Original Article

Forearm Muscle Activity During the Handgrip Test in Breast Cancer Survivors: A Cross-Sectional Study

Iván José Fuentes-Abolafio,[a,b] Cristina Roldán-Jiménez,[a,b] Marcos Iglesias Campos,[c] Bella I Pajares-Hachero,[b,c] Emilio Alba-Conejo,[c] Antonio Cuesta-Vargas[a,b,d]

Abstract

We recruited 102 breast cancer survivors at a secondary care in Malaga. Included breast cancer survivors showed a good upper limb functionality but a reduced forearm muscle activity. Forearm muscle activity showed a poor significant correlation with the cancer-related fatigue . Handgrip strength also showed a poor correlation with the upper limb functionality. Both outcomes tended to lower values with higher levels of cancer-related fatigue.

Introduction/Background: Breast cancer survivors (BCS) frequently show upper limb dysfunctions. The forearm muscle activity measured by surface electromyography (sEMG) in this population has not been studied. This study aimed to describe forearm muscle activity in BCS, as well as to assess its possible relationship with other variables related to upper limb functionality and cancer-related fatigue (CRF). **Materials and Methods:** A cross-sectional study was carried out including 102 BCS as volunteers at a secondary care in Malaga, Spain. BCS were included if they were aged between 32 and 70 years old, without evidence of cancer recurrence at the time of recruitment. The forearm muscle activity (microvolts, µV) was assessed by sEMG during the handgrip test. The handgrip strength was assessed by dynamometry (kg), the upper limb functionality (%) was measured by the upper limb functional index (ULFI) questionnaire and the CRF was also assessed by revised Piper Fatigue Scale (0-10 points). **Results:** BCS reported reduced forearm muscle activity (287.88 µV) and reduced handgrip strength (21.31 Kg), a good upper limb functionality (68.85%), and a moderate cancer-related fatigue (4.74). Forearm muscle activity showed a poor significant correlation ($r = -0.223$, $P = .038$) with the CRF. Handgrip strength showed a poor correlation with the upper limb functionality ($r = 0.387$, $P < .001$) and age ($r=-0.200$, $P = .047$). **Conclusion:** BCS showed a reduced forearm muscle activity. BCS also presented a poor correlation between forearm muscle activity and handgrip strength. Both outcomes tended to lower values with higher levels of CRF, while preserving a good upper limb functionality.

Clinical Breast Cancer, Vol. 000, No.xxx, 1–7 © 2023 The Authors. Published by Elsevier Inc.
This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)
Keywords: Cancer-related fatigue, Electromyography, Upper extremity, Hand Grip Strength, Breast cancer survivor

Introduction

Worldwide, breast cancer (BC) is the most frequently diagnosed cancer in women and accounts for 30% of all new cancer diagnoses in women.[1-5] BC is also the leading cause of cancer death in women[2,5,6] and accounts for 15% of all cancer deaths.[2,3] However, survival rates have increased by 38% to 40% in recent years thanks to early detection and the advancement in treatments.[2-4] In this way, the current survival rates for women diagnosed with BC are 89% at 5 years after diagnosis.[7]

Breast cancer survivors (BCS) women experience subsequent morbidity and treatment-related side effects, which may acutely or chronically compromise the musculoskeletal system.[8] Thus, besides pain and cancer-related fatigue, women can develop a wide range of upper limb dysfunctions after BC treatments, such as impaired range of motion (RoM), decreased muscle strength, shoulder weakness, lymphedema, neurologic symptoms, swelling, altered postures and kinematics, and limitations in activities of daily

[a]Departamento de Fisioterapia, Facultad de Ciencias de la Salud, Universidad de Málaga, Andalucia Tech, Málaga, España
[b]Instituto de Investigación Biomédica de Málaga y Plataforma en Nanomedicina-IBIMA Plataforma BIONAND, Málaga, España
[c]UGCI Oncología Médica Hospitales Universitarios Regional y Virgen de la Victoria Campus de Teatinos, S/N, 29010. Málaga, España
[d]School of Clinical Science, Faculty of Health Science, Queensland University Technology, Brisbrane, Queensland,Australia

Submitted: Sep 27, 2022; Revised: Jan 13, 2023; Accepted: Jan 16, 2023; Epub: xxx

Corresponding author: Cristina Roldán Jiménez, PhD, Departamento de Fisioterapia, Facultad de Ciencias de la Salud, Universidad de Málaga. Arquitecto Francisco Peñalosa s/n. (ampliación Campus Teatinos) 29071 Málaga, Spain.
E-mail contact: cristina.roldan@uma.es

1526-8209/$ - see front matter © 2023 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)
https://doi.org/10.1016/j.clbc.2023.01.008

Please cite this article as: Iván José Fuentes-Abolafio et al, Forearm Muscle Activity During the Handgrip Test in Breast Cancer Survivors: A Cross-Sectional Study, Clinical Breast Cancer, https://doi.org/10.1016/j.clbc.2023.01.008

