table 3, an increase that approximates the 1.25 times greater rate of decline observed in past studies when performance changes were tracked over time as opposed to being measured cross-sectionally.

Only for the 90–94 age group were the proposed criterion standards based directly (without adjustment) on the scores achieved in the normative database, a decision which seemed logical considering that the goal of maintaining independent functioning until late in life had already been met by these participants. For all other age groups, the proposed standards were set higher than the normative scores in order to allow for the greater amount of physical decline expected when performance is tracked longitudinally versus cross-sectionally.

Because there is no evidence in the literature suggesting that thresholds for maintaining physical independence should be different for men than for women, the fitness standards proposed for those over 90 on each test item are the same for both sexes. Interestingly, as seen in Table 3, the actual scores obtained by the 90-to 94- year-old men and women in the normative database were nearly identical on all fitness measures except upper body strength, despite the fact that men scored better than women on all test items at younger ages (e.g., at ages 60–64). This pattern of age-related decline where fitness scores of men are higher than those of women in younger age groups but then tend to converge and become more similar in later years due to a more rapid rate of physiologic decline in certain key areas (e.g., muscle mass and aerobic capacity) is consistent with findings reported elsewhere (Doherty, 2003; Goodpaster et al., 2006; V. A. Hughes et al., 2001; Paterson et al., 2007).

Table 3. Fitness Means and *SD* (in Parentheses) for the Subset (*N* = 2,140) of Normative Study Participants (Rikli & Jones, 1999b) Who Were Rated as Moderate Functioning as Determined by Age-Adjusted Scores on the Composite Physical Function Scale[a]

	Age groups							% Of decline over 30 years
	60–64 (*n* = 144)	65–69 (*n* = 369)	70–74 (*n* = 538)	75–79 (*n* = 515)	80–84 (*n* = 306)	85–89 (*n* = 180)	90–94 (*n* = 88)	
Lower body strength (number of chair stands in 30 s)								
Women	13.8 (3.6)	13.7 (3.5)	12.8 (3.1)	12.5 (3.6)	11.9 (5.2)	10.7 (4.1)	9.2 (4.3)	33.3
Men	14.8 (4.7)	14.0 (4.5)	13.0 (4.0)	12.9 (3.6)	12.4 (3.6)	10.1 (4.6)	9.4 (3.6)	36.4
Upper body strength (number of arm curls in 30 s)								
Women	15.4 (4.1)	14.8 (3.8)	14.1 (4.0)	13.9 (4.0)	13.4 (4.0)	12.5 (3.2)	11.0 (3.9))	28.6
Men	18.0 (5.0)	17.2 (5.1)	17.3 (5.1)	15.5 (3.9)	15.6 (3.8)	13.4 (3.2)	12.3 (3.4)	31.9
Aerobic endurance (yards walked in 6 min)								
Women	578 (81)	550 (102)	539 (87)	503 (100)	484 (83)	456 (98)	407 (125)	29.6
Men	610 (89)	597 (92)	568 (100)	500 (142)	505 (99)	443 (126)	404 (131)	33.8
Alternate aerobic endurance (number of steps in 2 min)								
Women	85.9 (24.5)	85.1 (24.2)	83.5 (21.9)	83.1 (23.0)	78.5 (19.7)	74.2 (18.4)	60.4 (22.1)	29.7
Men	92.6 (20.8)	89.3 (25.1)	92.5 (20.6)	90.1 (27.0)	81.2 (27.1)	75.5 (28.5)	60.0 (22.1)	35.2
Agility/dynamic balance (8-foot up-and-go, s)								
Women	5.4 (1.2)	5.6 (1.0)	6.0 (1.3)	6.3 (1.2)	6.6 (1.4)	7.2 (1.6)	7.8 (1.6)	30.8[b]
Men	5.2 (1.6)	5.6 (1.3)	6.2 (2.5)	6.2 (1.9)	6.4 (1.4)	7.4 (3.1)	7.7 (2.0)	32.5[b]

Notes: [a]See Table 2 for a definition of moderate functional ability. Mean decline = 32.2%.

