Original Article

Home Exercise Program is an effective tool in improving upper limb function and quality of life in breast cancer survivors: A retrospective observational study

BRUNO CORRADO , GIANLUCA CIARDI, CLEMENTE SERVODIO IAMMARRONE, GRAZIA ARPINO

Federico II University of Naples, Italy

ABSTRACT

Background*:* Home Exercise Program is a mainstay of upper limb dysfunction prevention in breast cancer survivors. However, only subjective assessment instruments have been used until now in order to prove its effectiveness. In the present observational retrospective study, we assessed, for the first time, the effects of Home Exercise Program on the upper limb function of breast cancer survivors via tridimensional motion analysis. We also aimed to show that good upper extremity performance positively influenced the quality of life of breast cancer survivors. Methods*:* From the 2016 database of breast cancer survivors who underwent upper limb tridimensional motion analysis 1 and 3 months after modified radical mastectomy, we enrolled 15 patients who spontaneously refused to undergo the post-surgical 14-day Home Exercise Program (group A). In addition, 15 patients who were homogeneous to those of group A, but who agreed to normally undergo Home Exercise Program were selected from the same database, in order to compare upper limb performance (group B). The Constant-Murley, Brief Fatigue Inventory and European Organization for Research and Treatment of Cancer quality of life scores during follow-up were analysed and compared. Results*:* Compared to those in group A, on tridimensional motion analysis, patients in group B showed a wider range of motion of the upper limb, with consequently better shoulder and elbow performance, lower incidence of lymphedema, minor fatigue, and better quality of life. Conclusions*:* We show objectively, by means of tridimensional motion analysis, that Home Exercise Program is an effective tool for preventing upper extremity dysfunction in breast

Corresponding author. *Federico II University of Naples, Italy.* https://orcid.org/0000-0003-0990-3428
E-mail: bruno.corrado@unina.it
Submitted for publication May 2018
Accepted for publication October 2018
Published *in press* November 2018
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2018.134.19

cancer survivors. Hence, it should always be recommended to such patients as it positively influences their quality of life. **Keywords:** Breast neoplasms; Surgical procedures; Upper extremity; Movement; Rehabilitation; Quality of life.

Cite this article as:
Corrado, B., Ciardi, G., Servodio, C., & Arpino, G. (2018). Home Exercise Program is an effective tool in improving upper limb function and quality of life in breast cancer survivors: A retrospective observational study. *Journal of Human Sport and Exercise*, *13*(4), 926-939. doi:https://doi.org/10.14198/jhse.2018.134.19

INTRODUCTION

Breast cancer is the most common invasive cancer among women in more economically developed countries (International Agency for Research on Cancer, 2014), where it represents the main cause of morbidity and mortality among the various oncology conditions (International Agency for Research on Cancer, 2008). In recent years, earlier detection and advances in medical and surgical therapies have considerably improved the survival rate of breast cancer patients, thus yielding a better prognosis (International Agency for Research on Cancer, 2008). Nevertheless, several physical complications can occur after surgical treatment, particularly those related to the ipsilateral shoulder and arm, including a reduction in the range of motion (RoM) (Blomqvist et al., 2004; Box et al., 2002), lymphedema (Markowski et al., 1981), pain (Kaunisto et al., 2013), numbness, muscle weakness (Shamley et al., 2012), and hematomas and seromas (Abe et al., 1998). The resulting upper limb dysfunction causes disability, which negatively influences the mood and quality of life (Hormes et al., 2010). Physical activity has been proposed to improve the physical functioning and quality of life of breast cancer survivors (Ligibel, 2011; Smith et al., 2011). Exercise programs have been found to be effective in improving upper-body RoM and performance of functional tasks following breast cancer treatment in previous studies (Mustian et al., 2009). A Home Exercise Program (HEP) has been proposed in several trials as a valid alternative to standard exercise, both supervised and unsupervised (Blair et al., 2014; Cornette et al., 2015; Demark-Wahnefried et al., 2012; Gautam et al, 2011; Jeffs et al., 2013; Letellier et al., 2014; Mascherini et al, 2017 and 2018; Rogers et al., 2015; Spector et al., 2014; van Waart et al., 2015; Vincent et al., 2013; Wenzel et al., 2013). However, there is no consensus regarding the manner in which the results of upper limb rehabilitation in breast cancer survivors should be evaluated; in fact, only subjective methods have been proposed thus far. Tridimensional (3D) motion analysis is a computerized non-invasive method that can accurately and objectively measure the manner in which the body and limbs move. Although 3D analysis of lower limb motion has become a gold standard for the study of gait and is currently commonly used in the scientific environment (Baan et al., 2012; Boudarham et al., 2013; Esposito et al., 2017; Esquenazi, 2014; Garbelotti et al., 2014; Mayich et al., 2014; Rathinam et al., 2014), no such analyses have been performed for the upper extremity. Upper limb motion is rapid and complex, which makes 3D motion analysis more difficult; hence, it is less commonly used.