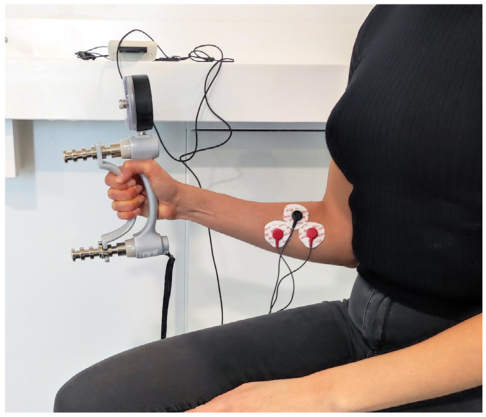
living.[9-16] Those impairments result from treatment, such as surgery or chest radiotherapy.[12] For example, mastectomy is a risk factor for reduced ROM, and a reduced ROM is related to a greater number of lymph nodes removed and some complications such as cording or seroma.[17] Upper limb dysfunctions in BCS have been assessed using questionnaires such as the Disability of the Arm, Shoulder and Hand (DASH),[14,18,19] the Shoulder Pain and Disability Index (SPADI)[10,20,21] or the Upper Limb Functional Index (ULFI).[22] Upper limb muscle strength has been frequently assessed by the handgrip strength using a dynamometer.[19,23,24] Moreover, impaired RoM and altered upper limb postures and kinematics have been analyzed using electromagnetic position and orientation movement tracking devices or a depth camera.[9,10,16] The electric signal from muscles recorded by surface electromyography (sEMG) allows for obtaining information about the time or intensity of superficial muscle activity.[25] However, the muscle activity of the main upper limb muscles by sEMG has been little studied in BCS women. A study investigated the effects of handgrip strength in the activation of shoulder muscles on the scapular plane.[26] Other studies compared the activity pattern from shoulder muscles between BCS and a healthy sample[27] and the presence of pain.[28] However, those studies did not include forearm muscle activity. Only 1 study analyzed the handgrip strength and electromyography (EMG) of the upper limbs, including superficial flexors of the wrist and fingers.[29] However, its analysis was focused on the relationship between EMG and other factors such as dominance or surgery side in BC women after surgery.[29] Thus, the objective of the present study is to describe forearm muscle activity assessed by sEMG during the handgrip test in BCS, as well as to assess its possible relationship with other variables related to upper limb functionality.

Materials and Methods

Design

In order to achieve the set-out objectives, a cross-sectional study was carried out, and 102 BCS women were recruited as volunteers between May 2017 and October 2018 from the Medical Oncology Unit at University Clinical Hospital Virgen de la Victoria (Málaga, Spain) by Medical Oncologists. BCS included in this study were between 32 and 70 years old and had been surgically treated for their primary tumor with no evidence of recurrence at the time of recruitment. BCS were not excluded if they were undergoing hormonal treatment, radiotherapy or antiHER therapy. BCS were excluded if they had suffered any cardiovascular event defined as stable or unstable angina, acute pulmonary oedema, cardiac rhythm disorders, or syncope of unrelated aetiology in the year prior to inclusion. The study was registered on the ClinicalTrial.gov database as NCT03879096. Ethical approval was obtained from the Portal de Ética de la Investigación Biomédica de Andalucía Ethics Committee, Spain (28042016). The study was conducted in accordance with the Helsinki Declaration[30] and was implemented and reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement.[31,32] Moreover, all participants in this study signed an informed consent form prior to enrolment. The STROBE checklist for this study is shown in Supplementary Appendix A.

Figure 1 A subject performing handgrip test with sEMG electrodes.



Procedure

Medical Oncologists carried out the recruitment and assessed the participants for eligibility in their consultations. If the participants met the eligibility criteria, they were invited to participate in this study. Participants were assessed only once. All participants in this study signed an informed consent form prior to inclusion. Participants attended physical medicine and rehabilitation outpatient sessions at the hospital for the assessment.

Clinical data on years from diagnosis, type of surgery (breast-conserving or mastectomy), type of adjuvant treatment (radiotherapy, chemotherapy, hormone therapy or monoclonal antibody) and current treatment (none, radiotherapy, monoclonal antibody or hormone therapy) was measured. Clinical history information and descriptive data (age, height, weight) were completed with the following measures:

Measures

Forearm Muscle Activity: forearm muscle activity was assessed by sEMG during the handgrip test, as was performed in a previous study.[33] Participants had to perform the handgrip test with their right hand 3 times. The EMG electrodes (Lessa, Barcelona, Spain, 37 × 41 mm, Ag/AgCl) were placed on the proximal third of the right forearm (Figure 1). Thus, while participants performed the handgrip test, the muscle activity of the right forearm muscles was collected following the European Society of Electromyography (SENIAM) recommendations.[34] The mean of the forearm muscle activity during the 3 repetitions of the handgrip test was calculated. Each participant carried out a 5-minute warm-up of their forearm muscles before performing the handgrip test. Then, participants performed 3 maximal isometric voluntary contractions for 5 seconds. Subjects were able to rest 60 seconds between each repetition. The sEMG raw signal was registered using the MEGA ME6000 (Mega Electronics Ltd, Kuopio, Finland). Dependent variables were obtained through electromyographic measures (Megawin 3.0.1., Mega Electronics Ltd, Kuopio, Finland) during

Please cite this article as: Iván José Fuentes-Abolafio et al, Forearm Muscle Activity During the Handgrip Test in Breast Cancer Survivors: A Cross-Sectional Study, Clinical Breast Cancer, https://doi.org/10.1016/j.clbc.2023.01.008

the handgrip test. Rectification medium voltage (RMS averaging) was measured. Two reference electrodes were positioned in line over the proximal third of the forearm to collect the electrical muscle activity of both the flexor digitorum superficialis and flexor digitorum profundus because the contractions of these muscles contribute to a more powerful grip.[35,36] A ground electrode was placed close to the reference electrodes. The size of the electrodes was 37 × 41 mm. Electrodes were placed following the suggestions of previous studies in the literature, with 2 reference electrodes in line and 1 ground electrode next to them.[37,38] The participants were also given an opportunity to familiarize themselves with performing the handgrip test while attached to electrodes. A physiotherapist assessed each trial to determine if extraneous noise or artifact was present, which could diminish the integrity of the signal. Moreover, before placing the electrodes on skin, patients' skin was cleaned and dried. The skin was cleaned by using alcohol. The appropriate preparation of the skin was conducted in order to reduce the impedance in the electrode-gel-skin interface and possible noises or artifacts.