[b]The percent of change in performance for the 8-foot up-and-go was calculated by dividing the amount of change by the higher score, so that the proportion of change would be calculated in a manner comparable to other test items.

Table 4. Criterion-Referenced Fitness Standards for Maintaining Physical Independence in Older Adults

	Age groups							% Of decline reflected over 30 years
	60–64	65–69	70–74	75–79	80–84	85–89	90–94	
Lower body strength (number of chair stands in 30 s)								
Women	15	15	14	13	12	11	9	40.0
Men	17	16	15	14	13	11	9	47.1
Upper body strength (number of arm curls in 30 s)								
Women	17	17	16	15	14	13	11	35.3
Men	19	18	17	16	15	13	11	42.1
Aerobic endurance (yards walked in 6 min)								
Women	625	605	580	550	510	460	400	36.0
Men	680	650	620	580	530	470	400	41.2
Alternate aerobic endurance (number of steps in 2 min)								
Women	97	93	89	84	78	70	60	38.1
Men	106	101	95	88	80	71	60	43.4
Agility/dynamic balance (8-foot up-and-go, s)								
Women	5.0	5.3	5.6	6.0	6.5	7.1	8.0	37.5
Men	4.8	5.1	5.5	5.9	6.4	7.1	8.0	40.0
Mean decline = 40.1								

Note: The proposed fitness standards were developed for use with the Senior Fitness Test (SFT) battery (Rikli & Jones, 2001, in press). The standards are based on actual SFT scores obtained by moderate-functioning older adults in a previously published cross-sectional database (Rikli & Jones, 1999b), with scores adjusted as appropriate to reflect other relevant information in the literature including an increased rate of decline over the years when performance is tracked longitudinally versus cross-sectionally.

Once fitness standards were established for the oldest age group (90–94 years) and were proposed for the youngest group (60–64 years) based on the rate of projected rate of decline that needed to be considered over the 30-year age span from 60–64 to 90–94, standards were then proposed for the remaining age groups based on additional age- and gender-related considerations, especially on the "curvilinear" nature of physical decline during aging that has been observed in almost all age-related research involving cardiovascular and neuromuscular functioning (American College of Sports Medicine, 2009; Doherty, 2003; Macaluso & De Vito, 2004; Paterson et al., 2007; Vandervoort, 2002). Typically, the rate of decline accelerates across decades from the 6th to the 7th and from the 7th to the 8th, with even greater declines seen from the 8th to the 9th decade. Therefore, as seen in Table 4, the proposed standards reflect a somewhat lesser rate of decline during the earlier years and a greater rate in later years. In proposing the standards, consideration was also given to previous findings indicating that lower body strength tends to decline at a faster rate than upper body strength (Paterson et al., 2007; Vandervoort, 2002).

The ultimately proposed standards of fitness for all age groups reflect "rounded off" numbers to make them consistent with SFT scoring procedures and to make them more user-friendly. As seen in Table 4, to be consistent with SFT scoring instructions, all standards for the chair stand, arm curl, and step test are reported in whole numbers, with standards for the 6-min walk presented in 5-yard increments. It is important to keep in mind that the recommended fitness standards are intended to be used as "guidelines" for evaluating fitness and for planning exercise interventions for older adults rather than as precise data points that have been calculated to smallest unit of measurement possible.

Additional information on administering the SFT items and on converting test protocols and performance tables to metric units are presented in the SFT Manual (Rikli & Jones, 2001, in press). Also included is additional information on how to use the performance tables to interpret test results and plan appropriate exercise interventions. As an example, if a 73-year-old male scores 19 on the chair stand test, 18 on the arm curl, and covers 500 yards on 6-min walk test, one sees by looking at Table 4 that he met (or surpassed) recommended fitness standards on the strength items (chair stand and arm curl) but not on the aerobic endurance test (6-min walk). Thus, an appropriate exercise prescription for this person would include additional emphasis on endurance types of activities.