In the present retrospective observational study, we aimed to analyse the effects of HEP on the upper limb function of breast cancer survivors via 3D motion analysis. Moreover, we sought to assess the impact of improved upper limb function on the development of lymphedema, shoulder health, cancer-related fatigue, and quality of life.

MATERIAL AND METHODS

Participants

From January 2016 to December 2016, 68 surgical patients with breast cancer were admitted to the Oncology Rehabilitation outpatient centre of the “Federico II” University Hospital in Naples, Italy, for physiatric assessment and 3D motion analysis of the upper limbs. All patients underwent modified radical mastectomy and axillary lymph node dissection (ALND) and completed active breast cancer treatment with chemotherapy and radiation therapy. Surgery was performed by the same surgeon with the same technique, and the post-surgical treatments were also similar. On the third day following surgery, all patients were visited by a specialist in Physical Medicine and Rehabilitation who recommended that they undergo a 14-day HEP after being discharged from the surgical department. On the last recovery day, the patients consulted a physical therapist who provided them with a brochure on HEP and information on how to complete the program. The brochure included exercises and guidelines (diet and skin care). The 14-day HEP was divided into 2 phases:

phase I (post-surgical days 3–9) and phase II (post-surgical days 10–14). Phase I comprised 8 upper limb exercises and phase II comprised 11 upper limb exercises (Table 1). The brochure described all the exercises using images and text, and provided instructions regarding the frequency, speed, and duration of each exercise. Patients were also recommended to perform the exercises within the pain-free RoM. Follow-ups were conducted at 1 month (T1) and 3 months (T2) at the Oncology Rehabilitation outpatient centre.

Table 1. 14-day Home Exercise Programme (Rip. = Repetitions; Ser. = Series)

Phase I			Rip.	Ser.
Day 3-9	*Exercise 1*	Lying on the back, with the arms at the sides and the knees bent, take a slow, deep breath through the nose trying to expand the chest. Relax and breathe out slowly and completely.	10	1
	Exercise 2	Lying on the back, with the arms at the sides and the knees bent, raise the arms together up to the vertical axis. Hold for 10 seconds.	5	5
	Exercise 3	Lying on the back, with the knees bent, clasp the hands together in front of the chest and move the arms up over the head. Hold for 10 seconds.	5	1
	Exercise 4	Sitting or standing, gently rotate both shoulders forward and up, and then slowly back and down, making a circle.	5	1
	Exercise 5	Sitting or standing, with the arms at the sides, raise the arms up to the shoulder height with the palms of the hands down. Then move the arms up over the head with the palms of the hands in. Return to the start position.	5	1
	Exercise 6	Standing with the legs apart, put the hands on the hips and move the elbows backwards and forwards.	10	1
	Exercise 7	Standing and facing the wall, place both the hands on the wall at shoulder level. Use the fingers to climb up or slide as high as possible. Return to the start position.	5	1
	Exercise 8	Standing with the affected side to the wall, place the hand on the wall at shoulder level. Walk the fingers up the wall as high as possible. Return to the start position.	5	1
Phase II			**Rip.**	**Ser.**
Day 10-14	*Exercise 1*	Sitting or standing, with the arms at the sides, move the hand of the affected side to the opposite shoulder. Return to the start position.	5	1
	Exercise 2	Standing with the legs slightly apart, move the arms laterally up to the shoulder level. Make circular movements with the arms for 10 seconds.	5	1
	Exercise 3	Standing, clasp the hands together behind the back with the palms down. Push the arms behind and upwards. Hold for 10 seconds.	5	1
	Exercise 4	Standing, clasp the hands behind the back with the palms out. Slide the hands upwards as high as possible. Hold for 10 seconds.	5	1
	Exercise 5	Standing or sitting, with the hands clasped together behind the head, bring the elbows together and then stretch them backwards.	5	1
	Exercise 6	Standing or sitting, hold a wand with both hands and move it at the shoulder height with the elbows stretched out. Move the arms up over the head, bend the elbows and move the wand behind the head. Return to the start position.	5	1
	Exercise 7	Lying on the back, stretch out the arms upwads and clasp the hands together. Move the arms over the head as far as possible. Return to the start position.	5	1
	Exercise 8	Standing with the arms at the sides, move the shoulders upwards and downwards.	5	1
	Exercise 9	Standing with the arms at the sides, move the shoulders backwards at the same time as far as possible.	5	1
	Exercise 10	Standing and facing the wall, stretch out the arms placing both the hands on the wall, at shoulder level, with the fingers pointed upwards. Hold for 10 seconds.	5	1
	Exercise 11	Standing and facing the wall, stretch out the arms placing both the hands on the wall, at shoulder level, with the fingers pointed downwards. Hold for 10 seconds.	5	1

