2014

Breast Cancer EDGE Task Force Outcomes - Clinical Measures of Strength and Muscular Endurance: A Systematic Review

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ABSTRACT
Background: Muscular strength deficits are a common morbidity following treatment for breast cancer. Accurate assessment of strength and muscular endurance following breast cancer treatments is essential in identifying deficits and planning rehabilitation strategies. **Purpose:** The purpose of this systematic review was to identify strength and muscular endurance outcome measures for use with women treated for breast cancer that possess strong psychometric properties and are clinically useful. **Methods:** Multiple electronic databases were searched between February and June 2013. Included studies of tools used to assess strength and muscular endurance met the following criteria: reported psychometric properties, clinically feasible methods, adults (preferably female), and published in the English language. Each outcome measure was reviewed independently and rated by two reviewers separately. A single Cancer EDGE Task Force Outcome Measure Rating Form was completed for each category of strength or endurance assessment, and a recommendation was made using the 4-point Breast Cancer EDGE Task Force Rating Scale. **Results:** Of the original 874 articles found, 22 were included in this review. Hand Grip Strength and Hand Held Dynamometry were rated 3, recommended for clinical use. Manual muscle test and one repetition maximum were rated 2B, unable to recommend at this time. Muscular endurance testing was rated 2A, unable to recommend at this time. **Conclusions:** Utilizing objective dynamometry for hand grip and muscle strength testing provides precise measurement to assess baseline status and monitor change among women treated for breast cancer.

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Key Words: psychometrics, dynamometry, outcome assessment, breast neoplasms

INTRODUCTION

Upper limb muscular weakness and diminished muscular endurance are common deficits among breast cancer survivors (BCS) after treatment and can result in upper limb dysfunction.[1] Strength deficits of 20% in scapular and gleno-humeral shoulder musculature were reported among 24 women with breast cancer within the first 6 months after treatment,[2] and in a sample of 75 BCS, shoulder musculature strength deficits ranging from 7% to 18% persisted more than a year after treatment.[3] Strength losses may stem from one or more aspects of cancer treatment. Surgical cancer treatment often involves resecting peripheral nerves that may result in nerve injury (such as stinger injuries), removing muscles (such as in a total radical mastectomy), or using muscles for reconstruction [such as in a transverse rectus abdominis myocutaneous (TRAM) flap]. All of these procedures may alter muscle action. Chemotherapy treatment may result in chemotherapy induced peripheral neuropathy (CIPN), which can include distal weakness and sensory loss[4] increasing the risk for balance impairment or falls.[5] Effects on muscle fibers may be cumulative depending on the treatments each BCS undergoes causing further loss of upper quadrant strength. Strength deficits can impact functional abilities of the upper limb in daily home and work activities,[6] ultimately adversely affecting quality of life.

Muscular endurance deficits are also documented after treatment for breast cancer. Muscular endurance is defined as the ability to sustain a force over time in order to complete an activity. In a study of 214 women with unilateral breast cancer diagnosed 6 months prior to data collection, muscular endurance measured using the Upper Body Strength and Endurance test, was significantly less on the treated side when compared to the untreated side.[7] These deficits persisted 18 months after surgery in 186 BCS.[8] Both muscular strength and muscular endurance can impair overall upper extremity function among women with breast cancer. Accurate documentation of both strength and muscular endurance prior to and following treatments for breast cancer aligns with the Prospective Surveillance Model for Breast Cancer recommendations to identify early and rehabilitate any deficits that develop postoperatively.[9]