The third stage of the standards development involved seeking input at various times during the process from members of a panel of experts in the fields of gerontological health, exercise, and measurement, a panel which included well-known scholars in their respective areas as well as program leaders/practitioners who had considerable "hands-on" experience in working with older adults. The major overriding feedback from panel members was that the methods followed in proposing the criterion "cut points" were logical, were based on the best data available, and that the resulting criterion performance standards were viable and would make a significant contribution to the field of gerontology and to the quality of older adult programs. Panel members also helped to identify various limitations of the study, which are acknowledged in the section on *Study Strengths and Limitations*, and provided important recommendations for the manuscript itself.

Step 3—Determining the Validity and Reliability of the Proposed Fitness Standards

Once fitness standards (cut-point scores) were proposed, their accuracy was evaluated by testing their validity and reliability as predictors of the intended goal (ability to function independently as measured by the CPF). In developing criterion standards, it is important to document not only the validity and reliability of the measurement tools being used (the SFT and CPF) but also the validity and reliability of the proposed standards themselves as predictors of the intended goal (physical independence in this case), a process that has been well defined elsewhere (Baumgartner et al., 2007; Cureton & Warren, 1990; Morrow et al., 2011; Safrit & Wood, 1995).

To estimate the validity and reliability of the proposed fitness standards, data were analyzed on a sample of 82 community-residing older adults (48 women and 34 men, mean age = 70.2; *SD* = 5.7) who were ambulatory without the use of assistive devices and were not to have been advised by their physician to refrain from exercise.

The validity of a criterion-referenced test addresses the question of consistency in properly classifying individuals as having met (or not met) the established standard on both the predictor test and the criterion test. In the present study, for example, a given fitness test standard would be considered valid if there were a high percent of participants who were consistent in meeting (or not meeting) the established standard for their age group on both the SFT item and the CPF scale.

The validity coefficients (*c* values) reported in Table 5 reflect the proportion of individuals who were accurately classified as having met or not met the proposed standards on both test items—the SFT item and the CPF measure of physical independence. As indicated, all values were quite high, approaching or exceeding the recommended threshold of .80 (Safrit & Wood, 1995), meaning that SFT standards generally had better than an 80% success rate in predicting functional ability and physical independence as measured by the CPF. Phi coefficients (φ), which indicate the correlation between dichotomous variables, were also reported as another recommended method for assessing classification consistency (Baumgartner et al., 2007).

Table 5. Validity of Criterion-Referenced Standards for Senior Fitness Test (SFT) Items

	Total			Women			Men		
Test item	*c*	φ	*n*	*c*	φ	*n*	*c*	φ	*n*
30-s chair stand	.87	.70	75	.86	.74	45	.86	.71	30
30-s arm curl	.83	.66	69	.83	.52	40	.86	.72	29
6-min walk	.91	.67	78	.88	.44	48	.97	.97	30
2-min step test	.91	.79	68	.92	.81	40	.89	.76	28
8-foot up-and-go	.79	.56	73	.80	.60	44	.79	.58	29

Note: *c* = validity coefficient, proportion of consistent classifications in having met or not met the standard on both measures—the SFT field measure and the Composite Physical Function (CPF) criterion measure for functional independence. φ = phi coefficient, indicates correlation between the classifications on each variable (SFT and CPF), another indication of classification consistency.

Test–retest reliability of the standards was determined by administering the SFT on two different occasions so that comparisons can be made regarding the consistency of the classifications on Day 1 compared with Day 2. Standards are considered to have good reliability when a large number of participants who meet (or do not meet) the established standard on Test Day 1 are consistent in also meeting (or not meeting) the standard on Day 2.

