Published in final edited form as:

Arch Phys Med Rehabil. 2017 February ; 98(2): 264–269. doi:10.1016/j.apmr.2016.07.017.

The Association between Maximal Bench Press Strength and Isometric Handgrip Strength among Breast Cancer Survivors

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Abstract

Objective—One-repetition maximum (1-RM) bench press strength is considered the gold standard to quantify upper-body muscular strength. Isometric handgrip strength is frequently used as a surrogate for 1-RM bench press strength among breast cancer (BrCa) survivors. The relationship between 1-RM bench press strength and isometric handgrip strength, however, has not been characterized among BrCa survivors.

Design—Cross-sectional study.

Setting—Laboratory.

Participants—Community-dwelling BrCa survivors.

Interventions—Not applicable.

Main Outcome Measure—1-RM bench press strength was measured with a barbell and exercise bench. Isometric handgrip strength was measured using an isometric dynamometer with three maximal contractions of left and right hands. All measures were conducted by staff with training in clinical exercise testing.

Results—Among 295 BrCa survivors, 1-RM bench press strength was 18.2 ± 6.1 kg (range: 2.2–43.0) and isometric handgrip strength was 23.5 ± 5.8 kg (range: 9.0–43.0). The strongest correlate of 1-RM bench press strength was the average isometric handgrip strength of both hands ($r=0.399$; $P<0.0001$). Mean-difference analysis suggested that the average isometric handgrip strength of both hands overestimated 1-RM bench press strength by 4.7 kg (95% limits of agreement: -8.2 to 17.6). In a multivariable linear regression model, the average isometric handgrip strength of both hands ($\beta=0.31$; $P<0.0001$) and age ($\beta=-0.20$; $P<0.0001$) were positively correlated with 1-RM bench press strength ($R^2=0.23$).

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Disclosures: The authors report there exist no conflicts of interest.

Prior presentation of data: This study has not been previously presented.

Clinicaltrials.gov identifier: NCT00194363

Conclusions—Isometric handgrip strength is a poor surrogate for 1-RM bench press strength among BrCa survivors. 1-RM bench press and isometric handgrip strength quantify distinct components of muscular strength.

Keywords

exercise; muscle strength; breast cancer; musculoskeletal; lymphedema

As a result of improvements in curative care, the population of 3-million breast cancer (BrCa) survivors in the United States continues to grow.¹⁻² Advances in curative care have led to an increased focus on quality-of-life issues among the BrCa survivor population.³ BrCa survivors often experience treatment-related long-term side effects and physiological sequelae that result in losses of muscular strength, increases in fatigue, and worsening physical function, which may negatively impact quality-of-life.⁴⁻⁵ Slowly-progressive weightlifting increases muscular strength, which is associated with reductions in cancer-related fatigue, the preservation of physical function, and improved quality-of-life among BrCa survivors.⁶⁻⁹

Appropriately individualizing exercise prescriptions to maximize effectiveness among BrCa survivors requires that muscular strength be accurately quantified. The one-repetition maximum (1-RM) bench press test is considered the gold standard for quantifying upper-body muscular strength.¹⁰⁻¹¹ There are, however, often multiple barriers to implementing the 1-RM bench press in widespread clinical and research use. These barriers include: (1) the need for trained fitness professionals for instruction and administration of the test to ensure proper form and maximize safety; (2) the test's lack of portability due to the need for cumbersome equipment; (3) time requirement to appropriately administer the test; (4) the potential for exacerbation of BrCa-related upper body morbidities; and (5) the inability of untrained individuals to achieve true 1-RM's.¹²⁻¹⁶ Isometric handgrip strength has been proposed as an alternative modality to quantify upper-body muscular strength.¹⁷⁻¹⁸ The isometric handgrip strength test circumvents many of the barriers of 1-RM bench press testing due to its relative simplicity to administer, portability, and time-effective measurement.¹⁹⁻²⁰ It is unknown, however, if isometric handgrip strength is an appropriate modality to quantify upper-extremity muscular strength among BrCa survivors, as compared to that of the 1-RM bench press.