Handgrip Strength. Jamar Hydraulic Hand Dynamometer Model SH5001 (Lafayette Instrument, Lafayette, LA) was used to assess the strength. Handgrip dynamometry is the main measure of grip strength. All participants performed the handgrip test according to the recommendations of the American Society of Hand Therapy (ASHT), that is, sat on a chair without armrests with their feet on the floor and a straight back, holding the dynamometer with the right arm. The elbow was flexed at 90°, and the wrist was in a neutral position (0°).[39] The participant performed 3 isometric maximal voluntary contractions for 5 seconds. The strength mean of the 3 isometric maximal voluntary contractions was calculated and reported in kg.

Upper limb functionality: the Spanish version of ULFI questionnaire was filled in by each participant. The Spanish version of ULFI has shown strong psychometric properties for reliability and validity. ULFI consists of a 25-item scale transferable to a 100-point scale which can assess the upper limb functionality.[22] Values are expressed as a functionality percentage (%). This scale has high internal consistency ($\alpha = 0.94$) and reliability ($r = 0.93$).[22]

Cancer-Related Fatigue (CRF). The Spanish version of the revised Piper Fatigue Scale (PFS-R) was used. This contains 22 items with scores ranging from 0 to 10 and includes 4 aspects of subjective fatigue. This scale has high reliability (Cronbach's α=0.96) in this population.[40] A total score was calculated as the overall sum (0-220 and transferred to a 0-10 point scale (0=none, 1-3=mild, 4-6=moderate, 7-10=severe),[41] with higher scores indicating greater fatigue.[40]

Bias

A large sample size of BCS was recruited in order to reduce or address any risk of selection or performance bias. This large sample size of BCS could allow to detect a clear correlation between the forearm muscle activity and the handgrip strength, the upper limb functionality or the CRF. Moreover, the cross-sectional design could reduce any risk of detection bias as it reduces the possibility of missing data. In order to reduce any risk of information bias, the upper limb functionality was assessed by objective outcomes such as forearm muscle activity by sEMG and handgrip strength, and subjective self-reported scales such as the ULFI.

Sample Size

The sample size was calculated using the software G Power 3.1.9.2 (University of Düsseldorf, Germany). To contrast the alternative hypothesis, the correlation magnitude that is going to be detected a priori between the forearm muscle activity and the upper limb functionality assessed will be 0.6 and considering a significance level of 0.05 (error α<5%), and a statistical power of 0.9 (90%), a sample consisting of 102 BCS was needed. Medical Oncologists carried out the recruitment in their consultations and made it possible to obtain the estimated sample size.

Data Analysis

Only descriptive analyses were carried out. Thus, qualitative measures were described by an absolute frequency and a percentage. Quantitative measures, as anthropometric variables, were reported using the mean and the standard deviation (SD) and through the maximum and the minimum. Distribution and normality were determined by one-sample Kolmogorov-Smirnov tests (significance <0.05). The Pearson Correlation Coefficient (r) was used to assess the possible bivariate correlations between the forearm muscle activity, the handgrip strength, the upper limb functionality, the CRF and age (years). The correlation was classified into 3 categories: poor (r≤0.49), moderate (0.50≤ r ≤0.74) and strong (r≥0.75). All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) Version 22.0 (IBMc Corp.,Armonk, NY) for Windows.

Results

Patients' Characteristics

Data from 102 included BCS were analyzed. The descriptive and clinical variables are shown in Table 1. Descriptive statistics of the study outcomes are reported in Table 2. Most of women had undergone breast-conserving surgery (86.30%), had received chemotherapy (51.96%), radiotherapy (53.92%) and were still under hormone therapy (61.40%). Time from diagnosis ranged from 0 to 8 years. The mean age of included women was 51.21 years old, and the mean body mass index (BMI) was 27.97 Kg/m^2, which could indicate a slight overweight on average among the women included in the study.

The mean forearm muscle activity showed by the sEMG during the handgrip test was 287.88 µV (187.08), while the mean strength in the handgrip test was 21.31 kg (5.13). The ULFI showed a mean upper limb functionality of 68.85% (22.38), which could be indicated of a good upper limb functionality in BCS. The mean CRF was 4.74 points (2.82). In this way, included BCS showed a moderate fatigue, although a good upper limb functionality.

The bivariate correlations between the forearm muscle activity, the handgrip strength, the upper limb functionality and the CRF are reported in Table 3. In summary, the forearm muscle activity during the handgrip test only showed a significant but weak, poor and inversely proportional correlation ($r = -0.223$, $P = .038$) with the CRF. The handgrip strength also showed an inversely proportional but not significant correlation with the CRF ($r = -0.208$, $P = .053$).