In 2010, the American Physical Therapy Association's (APTA) Oncology Section created the Evaluation Database to Guide Effectiveness (EDGE) Task Force to develop recommendations for outcome measures to be used when assessing the status of cancer survivors.[10] This systematic review continues the work of the Oncology Section Breast Cancer EDGE Task Force by evaluating the ways in which strength and muscular endurance are measured clinically. Strong psychometric properties of outcome measures including reliability, validity, minimal detectable change (MDC) and/or minimally clinically important difference (MCID), are needed to justify clinical use. Tools used to measure outcomes should be validated in the population in which they are used. For example, a measure used to evaluate a shoulder impairment caused by a postsurgical shoulder arthroplasty may not be a useful tool for the patient with shoulder impairment secondary to breast cancer treatment including surgery. The clinical presentation of the above two patient populations may vary with different postoperative precautions, treatment guidelines, and treatment progression. In addition to strong psychometric properties, clinical utility is an important consideration. Qualities of clinical utility include availability of resources, cost, ease of use including time necessary to complete testing and clinician training, scoring and interpretation, and availability of normative data for comparison. An outcome measure may have outstanding psychometric properties, however, clinicians ultimately need a measure that is easy to administer with the least amount of patient and provider burden. The purpose of this systematic review was to identify strength and muscular endurance outcome measures for use with BCS that possess strong psychometric properties and are clinically useful.

METHODS

Search strategy

The primary search strategy was conducted between February and June 2013 using multiple electronic databases, including Web of Science, Pubmed/Medline, CINAHL, Ovid, Google Scholar, Sports Discus, Cochrane Review, PEDro, and Academic Search. Search terms used alone and in combination included: strength measure/measurement/test, muscular endurance measure/measurement/test, manual muscle test, psychometric properties, clinimetrics, dynamometer/dynamometry, power, energy, along with the following MESH terms: "Muscle strength dynamometer" OR "Muscle Strength" OR "Hand Strength." Studies of tests of muscle strength and muscular endurance had to meet the following inclusion criteria: reported psychometric properties, clinically feasible methods, adults (preferably female), and published in the English language. Exclusion criteria included non-clinical measures of strength and muscular endurance as well as studies of functional mobility measures (Timed Up and Go, Sit to Stand, gait speed, etc). Bibliographic review of relevant articles was conducted as well as review of journals focusing on orthopedics or fitness measures. The publication dates were limited to 1/1/1995 and after, as long as the inclusion criteria were met. Studies conducted on participants who had breast cancer were preferred; however, if none were available, similar populations were considered when evaluating the psychometric properties. Each outcome measure was reviewed independently and rated by two reviewers separately. If an outcome measure rating was found to be in disagreement between the two independent reviewers, the disagreement was resolved by discussion with 4 reviewers until agreement was obtained.

After completion of the literature search, relevant articles were classified into 4 strength categories and one additional category for muscular endurance. The 4 strength categories were: manual muscle testing (MMT), one-repetition maximum (1-RM) testing, hand grip strength (HGS) using dynamometry, and hand-held dynamometry (HHD). The categories for strength measurement tools were selected based on characteristics of each measurement tool described in the available literature.

Data Extraction and Synthesis

Relevant data were extracted and recorded on the Cancer EDGE Task Force Outcome Measure Rating Form for each study (Appendix). Relevant data included intra-, inter-, and test-retest reliability values, with confidence intervals as available, validity, MDC, standard error of measurement (SEM), and MCID. Studies were then grouped together into common categories and a single Cancer EDGE Task Force Outcome Measure Rating Form was completed for each category of strength assessment or muscular endurance assessment. Upon completion of the Cancer EDGE Task Force Outcome Measure Rating Form, a recommendation was made using the 4-point Breast Cancer EDGE Task Force Rating Scale (Figure 1).[10] Determination of good psychometric properties related to reliability was determined by either the Intraclass Correlation Coefficient (ICC) or Kappa values (K). The ICCs greater than 0.75 are considered good to excellent, 0.5-0.74 moderate, and below 0.5 considered poor.[11] Kappa values greater than 80% demonstrated excellent agreement, 61% to 80% substantial agreement, 41% to 60% adequate agreement, and less than 40% showed poor agreement.[11] Validity was assessed by ICCs or Pearson Product Correlation Coeffecient (r), and rated using the same values noted previously. Clinical utility was assessed using criteria noted earlier (availability of resources, cost, ease of use including time necessary to complete testing and clinician training, scoring and interpretation, and availability of normative data for comparison).