To this end, we examined the relationship between isometric handgrip strength and 1-RM bench press strength among BrCa survivors by analyzing data from the Physical Activity and Lymphedema (PAL) trial. The PAL trial was a randomized controlled study designed to determine the safety of weightlifting as a clinical intervention for BrCa survivors with or at-risk for upper-body lymphedema. We hypothesized that isometric handgrip strength would be a strong surrogate for 1-RM bench press strength.

METHODS

Participants

The primary aim of the PAL trial was to assess the safety of slowly-progressive weightlifting in two distinct groups of BrCa survivors: those with BrCa-related lymphedema (N=141) and those at risk for BrCa-related lymphedema (N=154).²¹ Participants in the PAL trial were randomized into either a slowly-progressive weightlifting intervention or into a non-exercise control group. The methods of the PAL trial, as well as the primary outcomes have been previously published.^{3, 14, 22} Briefly, BrCa survivors were recruited throughout the Philadelphia metropolitan area between October 1, 2005 and February 2007, with data collection ending in August 2008. Eligibility criteria for potential trial participants included the following: (1) female BrCa survivor 1-15 years post-diagnosis; (2) free from cancer at study entry; (3) 1 lymph node removed; and (4) no medical conditions or contraindicated medications that would prohibit the participant from engaging in an exercise program. Additional criteria included: (5) body mass index (BMI) $\leq 50 \text{ kg/m}^2$; (6) no future plans for surgery during the study; (7) no history of bilateral lymph node removal; (8) no weight lifting in the previous year; and (9) stable body weight while not attempting to lose weight.²³ BrCa survivors who regularly engaged in aerobic exercise were not excluded from the study.²² The study was approved by the University of Pennsylvania institutional review board. Participants provided informed consent and written clearance from their physician before participation.

Muscular Strength Measures

Study participants completed muscular strength measurements at baseline. These measurements were conducted under the supervision of a trained exercise physiologist. All participants performed a 1-RM barbell bench press to quantify upper-body strength. The initial weight attempted was based on the participant's self-reported rating of difficulty (1 to 10, 10 being the most difficult) after performing a warm-up set of 4-6 repetitions with a weight of 2.3-kg (5-lb). During the test, weight was progressively increased until the participant: (1) characterized the lift as a maximal effort; (2) was noticeably unable to perform the lift with proper biomechanics; (3) was physically unwilling or unable to attempt to lift more; or (4) reported a problem that required stopping. The 1-RM bench press test is safe among BrCa survivors.^{7-8, 22, 24-25}

Study participants completed a maximal isometric handgrip strength test at baseline using a Jamar dynamometer. The trained exercise physiologist provided instruction and demonstration on how to use the dynamometer. Participants were seated with their elbow flexed at a 90° angle and performed three maximal contractions in each hand in an alternating fashion with a 60-second rest period between each contraction. All participants were given standard uniform encouragement.²² We calculated six possible handgrip strength metrics that included: (1) the mean isometric strength of dominant hand; (2) the maximal isometric strength of the dominant hand; (3) the mean isometric strength of both hands; (4) the maximal isometric strength of both hands; (5) the mean isometric strength of the non-BrCa affected side; and (6) the maximal isometric strength of the BrCa affected side. These various handgrip strength metrics were calculated to examine the differential influence of an

isolated maximal effort (vs average maximal effort), the role of hand dominance, and the role of BrCa and their respective relationships with 1-RM bench press strength.

Demographic and Clinical Variables

Demographic characteristics including age (years), race (white, black, or other), and hand dominance were self-reported by participants at baseline. Clinical characteristics including BrCa stage (I, II, or III), time since diagnosis (months), menopausal status (pre or post), and location of BrCa (dominant vs. non-dominant side) were obtained from cancer state registry, surgical pathology reports, or via self-report. Lymphedema severity was quantified using water displacement volumetry.²¹ BrCa treatment therapies, including chemotherapy and radiation, were self-reported. General physical health and mental health were quantified using SF-36 questionnaire.²⁶ Anthropometric measures, including height and weight, were used to calculate body-mass index (BMI, kg/m²). Lean body mass (muscle mass) was quantified using dual-energy x-ray absorptiometry (DXA; Hologic Discovery, Bedford MA).²¹