As indicated in Table 6, the test–retest reliability of the standards (represented by P_a, proportion of agreement) was quite high for all test items, with most values being in the .80 to .97 range. The P_a values in this study, which can be interpreted as percentages, means that there generally was well over 80% consistency in participant classifications from one test day to the next, thus suggesting that the proposed standards are reliable and stable. Kappa values (k_q) were also presented as an aide in interpreting the chance factor in determining degree of agreement, with values above .50 being desirable (Looney, 1989; Mahar & Rowe, 2008).

Results, Summary, and Discussion

The purpose of this research was to develop and validate criterion standards that estimate the level of fitness needed by older adults to remain physically independent into later life. The major study results are the proposed fitness standards for each SFT item as presented in Table 4. The proposed standards are based on actual fitness scores obtained by a subset of 2,140 moderate-functioning women and men, ages 60–94, who were part of a larger previously published study to establish normative standards for older Americans. In converting actually observed scores to recommended standards, adjustments were made as appropriate to reflect other relevant information from the literature, especially that indicating a greater rate of decline when performance is tracked longitudinally versus cross-sectionally. It was important that standards be set high enough so that a person's level of fitness would not decline below the level needed for independent functioning in spite of normal age-related changes.

For the 90–94 age group only, actual observed scores (rather than adjusted scores) were proposed as the recommended fitness standards, as this group already had demonstrated that they had retained sufficient fitness to perform the activities needed for living independently. Previous studies suggest that the standards for 90–94 years old, even though based on a relatively small proportion of participants, are reasonable and in line with other findings concerning the level of fitness needed for independent functioning. The proposed 400-yard standard for 90–94 years old on the 6-min walk is within range of the 360–600 m (329–589 yards) previously reported recommendation for the minimum walking distance needed to function independently—that is, to be able to navigate within the community to do one's own shopping and errands (Cohen, Sveen, Walker, & Brummel-Smith, 1987; Lerner-Frankiel, Vargas, Brown, Krusell, & Schoneberger, 1986). The 400-yard standard on the 6-min walk is also similar to the ¼ mile (440 yards) criteria used by Medicare as a cut-point for defining mobility limitation and disability (U.S. Department of Health and Human Services, 2006).

On the 8-foot up-and-go, the proposed standard of 8.0 s for 90–94 years old to complete the test is similar to but appropriately faster than the 8.5 s cut-point that has been identified as a predictor of falling (Rose, Jones, & Lucchese, 2002). Performing below (better than) the 8.5 cut-point for predicting falls is an especially important consideration, given

Table 6. Test–Retest Reliability of Criterion-Referenced Standards for Senior Fitness Test (SFT) Items

	Total			Women			Men		
Test Item	P_a	k_q	*n*	P_a	k_q	*n*	P_a	k_q	*n*
30-s chair stand	.89	.79	73	.89	.78	42	.90	.80	31
30-s arm curl	.80	.60	71	.79	.58	39	.81	.62	32
6-min walk	.93	.86	73	.91	.82	44	.97	.94	29
2-min step test	.88	.76	69	.90	.80	39	.87	.74	30
8-foot up-and-go	.90	.80	71	.88	.76	40	.94	.88	31

Note: P_a = proportion of agreement in participants being consistently classified as having met or not met the SFT performance standard on both Day 1 and Day 2. k_q = modified kappa, provides a correction for chance in reporting classification consistency (Looney, 1989).

that falls and fall-related injuries are a major cause of loss of independence and escalating health care costs (Centers for Disease Control and Prevention, 2011). In addition, when comparing the newly proposed criterion standards with the previously published SFT normative percentile tables, it was found that all 70 of the proposed standards (five test items across seven age groups for both men and women) fell at or above the 40th percentile rank. This means that at least 40% of the normative population would not have met the fitness standard associated with independent functioning, an observation that is reasonably consistent with statistics reported elsewhere indicating that 40%–50% of the over 65 population have difficulty with common activities needed for daily living and, thus, may be at risk for loss of independence (Federal Interagency Forum on Aging-Related Statistics, 2010; Webber et al., 2010).