Please cite this article as: Iván José Fuentes-Abolafio et al, Forearm Muscle Activity During the Handgrip Test in Breast Cancer Survivors: A Cross-Sectional Study, Clinical Breast Cancer, https://doi.org/10.1016/j.clbc.2023.01.008

Table 1 Participant Descriptive and Clinical Variables (n=102)

		Mean (SD)	Min-Max
Age (y)		51.21 (8.96)	32.0-70.0
Height (m)		1.62 (0.7)	1.42-1.78
Weight (Kg)		73.72 (13.30)	47.20-108.50
BMI (Kg/m^2)		27.97 (5.28)	20-47.70
Y from diagnosis		2.06 (1.63)	0-8
Surgical intervention			Percentage (n)
	Breast-Conserving surgery		86.3% (88)
	Mastectomy		13.7% (14)
Cancer treatment			
	Chemotherapy		51.96% (53)
	Radiotherapy		53.92% (55)
	Hormone Therapy		45.09% (46)
	Monoclonal Antibody		38.23% (39)
Current treatment			
	None		21.1% (21)
	Chemotheraphy		1.8% (2)
	Radiotherapy		5.3% (5)
	Monoclonal antibody		10.4% (11)
	Hormone therapy		61.4% (63)

Forearm muscle activity was not correlated with handgrip strength ($r = 0.22$, $P = .824$) or the upper limb functionality ($r = 0.163$, $P = .126$). However, handgrip strength showed a directly proportional correlation with the upper limb functionality ($r = 0.387$, $P < .001$) and an inversely poor correlation with age ($r = -0.200$, $P = .047$).

Discussion

The objective of this study was to describe forearm muscle activity assessed by sEMG during the handgrip test in BCS. Moreover, we intended to assess any possible correlation between forearm muscle activity and handgrip strength, CRF or upper limb functionality. As a main finding, forearm sEMG only had a weak an inversely correlation with CRF, while the only outcome that correlated with upper limb function was handgrip strength.

Regarding forearm muscle activity, it showed a significant poor and inversely proportional correlation ($r = -0.223$, $P = .038$) with CRF assessed by the PFS-R scale. That is, the more fatigue, the less forearm muscle activity. The inversely proportional correlation between forearm muscle activity and CRF could be explained by cancer treatmentś toxicity, which may have affected nerve conduction. It has been reported that chemotherapy can induce a peripheral neuropathy in 30% to 40% of patients treated with taxanes and platinum analogues.[42] Taxanes are tubulin inhibitors that damage neuronal axons, while platinum analogues accumulate in the cell body of sensory nerves and cause DNA damage. In this way, taxanes and platinum analogues can produce paresthesia, pain, sensory deficits, but rarely as motor weakness.[43] However, BCS patients from the present study were not classified according to the treatment received or the presence or absence of neuropathies, so any conclusion can be made in this regard

The descriptive results reported that BCS have a mean value of 287.88 (187.08) µV during the handgrip test. A previous study showed a mean forearm muscle activity of 499.29 (224.20) µV during the handgrip test in healthy subjects,[33] so BCS have a reduced forearm muscle activity in comparison with healthy subjects. Perez et al.[29] reported a muscle activity of the superficial flexors of wrist and fingers during the handgrip test in BCS that ranged from 29.57 µV to 47.63 µV depending on whether the arm was dominant or not, or whether the arm was operated on or not,[29] as well as a larger decline electromyographic activity and handgrip strength in the upper limb affected by BC surgery. However, the data from both studies cannot be compared as the method used to obtain the variable was different.

Regarding handgrip strength, BCS also had a reduced handgrip strength (21.31 Kg) in comparison with healthy subjects (25.50 kg).[33] Present results conclude with Perez et al.,[29] that also reported a reduced handgrip strength in BCS, which ranged from 18.53 kg to 20.33 kg. In line with these results, Cantarero-Villanueva et al.[23] reported a lower median handgrip strength in BCS (18.30 Kg). However, other studies found values higher than in the present study. For example, Rogers et al.[44] found that BCS had a value of 24.1±6.4 Kg in their dominant arm, and Smoot et al.[45] reported a larger handgrip strength 1 month postoperative in BC women (24.3 Kg in the unaffected side and 24.0 Kg in the affected side). Morishita et al.[46] also reported a larger mean handgrip strength in the right arm in different cancer survivors (26.3 ± 7.8 Kg). This difference could be due to the inclusion of different cancer survivors, such as lung cancer survivors, BCS or gastric cancer survivors,[46] and not just BCS as in our study. Rogers et al.,[44] Cantarero-Villanueva et al.,[23] Perez et al.[29] and Smoot et al.[45] also reported a reduced handgrip strength in BCS, in comparison with healthy subjects in a previous study.[33] In any case, although the results obtained in our study on the handgrip strength are lower than results shown by other studies,[33,44,46] the mean handgrip strength of the included BCS is larger than the cut-off point established by the European Consensus for sarcopenia in 2010 (<20 Kg)[47] and 2019 (<16 Kg).[48] This

Table 2 Descriptive Statistics of the Study Outcomes

	Minimum	Maximum	Mean	SD
Forearm muscle activity (sEMG, µV)	14.00	974.00	287.88	187.08
Handgrip strength (Kg)	9.33	34.67	21.31	5.13
Upper limb functionality (ULFI, %)	.00	100.00	68.85	22.38
CRF (PFS-R,1-10 points)	.00	12.78	4.74	2.82

Abbreviations: CRF = Cancer-related fatigue; PFS-R = the revised Piper Fatigue Scale; sEMG = surface electromyography; SD = standard deviation; ULFI = upper limb functional index.