Statistical Analysis

All statistical analyses were completed using Stata IC Version 14.1. Descriptive statistics are presented as means and standard deviations for continuous variables and counts and percentages for categorical variables. The primary statistical methods used to examine the relationship between 1-RM bench press strength and various isometric handgrip strength measures included: (1) Pearson correlations (r); (2) Bland-Altman mean-difference analysis to compare the degree of agreement and extent of bias between isometric handgrip strength and 1-RM bench press strength, and (3) multivariable linear regression to identify demographic, anthropometric, and clinical measures that were correlated with 1-RM bench press strength. $P < 0.05$ were used as the threshold for statistical significance.

RESULTS

Participant Characteristics

Demographic and clinical variables are described in Table 1. Study participants (N=295) had an average age of 55.9 (± 8.8 years) and were predominantly white (65%) or black (30%). The majority of participants (N=132) were diagnosed with Stage I (45%) or Stage III (N=92, 31%) BrCa. The average time since diagnosis was 60.8 (± 39.3 months). Half of the study participants (N=148, 50%) had BrCa on their dominant side and 48% of participants (N=141) had lymphedema. The average participant had a total body mass of 79.2kg (± 16.9 kg), a lean body mass of 48.3kg (± 7.6 kg), a height of 163cm (± 7.0 cm), and a BMI of 29.2 (± 6.1 kg/m²).

Relationship between 1-RM Bench Press Strength and Isometric Handgrip Strength

The average 1-RM bench press strength was 18.2 $\pm$ 6.1 kg (range: 2.2-43.0). The average isometric strength values for each handgrip metric are described in Table 2. All isometric handgrip strength metrics were statistically significantly ($P < 0.0001$) correlated with 1-RM bench press strength, but the magnitude of the correlations with 1-RM bench press strength was modest (r 's ranging from 0.29 to 0.39). The average maximal isometric strength of both

hands yielded the strongest grip strength 26.6kg (± 6.3 kg, $r=0.369$, $\beta=0.361$) and average isometric strength of both hands was the strongest correlate (23.5 ± 5.8 kg, $r=0.399$, $\beta=0.417$) of 1-RM bench press strength.

Univariable linear regression analyses of demographic, clinical, and anthropometric correlates of 1-RM bench press strength are described in Table 3. We selected the isometric handgrip strength variable that was most strongly correlated with 1-RM bench press strength for consideration in our linear regression analyses (average isometric strength of both hands). Age correlated with bench press strength: for each one-year increase in age, 1-RM bench press strength was lower by 0.28 kg. Among clinical variables, BrCa on patient's dominant side, arm volume, menopausal status, and chemotherapy treatment were positively correlated with 1-RM bench press strength. Among anthropometric variables, total body mass, lean body mass, and height were positively correlated with 1-RM bench press strength. Physical health was also positively correlated with 1-RM bench press strength. In multivariable regression analyses, handgrip strength (mean of both hands) [$\beta=0.31$, 95% CI 0.20 to 0.43] and age [$\beta=-0.20$, 95% CI -0.28 to -0.13] were the strongest correlates of 1-RM bench press strength, and accounted for 23% of the variance in 1-RM bench press strength ($R^2=0.23$; $P<0.0001$).

Mean-difference analysis (Figure 1) indicated that isometric handgrip strength overestimated 1-RM bench press strength by an average of 4.7 kg (95% limits of agreement: -8.2 to 17.6). This overestimation was consistent across the range of muscular strength values ($P<0.001$).

DISCUSSION

The major finding of this analysis is that isometric handgrip strength is a poor surrogate for 1-RM barbell bench press strength among BrCa survivors. The results of this analysis suggest that 1-RM bench press and isometric handgrip strength measure distinct components of upper-body muscular strength. These results are consistent with a prior study conducted among older adults.²⁷ We calculated several metrics of isometric handgrip strength and all correlations with 1-RM bench press strength were modest or weak in magnitude. This analysis demonstrates that these two common modalities used to quantify upper-extremity muscular strength are not interchangeable.