Study Strengths and Limitations

An important strength of this research is that the proposed fitness standards are based on actual data collected from a large geographically representative study of over 7,000 community-residing older Americans, with a special focus on scores of the 2,140 subset of participants who met the age-adjusted criteria for a rating of moderate functioning. The ultimately proposed standards also reflect well-documented information from the literature (both longitudinal and cross-sectional) about patterns of age- and gender-related declines in performance and are based on easy-to-use measurement tools with strong psychometric properties.

The newly proposed fitness standards should also have value as a complement to the national Physical Activity Guidelines for Americans (2008) and similar documents developed in other countries. Although much research has gone into the preparation of these guidelines, experts in the field of aging and physical activity report that confusion still exists regarding their application to older adults, particularly regarding the threshold requirements "to remain healthy and independent" (S. L. Hughes et al., 2011, p. 828). Thus, the fitness standards proposed in this research should help add clarity about the level of fitness and physical activity needed to remain independent.

The major limitations in this research are similar to those in other studies involving the initial development of criterion-referenced standards of performance in that there is, by necessity, a reliance on nonexperimental untested predictions. Longitudinal intervention studies will be required to test the ultimate accuracy of the standards relative to their ability to predict the level of fitness needed at various ages to retain independent functioning in later in life.

Additional research is also needed to address the potential limitation associated with use of self-report to assess functional ability level, particularly as measured by the CPF. Although evidence exists to support the reliability and validity of the CPF (Rikli & Jones, 1998) and of other self-report measures of physical ability (Guralnik, et al., 1995; Hoeymans et al., 1997), additional studies are needed to confirm the effectiveness of the CPF for use in criterion standards development and also to clarify the relationship between rate of physical decline and decline in functional ability.

Finally, with the baseline data for this research collected on mostly white (89.1%), relatively well-educated American (M = 14.5 years of education; Rikli & Jones, 1999b), additional studies are needed to determine the degree to which results can be generalized to other populations. With this research being, to our knowledge, the first attempt at setting criterion-referenced fitness standards for older adults, there clearly is a need for additional studies to further confirm, clarify, and expand this initial work.

Conclusion and Implications

In conclusion, the criterion standards as proposed appear to have sufficiently strong empirical and rational support to justify their use by both researchers and practitioners as reasonable estimates of the level of fitness associated with remaining physically mobile and independent in later life. The SFT battery of test items with its accompanying criterion standards provides a unique and previously unavailable method for evaluating physical fitness in older adults and for planning exercise interventions that target areas of weakness. The criterion standards also provide the first of their type, easy to interpret reference points to indicate when fitness capacity indices in older adults may be at a level that could put them at risk for premature loss of physical independence.

Acknowledgments

Appreciation is extended to an advisory panel of experts, both scientists and practitioners, who provided valuable input and feedback during various phases of this project. Members of the scientific review panel were Wojtek Chodzko-Zajko, Professor and Head, Department of Kinesiology

and Community Health, University of Illinois, Urbana-Champaign; Matthew Mahar, Professor of Kinesiology, East Carolina University, Greenville; Miriam Morey, Professor of Medicine, Duke University; James R. Morrow, Jr., Regents Professor of Kinesiology, University of North Texas, Denton; Naoko Muramatsu, Associate Professor of Community Health Sciences, University of Illinois, Chicago; Donald Paterson, Research Director, Canadian Centre for Activity and Aging, University of Western Ontario; Debra Rose, Director, Center for Successful Aging, California State University, Fullerton; and Dawn Skelton, Professor, Aging and Health, Glasgow Caledonian University, Glasgow. Program leader/practitioner panel members were Jordan Aquino, Assistant Director, Pain Management Center, California State University, Fullerton (CSUF); Jeana Miller, Operations Manager, CSUF Center for Successful Aging; Jan Montague, President, Whole Person Wellness Solutions Inc., Cincinnati; and Karen Schlieter, Assistant Director, FallProof Balance and Mobility Instructor Certificate Program, CSUF.