Please cite this article as: Iván José Fuentes-Abolafio et al, Forearm Muscle Activity During the Handgrip Test in Breast Cancer Survivors: A Cross-Sectional Study, Clinical Breast Cancer, https://doi.org/10.1016/j.clbc.2023.01.008

Table 3 Bivariate Correlations (r, p) Between Forearm Muscle Activity, Handgrip Strength, Upper Limb Functionality and CRF

	Upper Limb Functionality (ULFI, %)	CRF (PFS-R, 1-10 Points)	Forearm Muscle Activity (sEMG, μV)	Handgrip Strength (Kg)	Age (y)
Upper limb functionality (ULFI, %)	1	-.195 (.081)	.163 (.126)	.387 (.000)[b]	-0.002 (0.983)
CRF (PFS-R, 1-10 Points)	-.195 (.081)	1	-.223 (.038)[a]	-.208 (.053)	-0.072 (0.492)
Forearm muscle activity (sEMG, μV)	.163 (.126)	-.223 (.038)[a]	1	.022 (.824)	-0.127 (0.207)
Handgrip strength (Kg)	.387 (.000)[b]	-.208 (.053)	.022 (.824)	1	-0.200 (0.047)[a]
Age (y)	-0.002 (0.983)	-0.072 (0.492)	-0.127 (0.207)	-0.200 (0.047)[a]	1

r: Pearson Correlation Coefficient; p: Bilateral Significance
Abbreviations: CRF = Cancer-related fatigue; PFS-R = the revised Piper Fatigue Scale; sEMG = surface electromyography; ULFI = upper limb functional index.
[a] $P < .05$
[b] $P < .001$.

could indicate that cancer treatments could cause premature aging that does not translate into sarcopenia, just muscle weakness. In this regard, it should be noteworthy that handgrip strength showed a significant and inversely poor correlation with age ($r = -0.200$, $P = .047$). That is to say: The more aged the patient is, the less grip strength the patient has. However, age was not correlated with the rest of the outcomes. Therefore, besides treatments, future research should consider the age of the patient when analyzing upper limb strength.

In the present study, although the handgrip strength showed a similar correlation with the CRF, it was not significant. This concur with a previous study that found no correlation between handgrip strength and fatigue in cancer survivors.[46] On the contrary, Cantarero-Villanueva et al.[23] showed a significant inversely proportional correlation between handgrip strength and CRF using the original Piper scale (Spearman correlation=-0.351,$P < .001$). This poor correlation could be due to the fact that CRF is multifactorial and not exclusively dependent on muscle strength, but depends on other factors such physical conditions, sleep disturbance, adverse reactions to medication, depression, and anxiety, affective and cognitive states, distress or spiritual suffering.[49,50]

Regarding CRF, BCS sample in the present study reported a moderate CRF (4.74 points) which could also be caused by the treatment's toxicity. This toxicity in turn could be responsible for the decrease in forearm muscle activity when CRF increases due to impaired nerve conduction without alteration of muscle strength, which is why the handgrip strength was not correlated with CRF.

BCS showed a good value in upper limb functionality, with a ULFI score of 68.85%. Hayes et al.[19] also reported a good upper limb functionality in BC women 6 months following diagnosis, with a DASH score of 10.8. It has been reported that the leading cause of upper limb dysfunction in BCS could be upper limb pain, which accounted for 60% of the DASH score in a previous study.[51] Another study suggested that upper limb dysfunction in BCS may be associated with neuropathies due to changes in the intercostobrachial nerve pathway.[52]

On the other hand, our results also reported that forearm muscle activity was not correlated with handgrip strength ($r = 0.22$, $P = .824$). This could be due to the fact that electrical muscle activity assessed in microvolts (μV) using the sEMG and handgrip strength calculated in kilograms (Kg) in the handgrip test represent 2 different dimensions. Moreover, the relationship between sEMG muscle activity and muscular strength seems to depend on the muscle studied. Thus, it has been reported a linear relationship between sEMG muscle activity and the adductor pollicis and first dorsal interosseous and soleus strength, and a nonlinear relationship for the biceps and deltoid in healthy subjects.[53] In addition to the muscle itself, there are other factors that could interfere in the relationship between sEMG muscle activity and muscle strength, such as the type of movement (isometric, concentric or eccentric), the muscle thickness, or symptoms such as muscle fatigue.[54,55]

Strengths and Limitations of the Study

The main strength of our study is the description of the forearm muscle activity by sEMG during the performance of the handgrip test, which had not been previously analyzed. Another strength of the study lies in the sample size. However, there are several limitations that must be taken into account when interpreting the results. First, the variation of the surgical time could be a limiting factor of the results. Moreover, sEMG always shows limitations such as the cross-talk phenomenon because the muscle under study may not be fully under the skin but covered by parts of other muscles or subcutaneous adipose tissue. Included BCS in our study reported a slightly overweight so their adipose tissue could be significant. Thus, weight variability as well as adipose tissue could affect the electromyographic signal, although the area analyzed in the different included BCS was always the same. Furthermore, we have not analyzed differences in forearm muscle activity between the dominant or non-dominant side or the operated side vs. the non-operated side. Forearm muscle activity and the handgrip strength were performed by included BCS on the right hand per protocol.