The poor correlation between isometric handgrip strength and 1-RM bench press strength may be the result of fundamental differences in exercise protocol biomechanics. The 1-RM bench press test is a multi-joint isotonic exercise that requires the simultaneous recruitment of multiple, large muscle groups undergoing concentric contractions. In contrast, isometric handgrip strength test is a single-joint exercise that isolates fewer and smaller muscle groups undergoing static contractions and is performed using one-hand at a time.²⁸⁻³¹ Such differences in exercise biomechanics and muscle recruitment patterns may help to explain our findings. Mean isometric strength of both hands was the strongest correlate ($\beta=0.417$, 95% CI 0.306-0.528, $P<0.0001$) of 1-RM bench press strength, and the maximum isometric handgrip strength on non-BrCa affected side was the weakest correlate ($\beta=0.236$, 95% CI 0.108 to 0.363). This pattern provides insight that isometric handgrip metrics that integrate

the strength of both hands are marginally stronger correlates of 1-RM bench press strength than isometric handgrip metrics that integrate one hand/side of the body.

Although isometric handgrip strength is a poor surrogate of 1-RM bench press strength, it is useful in various clinical settings. Among a wide variety of muscular strength measures, isometric handgrip strength is considered to be the simplest method.³²⁻³³ Given its simplicity, portability, and relatively low impact, isometric handgrip strength testing is common in many clinical and epidemiological studies that focus on at-risk individuals.³⁴⁻³⁵ Isometric handgrip strength is also a strong predictor of functional limitations, disability, quality of life, and mortality.^{17-18, 36} Despite the poor correlation of isometric handgrip strength with 1-RM bench press strength, isometric handgrip strength testing has established clinical utility.

The results of our study may have important implications for exercise prescription BrCa survivors in clinical settings. Upper-extremity muscular strength among BrCa survivors is significantly below age-matched normative values, consequently BrCa survivors may benefit from muscular strengthening activities.³⁵ Multiple randomized clinical trials have demonstrated that resistance-based exercise can be safely prescribed during BrCa treatment.³⁷⁻³⁸ This recommendation has been endorsed by the American College of Sports Medicine.³⁹ However, BrCa survivors often experience upper-extremity morbidity as a result of cancer treatment. Between 10 and 64% of BrCa survivors report upper-extremity symptoms for up to 36 months after treatment.⁴⁰ Identifying and characterizing these upper-extremity morbidities are critical to delineate therapeutic goal setting and to appropriately individualize the exercise prescription. Although the 1-RM bench press remains the gold-standard modality to quantify upper-extremity strength, it may not always be feasible, safe, or available in a variety of clinical settings. Therefore our data provide rehabilitation and exercise professionals with detailed insight to interpret how to best use isometric handgrip strength as a testing modality. A multidisciplinary team, including rehabilitation physicians, physical therapists, and exercise physiologists, may be necessary to provide comprehensive rehabilitative care to breast cancer survivors, such as that proposed in the prospective surveillance model.⁴¹

Study Limitations

There are several limitations to this analysis. The main limitation is the study population as this was a secondary analysis of a randomized trial. It is possible that BrCa survivors who participated in the PAL trial were not representative of the wider BrCa survivor population with respect to muscular strength. Conversely, there are several strengths to this analysis. The muscular strength measures of 1-RM bench press strength and isometric handgrip strength included a wide range of values. Isometric handgrip strength was measured repeatedly in both hands following a standardized protocol that allowed us to examine a variety of isometric handgrip strength summary measures. We were also able to examine the influence of hand dominance and BrCa. We examined a variety of covariates that may influence muscular strength including age, race, lymphedema arm volume, lean muscle mass quantified using DXA, and self-reported measures of physical and mental health.

Conclusion

In conclusion, isometric handgrip strength is a poor surrogate for 1-RM bench press strength among BrCa survivors. 1-RM bench press and isometric handgrip strength quantify distinct components of muscular strength among BrCa survivors and should not be considered exchangeable. This analysis may be useful to rehabilitation and exercise professionals who design slowly-progressive weightlifting programs or clinical researchers who seek to quantify upper-body muscular strength among BrCa survivors.