References

Administration on Aging. (2010). *A profile of older Americans: 2010*. Washington, DC: A report of the Administration on Aging, U.S. Department of Health and Human Services.

American College of Sports Medicine. (2009). ACSM position stand: Exercise and physical activity for older adults. *Medicine and Science in Sports and Exercise*, *41*, 1510–1530. doi:10.1249/MSS.0b013e3181a0c95c

Bassey, E. J., & Harries, U. J. (1993). Normal values for handgrip strength in 920 men and women over 65 years, and longitudinal changes over 4 years in 620 survivors. *Clinical Science*, *84*, 331–337.

Baumgartner, T. A., Jackson, A. S., Mahar, M. T., & Rowe, D. A. (2007). *Measurement for evaluation in physical education and exercise science* (8th ed.). Boston: McGraw-Hill.

Centers for Disease Control and Prevention. (2011). *Costs of falls among older adults*. Retrieved from http://www.cdc.gov/ncipc/factsheets/fallcost.htm

Cesari, M. (2011). Role of gait speed in the assessment of older patients. *Journal of the American Medical Association*, *305*, 93–94. doi:10.1001/jama.2010.1970

Cohen, J. J., Sveen, J. D., Walker, J. M., & Brummel-Smith, K. (1987). Establishing criteria for community ambulation. *Topics in Geriatric Rehabilitation*, *3*(1), 71–77.

Cress, M. E., & Meyer, M. (2003). Maximal voluntary and functional performance levels needed for independence in adults ages 65 to 97 years. *Physical Therapy*, *83*, 37–48.

Cress, M. E., Petrella, J. K., Moore, T. L., & Schenkman, M. L. (2005). Continuous-scale physical functional performance test: Validity, reliability, and sensitivity of data for the short version. *Physical Therapy*, *85*, 323–335.

Cureton, K. J., & Warren, G. L. (1990). Criterion-referenced standards for youth health-related fitness tests: A tutorial. *Research Quarterly for Exercise and Sport*, *61*, 7–19.

Doherty, T. J. (2003). Invited review: Aging and sarcopenia. *Journal of Applied Physiology*, *95*, 1717–1727. doi:10.1152/japplphysiol.00347.2003

Federal Interagency Forum on Aging-Related Statistics. (2010). *Older Americans 2010: Key indicators of well-being*. Washington, DC: U.S. Government Printing Office.

Fiatarone Singh, M. S. (2002). Exercise to prevent and treat functional disability. *Clinics in Geriatric Medicine*, *18*, 431–462.

Fleg, J. L., Morrell, C. H., Bos, A. G., Brant, L. J., Talbot, L. A., Wright, J. G., et al. (2005). Accelerated longitudinal decline of aerobic capacity in health older adults. *Circulation*, *112*, 674–682. doi:10.1161/CIRCULATIONAHA.105.545459

Giuliani, C. A., Gruber-Baldini, A. L., Park, N. S., Schrodt, L. A., Rokoske, F., Sloane, P. D., et al. (2008). Physical performance characteristics of assisted living residents and risk for adverse health outcomes. *The Gerontologist*, *48*, 203–212. doi:10.1093/geront/48.2.203

Goodpaster, B. H., Park, S. W., Harris, T. B., Kritchevsky, S. B., Nevitt, M., Schwartz, A. V., et al. (2006). The loss of skeletal muscle strength, mass, and quality in older adults: The health, aging, and body composition study. *Journal of Gerontology: Medical Sciences*, *61A*, 1059–1064.

Guralnik, J. M., Ferrucci, L., Pieper, C. F., Leveille, S. G., Markides, K. S., Ostir, G. V., et al. (2000). Lower extremity function and subsequent disability: Consistency across studies, predictive models, and value of gait speed alone compared with the Short Physical Performance Battery. *Journal of Gerontology: Medical Sciences*, *55A*, 221–231.