Implications for Clinical Practice

Results from the present study found that forearm sEMG during handgrip test only correlates inversely with CRF, while the only outcome that correlates with upper limb function was handgrip strength. Therefore, clinicians are advised to assess handgrip by dynamometry in combination with patient-reported outcomes such as ULFI in those BCS with affected upper limb function. Given the correlation between handgrip strength and upper limb function, strength exercise intervention may be used to prevent upper limb dysfunctions in this population. Future research should assess possible relationships between muscle activity in sEMG and muscle mass assessed by ultrasound variables such as muscle thickness. Moreover,

Please cite this article as: Iván José Fuentes-Abolafio et al, Forearm Muscle Activity During the Handgrip Test in Breast Cancer Survivors: A Cross-Sectional Study, Clinical Breast Cancer, https://doi.org/10.1016/j.clbc.2023.01.008

an in-depth analysis of variables related to muscle function such as muscle strength, muscle mass and muscle activity in sEMG could be indicative of the muscle impairment suffered by BCS. Lastly, future research should study the possible influence of chemotherapy-induced peripheral neuropathy, obesity or years from diagnosis in muscle activity.

Conclusion

Forearm sEMG during handgrip test only correlates inversely with CRF in BCS, while handgrip dynamometry correlates with upper limb function. BCS show a reduced forearm muscle activity as well as reduced handgrip strength. Moreover, BCS women show lower forearm muscle activity and lower handgrip strength when CRF is larger, while preserving, on the contrary, good upper limb functionality assessed by self-reported scales.

Clinical Practice Points

- Breast cancer survivors experience treatment-related side effects like pain, cancer-related fatigue, or upper limb dysfunctions.
- Breast cancer survivors reported a good upper limb functionality, a moderate cancer-related fatigue, a reduced handgrip strength, and a reduced forearm muscle activity.
- Forearm muscle activity showed a poor significant correlation ($r = -0.223$, $P = .038$) with the CRF, and handgrip strength also showed a poor correlation with the upper limb functionality.
- The greater the cancer-related fatigue, the less handgrip strength and forearm muscle activity
- Clinicians should assess handgrip by dynamometry in combination with patient-reported outcomes such as ULFI in those breast cancer survivors with affected upper limb function.

Authorship

AIC-V and E-AC have made a contribution to the conception of this study. AIC-V, BP-H and MI-C drafted the protocol. BP-H, EA-C, MI-C partly drafted the manuscript. IJF-A, CR-J and AIC-V participated in the analysis and interpretation of data and were involved in drafting the manuscript, as well as revising it critically for important intellectual content. All authors gave final approval of the version to be published.

Disclosure

The authors have stated that they have no conflicts of interest.

Acknowledgment

We would like to offer my special thanks to the participants if this project. Assistance provided by Cátedra de Fisioterapia of Universidad de Malaga was greatly appreciated. This research project was partially funded by Contract N° PS16060 in IBIMA between Novartis-IBIMA (Traslation Research in Cancer B-01 & Clinimetric F-14) for the physiotherapist of the assessment.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.clbc.2023.01.008.