Acknowledgments

Funding Source: Supported by R01-CA106851 from the National Cancer Institute

Abbreviations

BrCa	Breast cancer
1-RM	one-repetition maximum

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Figure 1.
Bland Altman Plot Comparing Mean Handgrip Strength of Both Hands versus Maximal Bench Press Strength

Table 1

Demographic and Clinical Characteristics of Sample

Variable	Mean±SD or N (%)
Demographic Variables	
Age – yr	55.9±8.8
Race	
White	191 (65%)
Black	90 (30%)
Other	14 (5%)
Clinical Variables	
BrCa Stage	
DCIS	1 (<1%)
I	132 (45%)
II	3 (1%)
III	92 (31%)
Unknown	67 (23%)
BrCa on Dominant Side	148 (50%)
Months since diagnosis	60.8±39.3
Lymphedema	141 (48%)
% Inter-limb volume difference	7.7±13.7
Chemotherapy	224 (76%)
Radiation	229 (78%)
Post-Menopausal	252 (86%)
Anthropometric Variables	
Total Body mass	79.2±16.9
Lean body mass	48.3±7.6
Height	1.63±0.07
BMI	29.2±6.1
Other Variables	
SF-36	
Physical health	48.1±9.1
Mental health	52.3±9.6

Table 2
Relationship between various handgrip strength metrics and maximal bench press strength

Handgrip Strength Metric	Mean±SD (kg)	Pearson <i>r</i>	<i>P</i>	β	95% CI	<i>P</i>
Mean Dominant Hand	24.1±6.4	0.359	<0.0001	0.344	0.240 to 0.448	<0.0001
Max Dominant Hand	25.6±6.5	0.363	<0.0001	0.341	0.239 to 0.443	<0.0001
Mean Both Hands	23.5±5.8	0.399	<0.0001	0.417	0.306 to 0.528	<0.0001
Max Both Hands	26.6±6.3	0.369	<0.0001	0.361	0.256 to 0.467	<0.0001
Mean Hand of Non-BrCa Side	23.8±6.0	0.350	<0.0001	0.358	0.247 to 0.468	<0.0001
Max Hand Non-BrCa Side	25.5±6.6	0.295	<0.0001	0.236	0.108 to 0.363	<0.0001

Table 3
Relationships between Demographic, Clinical, and Anthropometric Characteristics and Maximal Bench Press Strength

	Univariable			Multivariable		
	β	95% CI	<i>P</i>	β	95% CI	<i>P</i>
Handgrip Strength Variable						
Mean Both Hands	0.42	0.31 to 0.53	<0.0001	0.31	0.20 to 0.43	<0.0001
Demographic Variables						
Age – yr	–0.28	–0.36 to –0.21	<0.0001	–0.20	–0.28 to –0.13	<0.0001
Race						
White	0.00	[reference]	—			
Black	0.05	–1.51 to 1.62	0.946			
Other	–1.47	–4.84 to 1.90	0.392			
Clinical Variables						
BrCa Stage						
DCIS	–2.70	–14.97 to 9.56	0.665			
I	0.00	[reference]	—			
II	1.19	–8.33 to 5.94	0.742			
III	0.52	–1.14 to 2.19	0.535			
Unknown	0.11	–1.73 to 1.96	0.904			
BrCa on Dominant Side	1.76	0.35 to 3.17	0.014			
Months since diagnosis	0.001	–0.01 to 0.02	0.936			
Lymphedema	–0.29	–1.72 to 1.13	0.687			
% Inter-limb volume difference	–0.05	–0.11 to –0.01	0.040			
Chemotherapy	1.78	0.12 to 3.43	0.035			
Radiation	0.82	–0.88 to 2.53	0.343			
Post-Menopausal	–2.52	–4.55 to –0.49	0.015			
Anthropometric Variables						
Total Body mass	0.05	0.01 to 0.09	0.026			
Lean body mass	0.19	0.10 to 0.28	<0.0001			
Height	0.17	0.07 to 0.27	0.001			
BMI	0.06	–0.05 to 0.18	0.278			

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Other Variables		Univariable	Multivariable
SF-36			
Physical health		0.10	0.02 to 0.18
Mental health		−0.01	−0.08 to 0.07
			0.908