Guralnik, J. M., Reuben, D. B., Buchner, D. M., & Ferrucci, L. (1995). Performance measures of physical function in comprehensive geriatric assessment. In L. Z. Rubenstein, D. Wieland, & R. Bernabei. (Eds.), Geriatric assessment technology: The state of the art (pp. 59–74). Milan, Italy: Editrice Kurtis.

Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G., et al. (1994). A short physical performance battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. *Journal of Gerontology: Medical Sciences*, *49*, 85–94.

Hoeymans, N., Wouters, E., Feskens, E., van den Bos, G., & Kromhout, D. (1997). Reproducibility of performance-based and self-reported measures of functional status. *Journal of Gerontology: Medical Sciences*, *52a*(6), M363–M368. doi:10.1093/gerona/52A.6.M363

Hollenberg, M., Yang, J., Haight, T. J., & Tiger, I. B. (2006). Longitudinal changes in aerobic capacity: Implications for concepts of aging. *Journal of Gerontology: Medical Sciences*, *61A*, 851–858.

Hughes, S. L., Leith, K. H., Marquez, D. X., Moni, G., Nguyen, H. Q., Desai, P., et al. (2011). Physical activity and older adults: Expert consensus for a new research agenda. *The Gerontologist*, *51*, 822–832. doi:10.1093/geront/gnr106

Hughes, V. A., Frontera, W. R., Wood, M., Evans, W. J., Dallal, G. E., Roubenoff, R., et al. (2001). Longitudinal muscle strength changes in older adults: Influence of muscle mass, physical activity, and health. *Journal of Gerontology: Biological Sciences*, *56A*, B209–B217. doi:10.1093/gerona/56.5.B209

Jackson, A. S., Sui, X., Hebert, J. R., Church, T. S., & Blair, S. N. (2009). Role of lifestyle and aging on the longitudinal change in cardiorespiratory fitness. *Archives of Internal Medicine*, *169*, 1781–1787. doi:10.1001/archinternalmed.2009.312

Kallman, D. A., Plato, C. C., & Tobin, J. D. (1990). The role of muscle loss in the age-related decline of grip strength: Cross-sectional and longitudinal perspectives. *Journal of Gerontology: Medical Sciences*, *45*, 82–88.

Lerner-Frankiel, M. B., Vargas, S., Brown, M., Krusell, L., & Schoneberger, W. (1986). Functional community ambulation: What are your criteria? *Clinical Management in Physical Therapy*, *6*(2), 12–15.

Looney, M. A. (1989). Criterion-referenced measurement: Reliability. In M. J. Safrit & T. M. Woods (Eds.), *Measurement concepts in physical education and exercise science* (pp. 137–152). Champaign, IL: Human Kinetics.

Macaluso, A., & De Vito, G. (2004). Muscle strength, power and adaptations to resistance training in older people. *European Journal of Applied Physiology*, *91*, 450–472.

Mahar, M. R., & Rowe, D. A. (2008). Practical guidelines for valid and reliable youth fitness testing. *Measurement in Physical Education and Exercise Science*, *12*(3), 126–145. doi:10.1080/10913670802216106

Morey, M. C., Pieper, C. F., & Cornoni-Huntley, J. (1998). Physical fitness and functional limitations in community-dwelling older adults. *Medicine & Science in Sports & Exercise*, *30*, 715–723.

Morrow, J. R., Jr., Jackson, A. W., Disch, J. G., & Mood, D. P. (2011). *Measurement and evaluation in human performance* (4th ed.). Champaign, IL: Human Kinetics.

National Center for Health Statistics. (1991). *National Health Interview Survey 1991(10): Vital Health Statistics*. Washington, DC: Author.