RESULTS

The initial literature search for muscle strength and muscular endurance resulted in 874 articles. The assessors reviewed the titles and 34 duplicates were removed. The remaining 840 titles and abstracts of the articles were then reviewed to identify studies that specifically addressed the research purpose. A total of 302 articles were retrieved and assessed for eligibility. After exclu-

4	**Highly Recommend**	Highly recommended; the outcome has good psychometric properties and good clinical utility; the measure has been used in research on individuals with or post breast cancer.
3	**Recommend**	Recommended; the outcome measure has good psychometric properties and good clinical utility; no published evidence that the measure has been applied to research on individuals with or post breast cancer.
2A	**Unable to Recommend at This Time**	Unable to recommend at this time; there is insufficient information to support a recommendation of this outcome measure; the measure has been used in research on individuals with or post breast cancer.
2B	**Unable to Recommend at This Time**	Unable to recommend at this time; there is insufficient information to support a recommendation of this outcome measure; no published evidence that the measure has been applied to research on individuals with or post breast cancer.
1	**Do not Recommend**	Poor psychometrics &/or poor clinical utility (time, equipment, cost, etc).

Figure 1. Breast Cancer EDGE Task Force Rating Scale.

sions were applied, 21 articles were included in the study. See Flow diagram detailing search process (Figure 2).

For the 4 categories assessing strength, 3 articles used MMT, 4 related to 1-RM testing, 8 to HGS, and 5 for HHD. For the category examining muscular endurance, multiple articles were excluded from analysis secondary to applying inclusion and exclusion criteria, leaving only one article with psychometric properties.

Two measures were given a 3, Recommended, by the Breast Cancer EDGE Task Force members and are recommended for clinical use: Hand Grip Strength and Hand Held Dynamometry. Two other measures: Manual muscle test and 1-RM were scored a 2B: Unable to recommend at this time, due to a lack of psychometric support. Muscle endurance was rated a 2A: Unable to recommend at this time, due to poor clinical utility. Furthermore, power was measured in these studies rather than the sustained force over time necessary to measure endurance. Table 1 lists the clinical usefulness of the muscular strength and endurance tests. Table 2 contains the Task Force ratings and clinical utility comments. Table 3 details the psychometric properties of the clinical measures of strength and muscular endurance.

DISCUSSION

An accurate and reliable assessment of strength and muscular endurance is an important component of evaluating the status of BCS prior to and following medical treatment in order to establish a comprehensive picture of their functional needs and goals, and monitor and document progress toward full return to function. The Prospective Surveillance Model for Breast Cancer relies upon the ability to prospectively monitor the status of BCS over time in order to prevent or rehabilitate early those morbidities that may accompany breast cancer treatments.[9] Findings from this systematic review indicate that the measurement of strength is best performed using objective dynamometry for both hand grip and extremity measures. No recommendations for the clinical measurement of muscular endurance can be made at this time.

Strength

Strength is considered the quantification of force output from muscular action. Clinical measurement of strength has long been performed using the manual muscle test system, ranking strength on a 0-5 scale (0 representing no muscular contraction and a 5 indicating full strength).[12] Two primary limitations to using MMT confound the effective evaluation of patient status. First, this method of evaluating strength is subjective. The tester must make assessments of how much force a patient can generate for those