References

1. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: A Cancer J Clin*. 2018;68:394–424. doi:10.3322/caac.21492.
2. Ferlay J, Soerjomataram I, Dikshit R, et al. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. *Int J Cancer*. 2015;136:E359–E386. doi:10.1002/ijc.29210.
3. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2017. *CA: A Cancer J Clin*. 2017;67:7–30. doi:10.3322/caac.21387.
4. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2019. *CA: A Cancer J Clini*. 2019;69:7–34. doi:10.3322/caac.21551.
5. Torre LA, Bray F, Siegel RL, Ferlay J, Lortet-Tieulent J, Jemal A. Global cancer statistics, 2012. *CA: A Cancer J Clin*. 2015;65:87–108. doi:10.3322/caac.21262.
6. Ginsburg O, Bray F, Coleman MP, et al. The global burden of women's cancers: a grand challenge in global health. *Lancet*. 2017;389(10071):847–860. doi:10.1016/S0140-6736(16)31392-7.
7. Rojas K, Stuckey A. Breast Cancer epidemiology and risk factors. *Clin Obst Gynecol*. 2016;59:651–672. doi:10.1097/GRF.0000000000000239.
8. National Cancer Institute. Office of Cancer Survivorship. Available at: https://cancercontrol.cancer.gov/ocs/. Accessed November 16, 2020.
9. Crosbie J, Kilbreath SL, Dylke E, et al. Effects of mastectomy on shoulder and spinal kinematics during bilateral upper-limb movement. *Physical Ther*. 2010;90:679–692. doi:10.2522/ptj.20090104.
10. Shamley D, Srinaganathan R, Oskrochi R, Lascurain-Aguirrebeña I, Sugden E. Three-dimensional scapulothoracic motion following treatment for breast cancer. *Breast Cancer Res Treat*. 2009;118:315–322. doi:10.1007/s10549-008-0240-x.
11. Lacomba MT, Del Moral OM, Coperias Zazo JL, Gerwin RD, Goñi AZ. Incidence of myofascial pain syndrome in breast cancer surgery: a prospective study. *Clin J Pain*. 2010;26:320–325. doi:10.1097/AJP.0b013e3181c4904a.
12. Hidding JT, Beurskens CHG, Van Der Wees PJ, Van Laarhoven HWM, Nijhuis-van Der Sanden MWG. Treatment related impairments in arm and shoulder in patients with breast cancer: a systematic review. *PLoS ONE*. 2014;9:e96748. doi:10.1371/journal.pone.0096748.
13. Stubblefield MD, Keole N. Upper body pain and functional disorders in patients with breast cancer. *PM R*. 2014;6:170–183. doi:10.1016/j.pmrj.2013.08.605.
14. Patel AU, Day SJ, Pencek M, et al. Functional return after implant-based breast reconstruction: a prospective study of objective and patient-reported outcomes. *J Plastic Reconstr Aesthetic Surg*. 2020;73:850–855. doi:10.1016/j.bjps.2019.11.038.
15. Myung Y, Choi B, Kwon H, et al. Quantitative analysis of shoulder function and strength after breast reconstruction a retrospective cohort study. *Medicine (Baltimore)*. 2018;97:e10979. doi:10.1097/MD.0000000000010979.
16. Brookham RL, Cudlip AC, Dickerson CR. Examining upper limb kinematics and dysfunction of breast cancer survivors in functional dynamic tasks. *Clin Biomech*. 2018;55:86–93. doi:10.1016/j.clinbiomech.2018.04.010.
17. Levy EW, Pfalzer LA, Danoff J, et al. Predictors of functional shoulder recovery at 1 and 12 months after breast cancer surgery. *Breast Cancer Res Treat*. 2012;134:315–324. doi:10.1007/s10549-012-2061-1.
18. Hudak Pamela L, Peter C, Amadio CB. Development of an upper extremity outcome measure: the DASH (Disabilities of the Arm, Shoulder, and Head). The Upper Extremity Collaborative Group (UECG). *Am J Ind Med*. 1996;29:602–608.
19. Hayes S, Battistutta D, Newman B. Objective and subjective upper body function six months following diagnosis of breast cancer. *Breast Cancer Res Treat*. 2005;94:1–10. doi:10.1007/s10549-005-5991-z.
20. Roach KE, Budiman-Mak E, Songsiridej N, Lertratanakul Y. Development of a shoulder pain and disability index. *Arthritis Care Res*. 1991;4:143–149. doi:10.1002/art.1790040403.
21. Williams JW, Holleman DR SD. Measuring shoulder function with the shoulder pain and disability Index. *J Rheumatol*. 1995;22:727–732.
22. Cuesta-Vargas AI, Gabel PC. Cross-cultural adaptation, reliability and validity of the Spanish version of the upper limb functional index. *Health Qual Life Outcomes*. 2013;26:126. doi:10.1186/1477-7525-11-126.
23. Cantarero-Villanueva I, Fernández-Lao C, Díaz-Rodríguez L, Fernández-De-Las-Peñas C, Ruiz JR, Arroyo-Morales M. The handgrip strength test as a measure of function in breast cancer survivors: relationship to cancer-related symptoms and physical and physiologic parameters. *Ame J Phys Med Rehabil*. 2012;91:774–782. doi:10.1097/PHM.0b013e31825f1538.
24. Benavides-Rodríguez L, García-Hermoso A, Rodrigues-Bezerra D, Izquierdo M, Correa-Bautista JE, Ramírez-Vélez R. Relationship between handgrip strength and muscle mass in female survivors of breast cancer: a mediation analysis. *Nutrients*. 2017;9:1–4. doi:10.3390/nu9070695.
25. Merletti R, Rainoldi A, Farina D. Surface electromyography for noninvasive characterization of muscle. *Exer Sport Sci Rev*. 2001;29:20–25.
26. Yun TW, Lee BH. Effects of hand grip strength on shoulder muscle activity in breast cancer patients. *Phys Ther Rehabil Sci*. 2016;5:95–100. doi:10.14474/ptrs.2016.5.2.95.
27. Galiano-Castillo N, Fernández-Lao C, Cantarero-Villanueva I, Fernández-de-las-Peñas C, Menjón-Beltrán S, Arroyo-Morales M. Altered pattern of cervical muscle activation during performance of a functional upper limb task in breast Cancer survivors. *Am J Physi Med Rehabil*. 2011;90:349–355. doi:10.1097/PHM.0b013e318214e406.

Please cite this article as: Iván José Fuentes-Abolafio et al, Forearm Muscle Activity During the Handgrip Test in Breast Cancer Survivors: A Cross-Sectional Study, Clinical Breast Cancer, https://doi.org/10.1016/j.clbc.2023.01.008