Paterson, D. H., Jones, G. R., & Rice, C. L. (2007). Ageing and physical activity: Evidence to develop exercise recommendations for older adults. *Applied Physiology, Nutrition, and Metabolism*, *32*(Suppl. 2E), S69–S108. doi:10.1139/H07-111

Paterson, D. H., & Warburton, D. E. R. (2010). Physical activity and functional limitations in older adults: A systematic review related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity*, *7*, 1–22. doi:10.1186/1479-5868-7-38

Physical Activity Guidelines for Americans. (2008). *U.S. department of health and human services*. Retrieved from www.health.gov/paguidelines

Rantanen, T., Masaki, K., Foley, D., Izmirlian, G., White, L., & Guralnik, J. M. (1998). Grip strength changes over 27 yr in Japanese-American men. *Journal of Applied Physiology*, *85*(6), 2047–2053.

Rikli, R. E., & Jones, C. J. (1998). The reliability and validity of a 6-minute walk test as a measure of physical endurance in older adults. *Journal of Aging and Physical Activity*, 6, 363–375.

Rikli, R. E., & Jones, C. J. (1999a). Development and validation of a functional fitness test for community-residing older adults. *Journal of Aging and Physical Activity*, *6*, 127–159.
Rikli, R. E., & Jones, C. J. (1999b). Functional fitness normative scores for community-residing adults, ages 60-94. *Journal of Aging and Physical Activity*, *6*, 160–179.
Rikli, R. E., & Jones, C. J. (2001). *Senior fitness test manual*. Champaign, IL: Human Kinetics.
Rikli, R. E., & Jones, C. J. (in press). *Senior fitness test manual* (2nd ed.). Champaign, IL: Human Kinetics.
Rose, D. J., Jones, C. J., & Lucchese, N. (2002). Predicting the probability of falls in community-residing older adults using the 8-foot up-and-go: A new measure of functional mobility. *Journal of Aging and Physical Activity*, *10*, 466–475.
Rosow, I., & Breslau, N. (1966). A guttman health scale for the aged. *Journal of Gerontology*, *21*, 556–559.
Safrit, M. J., & Wood, T. M. (1995). *Introduction to measurement in physical education and exercise science* (3rd ed.). St. Louis, MO: Mosby-Year Book, Inc.
Seeman, T. E., Charpentier, P. A., Berkman, L. F., Tinetti, M. E., Guralnik, J. M., Albert, M., et al. (1994). Predicting changes in physical performance in a high-functioning elderly cohort: MacArthur Studies of Successful Aging. *Journal of Gerontology: Medical Sciences*, *49*, 97–108.
Siu, A. L., Reuben, D. B., & Hays, R. D. (1990). Hierarchical measures of physical function in ambulatory geriatrics. *Journal of the American Geriatrics Society*, *38*, 1113–1119.
Stathokostas, L., Jacob-Johnson, S., Petrella, R. J., & Paterson, D. H. (2004). Longitudinal changes in aerobic power in older men and women. *Journal of Applied Physiology*, *97*, 781–789. doi:10.1152/japplphysiol.00447.2003
Studenski, S., Perera, S., Patel, K., Rosano, C., Faulkner, K., Inzitari, M., et al. (2011). Gait speed and survival in older adults. *Journal of the American Medical Association*, *305*, 50–58. doi:10.1001/jama.2010.1923
U.S. Department of Health and Human Services. (2006). *Medicare Current Beneficiary Survey (MCBS), Centers for Medicare and Medicaid Services*. Retrieved from http://www.cms.hhs.gov/MCBS
Vandervoort, A. A. (2002). Aging of the human neuromuscular system. *Muscle & Nerve*, *25*, 17–25. doi:10.1002/mus.1215
Webber, S. C., Porter, M. M., & Menec, V. H. (2010). Mobility in older adults: A comprehensive framework. *The Gerontologist*, *50*, 443–450. doi:10.1093/geront/gnq013
Welk, G. J. & Meredith, M. D. (Eds.). (2008). *Fitnessgram/Activitygram reference guide*. Dallas, TX: The Cooper Institute.
Winegard, K. J., Hicks, A. L., Sale, D. G., & Vandervoort, A. A. (1996). A 12-year follow-up study of ankle muscle function in older adults. *Journal of Gerontology: Biological Science*, *51A*, B202–B207. doi:10.1093/gerona/51A.3.B202