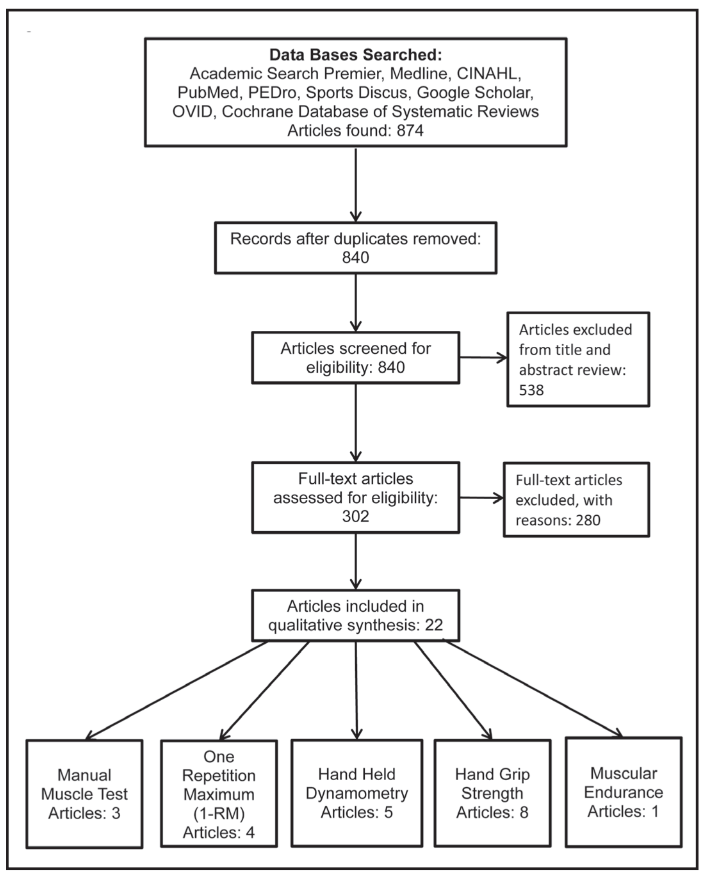

Figure 2. PRISMA flow of literature search.

Table 1. Clinical Usefulness of Strength and Muscular Endurance Testing Methods

Measure	Equipment Needed	Cost	Ease of Use	Scoring/Interpretation	Normative Data
MMT	No	None	High	Easy	Yes*
1-RM	No	Minimal	High	Easy	Yes
HGS	Yes	Moderate	High	Easy	Yes
HHD	Yes	Moderate	High	Easy	Yes

Abbreviations: MMT, manual muscle test; 1-RM, one repetition maximum; HGS, hand grip strength; HHD, hand-held dynamometry
*This is based on the rating of a 5 being 'normal' strength.

Table 2. Breast Cancer EDGE Task Force Ratings and Clinical Utility of the Strength Measures for Breast Cancer Survivors

Measure	Breast Cancer EDGE Task Force Rating	Clinical Utility
Hand Grip Strength	3	Equipment is easy to use clinically and staff training is simple. Good clinical utility.
Hand-held Dynamometry	3	Easy to use clinically. Methodology similar to Manual Muscle Testing. Normative data available. Good clinical utility.
Muscle Endurance	2A	Not often tested clinically. Isokinetic testing used in one study that is not clinically feasible. Power is measured more than muscular endurance.
Manual Muscle Test	2B	Highly useful in the clinic but poor psychometric properties do not support use.
1-Repetition Maximum	2B	Not often used clinically. Psychometric support is limited.

grades greater than 3 (antigravity grades of 3+, 4-, and 4), and although testers have been shown to be able to make this judgment consistently within a single participant, the differences in force exerted by multiple testers of a 3+ for the same participant are quite variable.[13] Secondly, the ranking of MMT grades is an ordinal rather than an interval scale; the difference between a 3 and a 4 is not necessarily the same as the difference between a 4 and a 5. This does not allow the clinician to accurately describe strength gains made through rehabilitative measures, and generally lacks the sensitivity needed to appreciate small gains in strength.

Accurate assessment of strength relies upon a unit of measure that is intuitively sound. Force is measured by Newtons (N), pounds (lb), or kilograms (kg); output on dynamometers is generally in pounds or kilograms. With a clear objective measurement unit, normative data for gender and age can be established. This normative data then serves as the basis to make a determination about the status of the strength levels in individuals with pathology. As such, multiple studies outside the realm of this review do provide normative data for hand grip and extremity strength using dynamometry. The reader is referred to these sources for this information.[14-16] Further rationale for the use of dynamometry as a sound objective measure of strength is that the unit scale for dynamometry is interval, with a consistent amount of change between each increment of measure. This type of data allows the clinician to monitor change accurately, and with greater sensitivity to change.