28. Prieto-Gómez V, Navarro-Brazález B, Sánchez-Méndez Ó, de-la-Villa P, Sánchez-Sánchez B, Torres-Lacomba M. Electromyographic analysis of shoulder neuromuscular activity in women following Breast Cancer Treatment: a cross-sectional descriptive study. *J Clin Med*. 2020;9:1804. doi:10.3390/jcm9061804.
29. Perez CS, Das Neves LMS, Vacari AL, De Cássia Registro Fonseca M, De Jesus Guirro RR, De Oliveira Guirro EC. Reduction in handgrip strength and electromyographic activity in women with breast cancer. *J Back Musculoskeletal Rehabil*. 2018;31:447–452. doi:10.3233/BMR-170848.
30. Association WM. World medical association declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. 2013;310:2191–21o4.
31. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC VJP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Lancet*. 2007;370(9596):1453–1457.
32. Vandenbroucke JP, von Elm E, Altman DG. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *Ann Intern Med*. 2007;147:W163–W194.
33. Trinidad-Fernández M, González-Molina F, Moya-Esteban A, Roldán-Jiménez C, González-Sánchez M, CV AI. Muscle activity and architecture as a predictor of hand-grip strength. *Physiol Measur*. 2020;41.
34. Surface electromyography for the non-invasive assessment of muscles. Accessed: March, 2021. Available at: www.seniam.org.
35. Lung BE, Anatomy B B. Shoulder and Upper Limb, Hand Flexor Digitorum Profundus Muscle.In: StatPearls [Internet]. Treasure Island (FL): StatPearls. *Publishing*. 2022 Jan2022 Oct;17.
36. Okafor L VM Anatomy, Shoulder and Upper Limb, Hand Flexor Digitorum Superficialis Muscle. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2020.
37. Perotto A DE Anatomical Guide for the Electromyographer: The Limbs and Trunk. 4th ed. AO Perotto. Springfield, IL 62704, Charles C Thomas Publisher Ltd, 2005, hardcover, 345 pp, illus, ISBN: 0-398-07577-8Ch.
38. Barbero M, Merletti R RA. *Atlas of Muscle Innervation Zones: Understanding Surface Electromyography and Its Applications*. Milan, Italy: New York, NY, USA: Springer; 2012:142p.
39. Elaine Ewing Fess CAM. *Clinical Assessment Recommendations. American Society of Hand Therapist*; 1981 [Accessed March, 2021]. Available at: https://asht.org/practice/clinical-assessment-recommendations.
40. Piper BF, Dibble SL, Dodd MJ, Weiss MC, Slaughter RE PSM. The revised Piper Fatigue Scale: psychometric evaluation in women with breast cancer. *Oncol Nurs Forum* 25:677-84.
41. Mock V. Clinical excellence through evidence-based practice: fatigue management as a model. *Oncol Nurs Forum*. 2003;30:787–796.
42. Windebank Anthony J, Grisold Wolfgang. Chemotherapy-induced neuropathy. *J Peripheral Nerv Sys*. 2008;13:27–46.
43. Zajaczkowską R, Kocot-Kępska M, Leppert W, Wrzosek A, Mika J, Wordliczek J. Mechanisms of chemotherapy-induced peripheral neuropathy. *Int J Mol Sci*. 2019;20:1451. doi:10.3390/ijms20061451.
44. Benjamin H, Rogers Justin C, Brown David R, Gater KHS. The association between maximal bench press strength and Isometric handgrip strength among breast cancer survivors. *Arch Phys Med Rehabil*. 2017;98:264–269.
45. Smoot B, Paul SM, Aouizerat BE, et al. Predictors of altered upper extremity function during the first year after breast cancer treatment. *Am J Phy Med Rehab*. 2016;95:639–655. doi:10.1097/PHM.0000000000000455.
46. Morishita S, Tsubaki A, Fu JB, Mitobe Y, Onishi H, Tsuji T. Cancer survivors exhibit a different relationship between muscle strength and health-related quality of life/fatigue compared to healthy subjects. *Eur J Cancer Care*. 2018;27:1–9. doi:10.1111/ecc.12856.
47. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis. *Age and Ageing*. 2010;39:412–413. doi:10.1093/ageing/afq034.
48. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age and Ageing*. 2019;48:16–31. doi:10.1093/ageing/afy169.
49. Berger AM, Gerber LH, Mayer DK. Cancer-related fatigue: Implications for breast cancer survivors. *Cancer*. 2012;118(SUPPL.8):2261–2269. doi:10.1002/cncr.27475.
50. Campos MPO, Hassan BJ, Riechelmann R, Del Giglio A. Cancer-related fatigue: a practical review. *Ann Oncol*. 2011;22:1273–1279. doi:10.1093/annonc/mdq458.
51. de Souza Cunha N, Zomkowski K, Fernandes BL, Sacomori C, de Azevedo Guimarães AC, Sperandio FF. Physical symptoms and components of labor tasks associated with upper limb disability among working breast cancer survivors. *Breast Cancer*. 2020;27:140–146. doi:10.1007/s12282-019-01004-y.
52. Siqueira TC, Frágoas SP, Pelegrini A, de Oliveira AR, da Luz CM. Factors associated with upper limb dysfunction in breast cancer survivors. *Supp Care Cancer*. 2020;29(4):1933–1940. doi:10.1007/s00520-020-05668-7.
53. Lawrence JH, De Luca CJ. Myoelectric signal versus force relationship in different human muscle. *J Appl Physiol*. 1983;54:1653–1659.
54. Akagi R, Kanehisa H, Kawakami Y, Fukunaga T. Establishing a new index of muscle cross-sectional area and its relationship with isometric muscle strength. *J Strength Cond Res*. 2008;22:82–87.
55. Cashaback JGA, Cluff T, Potvin JR. Muscle fatigue and contraction intensity modulates the complexity of surface electromyography. *J Electromyogr Kinesiol*. 2013;23:78–83. doi:10.1016/j.jelekin.2012.08.004.

Please cite this article as: Iván José Fuentes-Abolafio et al, Forearm Muscle Activity During the Handgrip Test in Breast Cancer Survivors: A Cross-Sectional Study, Clinical Breast Cancer, https://doi.org/10.1016/j.clbc.2023.01.008