Using HHD to measure strength in a clinical realm is as simple as MMT, yet provides a quantification of a maximal voluntary isometric contraction. The testing positions to measure muscular strength do not differ from MMT positions, yet the numerical output of a dynamometer can serve as a basis to determine the magnitude of a strength deficit when compared to normative values. The standard error of measurement of two HHDs examined in this review varies from 4.9-12.5 N.[17,18] The equivalency between 1 kg or 2.2 lbs is 9.8 N. With a SEM of no greater than 12.5 N, the error of measurement is less than 1.3 kg. Hand grip dynamometers have a standard error of measure of 0.77 – 2.3 kg.[19,20] These small SEM allow a clinician to be confident that change in excess of 1.5 kg is real change. Few studies have examined the MDC or MCID for dynamometry, but an study investigating the smallest detectable difference, which is synonymous with the MDC, found that value to be 3 kg.[17] Clinically meaningful change will vary dependent upon the muscle group tested and require the clinical judgment of the practitioner; however, any change in excess of 3 kg can be considered real change.

One limitation in the use of HHD is the variability resulting from the strength and size of the tester. Researchers have reported that differing values can be obtained related to differing gender, body weight, and grip strength of the tester.[21] Use of external fixation for the dynamometer can improve the interrater reliability of dynamometry in a clinical setting. Studies have investigated different devices including brackets,[22-24] or

Table 3. Psychometric Properties of Strength and Muscular Endurance Methods or Tools

	Hand Grip Strength	Hand-held Dynamometry	Muscular Endurance	Manual Muscle Testing	1-RM
Intra-tester reliability	ICC = 0.91 – 0.95 (CI = 0.80-0.96)[31] r 0.82 - 0.91[19] ICC = 0.94 - 0.98[32] (*healthy*) ICC = 0.87 - 0.97[32] (*cervical radiculopathy*) ICC = 0.90 – 0.93 (CI = 0.83-0.96)[33] (*Jamar)* ICC = 0.95 – 0.96 (CI = 0.91-0.98)[33] *(NK)* ICC = 0.97 - 0.99 (CI = 0.90-0.99)[34] *(healthy)* ICC = 0.86 – 0.92 (CI = 0.61-0.97)[34] *(critically ill)*	ICC = 0.89 – 0.98 (CI = 0.62-0.99)[17] *(healthy)* ICC 0.93-0.98[35] *(older adults)*			
Inter-rater reliability	r = 0.99[19] ICC 0.98[32] *(healthy)* ICC 0.96 – 0.97 (CI = 0.83-0.99)[34] *(healthy)* ICC 0.89 – 0.92 (CI = 0.54-0.97)[34] *(critically ill)* ICC = 0.95 - 0.96[20] ICC = 0.94 – 0.98[36]	ICC = 0.77-0.97[34] *(healthy)* ICC = 0.72 – 0.79 (CI = -0.19-0.95)[34] *(healthy)* ICC = 0.62 – 0.71 (CI = -0.21-0.93)[34] *(critically ill)* ICC = 0.91 – 0.96 (CI = 0.85-0.98)[37] *(critically ill)*		ICC = 0.83 (CI = 0.67-0.91)[38] ICC = 0.99 (CI = 0.97-1.00)[39] k = 0.54 (CI = 0.25-0.72)[40] Specific muscles[38] ICC = 0.29/0.53 *(left/right elbow flex)* ICC = 0.53/0.68 *(left/right shoulder abductor)* ICC = 0.50/0.61 *(left/right wrist extension)*	1-RM [41] Lat pull downs, bench press, elbow flexion *Males* 1-RM: r = 0.89 - 0.98 40%: r = 0.80 - 0.98 60%: r = 0.79 – 0.96 80%: r = 0.89 - 0.98 *Females* 1-RM: r = 0.79 - 0.98 40%: r = 0.80 - 0.96 60%: r = 0.80 - 0.95 80%: r = 0.80 to 0.9
Test-retest reliability		r = 0.90 (CI = 0.81-0.94)[18] *(cancer)* ICC = 0.90 *(cancer)*[18] ICC = 0.93 (CI = 0.47-0.98)[34] *(healthy)* ICC = 0.42 – 0.82 (CI = -0.54-0.94)[34]*(critically ill)*	r = 0.95[42] (*males)* r = 0.92[42] *(females)*		
SEM	2.2-2.3#[19] 1.68-2.29#[20]	10.6 N *(NK dynamometer; elbow extension)*[18] 4.9 – 12.5N *J-Tech Powertrack 2 (7 UE muscle tests)* [17]			
Validity	***of MicroFet compared to Jamar*** ICC = 0.97 – 0.99 (CI 0.93-1.00)[31] ***as a measure of function*** Fatigue/pain/mood state/UE ROM/function: □ = 0.22 - 0.53[43] ***as a measure of functional mobility*** r = 0.61-0.84[36] *(TUG)* r = 0.41-0.61[36] *(Gait Speed)*		***Concurrent Validity*** r = 0.86[42] *(males)* r = 0.79[42] *(females)*		

Abbreviations: ICC, intraclass correlation coefficient; r, Pearson's Coefficient Correlation; CI, confidence interval; SEM, standard error of measurement; #, pounds; UE, upper extremity; ROM, range of motion; TUG, timed up and go; r, Pearson's Coefficient Correlation; CI, confidence interval; ICC, intraclass correlation coefficient; SEM, standard error of measurement; SDD, standard deviation of difference; UE, upper extremity; N, newtons straps.[25,26] Mobilization belts are readily available in clinics, and when strapped around the dynamometer and fixed opposite to the direction of force, provide a consistent resistance for maximal voluntary contractions regardless of the tester. Another limitation of the use of HHD and HGS among women diagnosed with breast cancer is that these studies have not investigated psychometric properties in this population. Reliability and validity estimates, nor MCIDs, have been established for use in women with breast cancer.

Muscular Endurance

Muscular endurance, the ability to sustain force output over time, is seldom assessed in a clinical setting. This lack of assessment is largely due to a lack of established reliable and valid clinical methods to perform such testing. Most studies in strength and conditioning literature use some percentage of 1-RM to determine the load, and test endurance using a repetition to failure activity. The number of completed repetitions, then, provides information about the level of endurance. Utilizing 40% to 60% of a maximum resistance in a repeated fashion is purported to increase muscular endurance.[27] The usefulness of this method is the ability to establish a baseline measure, perform an intervention aimed at increasing endurance through exercise at 40% to 60% of 1-RM, and then retesting to determine the change in the number of repetitions to failure. The limitation of this methodology is that normative data for age, gender, and muscle group is difficult to establish, as the number of repetitions to failure is largely dependent upon the muscle mass of the individual.[28]

The literature search for this review revealed two studies examining muscular endurance in the breast cancer population. Both studies used a repetition to failure activity; however, they also present methodological limitations. One study of 40 BCS within the first 6 months after diagnosis measured endurance in the typical repetition to failure count, using 90% of 1-RM activity for activities for shoulder flexion, extension, protraction, and retraction comparing the involved limb to the noninvolved limb.[29] Results of the study did not reveal any significant differences between limbs except greater muscular endurance on the involved limb for shoulder flexion.[29] The limitation in this study is the use of 90% 1-RM, which is in excess of the recommended 40% to 60% 1-RM by the American College of Sports Medicine (ACSM), and by using 90% 1-RM, the musculature recruited for the activity was likely more type Type II anaerobic fast twitch fibers. Endurance activities typically recruit Type I aerobic slow twitch fibers. The second study examining 211 unilateral BCS 6 months after diagnosis did show a statistically significant difference in muscular endurance between involved and noninvolved limbs ($p \leq 0.05$) using a novel test of muscular endurance called the Upper Body Strength and Endurance (UBSE) test.[7] In this test, participants repeatedly lifted an incrementally increasing amount of resistance until failure; progression was based on 30 successfully completed repetitions at one weight before increasing the weight by 0.5 kg; the last weight lifted at failure was recorded for analysis.[7] This test used the repetition to failure endpoint to measure muscular endurance, but instead of a fixed percentage of 1-RM, used a progressively increasing resistance. This test does show some potential to be clinically useful but can be time-consuming to perform (15-20 minutes depending on the level of endurance). Additionally, this test has minimal psychometric testing results as it only reports low correlation with self-reported arm function using the Disabilities of the Arm, Shoulder, and Hand (DASH) ($r=-0.26$), and has no reported reliability, MDC, or MCID testing. Further refinements in muscular endurance testing are needed.

Isokinetic dynamometry offers a more reliable and valid method to measure muscular endurance. In a study of 36 healthy participants, Roy et al[30] tested an upper extremity endurance protocol using a Biodex stationary dynamometer, measuring maximal voluntary isometric contraction (MVIC) levels pre- and post-endurance activity. The results of this study indicated a statistically significant decline in MVIC after the endurance activity, with a good test-retest reliability reported (ICC = 0.84).[30] These findings suggest that rather than measuring repetitions to failure as a unit to quantify endurance, perhaps measuring MVIC pre- and post-activity may provide a more reliable and valid method to measure endurance. This method is limited in its scope of use as most clinics lack this expensive piece of equipment, but suggests that MVIC may be useful in developing a clinically feasible test for muscular endurance.

This systematic review was unable to recommend any clinical methods to measure muscular endurance. Further research establishing a standardized, reliable, and valid method of measuring muscular endurance is necessary. This clinical method should employ the guiding principles of 40% to 60% maximum resistance over a time period, have some quantifiable but reliable normative unit of measure, and must be responsive enough to detect differences between healthy and injured tissue.

CONCLUSION

Precise strength and muscular endurance measurement allow the clinician to accurately identify impairments in body structures that may impact activity and participation. Accurate assessment is integral for effective prospective surveillance for cancer survivors. Utilizing objective dynamometry for hand grip and muscle strength testing provides precise measurement to establish status and monitor change. Further research is necessary to devise a muscular endurance test for clinical use as well as studies involving BCS.

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Appendix. Cancer EDGE Task Force Outcome Measure Rating Form

Oncology Section — American Physical Therapy Association — Celebrate Living

Cancer EDGE Taskforce Outcome Measure Rating Form
(Adapted from Neurology Section EDGE form)

Instrument name:	
Reviewer:	
ICF Domain (check all that apply): _____body function/structure _____ activity _____participation	
Type of measure: __ performance-based _____self-report	
Languages available: English	
Population developed in:	
Validated populations:	
Instrument properties	
Reliability (test-retest, intra-rater, inter-rater)	Results for the intra-tester reliability:
Validity (concurrent, criterion-related, predictive)	
Ceiling/ floor effects	
Sensitivity to change (responsiveness, MCID, MDC)	
Reference Values for Interpretation	
Instrument use	
Equipment required	
Time to complete	
How is the instrument scored? (e.g. total score, subscales, etc.)	
Level of client participation required (proxy participation?)	
Effect of Training (if applicable)	

Is this tool appropriate for individual patient decision-making? Yes _____ No _____

(available MDC, MCID, Likelihood ratios?)

Comments:

Availability:

- Score Sheets:
  _____ Public Domain _____Available but copyrighted _____Unavailable
- Instructions:
  _____ Public Domain _____Available but copyrighted _____Unavailable
- Computer-based or Web-based scoring available: ____ yes _____ no

Purchase price:

Purchase Contact Info:

Assessment of Overall Usefulness (Primary Reviewer):

Secondary Reviewer Comments:

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