Measures and Procedures

The follow-up assessments included the evaluation of shoulder and elbow movements via 3D motion analysis, shoulder disability using the Constant-Murley Score, forearm circumference for lymphedema determination, fatigue using the Brief Fatigue Inventory, and quality of life using the European Organization for Research and Treatment of Cancer (EORTC) QLQ–BR23. The QLQ–BR23 is a questionnaire developed by the EORTC to evaluate the quality of life of women affected by breast cancer; it consists of 23 items, wherein the patient has to indicate the frequency of certain situations. Each item has 4 possible answers.

Data of the 68 patients were analysed, and we found that 15 patients refused to undergo the 14-day HEP for several personal reasons. Those patients were assigned to group A of the current observational retrospective study (mean age, 54.7 years). Subsequently, 15 other patients, who were homogeneous to those included in group A in terms of the baseline demographic characteristics but normally underwent HEP, were selected from among the same group of 68 patients to compare the upper limb performance and were assigned to group B (mean age, 55.8 years).

Movements of the upper limb were measured via stereophotogrammetric recording of active markers using a SMART-DX (BTS Bioengineering Corp., Brooklyn NY, USA) system with 6 cameras. According to the International Shoulder Group (ISB) protocol (van Andel et al., 2008), 5 markers were placed over prominent bony landmarks at the thorax, scapula, humerus, and ulna: spinous process of the vertebra T1, spinous process of the vertebra T10, acromion process of the scapula, lateral epicondyle of the humerus, and ulnar styloid process. A sixth marker, namely the target marker, was placed on a shaft in front of the subject at shoulder height, at a distance slightly more than the sum of the lengths of the arm and forearm. The patient sat on a chair, with the feet resting on the floor, the knees and hips bent at 90°, and the hands on the thighs. The patient was then asked to perform movements without moving her back away from the backrest. Each subject performed 3 tasks that represent the range of daily functional activity. The tasks were chosen after reviewing earlier studies published in the literature (Magermans et al., 2005; Mosqueda et al., 2004). The following tasks were completed:

Hand-to-mouth (HTM): the patient, seated with the hand on the thigh, was asked to bring the hand to the mouth.

Reaching-arm (RA): the patient, seated with the hand on the thigh, was asked to move the hand toward the shaft placed in front of her.

Hand-to-head (HTH): the patient, seated with the hand on the thigh, was asked to raise the arm to touch the top of the head.

All movements were performed at the highest possible speed for the subject. At the "go" command, the subject conducted the movements cyclically until the operator gave the stop signal. A trial of at least 12 repetitions was performed for each task. We evaluated the movement duration (s) and the angular velocity (°/s), respectively, at the elbow for the HTM and RA tasks and at the shoulder for the HTH task. Furthermore, 3 standard RoM tasks were performed. These tasks were necessary to develop a complete upper limb analysis report and to compare, for each subject, the isolated active RoM and the amount of RoM used in the functional tasks. The subjects were asked to actively reach their maximum joint angle during the tasks. The following RoM tasks were completed:

Shoulder flexion/extension

Shoulder abduction/adduction

Elbow flexion/extension

Analysis

Data analysis was performed using SPSS for Windows, version 15.0. The Student's t-test and the ANOVA were used in order to compare the means of the two groups. A 95% confidence interval was chosen (P<0.05).

RESULTS

All the participants were analysed for the following primary and the secondary outcomes: computerized 3D motion analysis, Constant-Murley score, presence of lymphedema, Brief Fatigue Inventory score, and European Organization for Research and Treatment of Cancer quality of life questionnaire.

Computerized 3D motion analysis

Table 2. Movement duration [seconds]

	T0		T1		T2	
	Group A (n=15)	Group B (n=15)	Group A (n=15)	Group B (n=15)	Group A (n=15)	Group B (n=15)
Hand to mouth	*0.85* *(0.25)*	*1.05* *(0.34)*	*1.26* *(0.06)*	*0.76** *(0.22)*	*1.62* *(0.37)*	*0.71** *(0.24)*
Reaching arm	*1.38* *(0.39)*	*1.03* *(0.37)*	*1.75* *(0.28)*	*0.86** *(0.28)*	*1.57* *(0.30)*	*0.70** *(0.13)*
Hand to head	*1.08* *(0.22)*	*0.77* *(0.40)*	*1.88* *(0.10)*	*0.67** *(0.37)*	*2.06* *(0.24)*	*0.55** *(0.35)*

Mean (st. dev.) **P value <0.05*

As reported in Table 2, patients who practiced HEP performed the HTM movement in lesser time as compared to the control subjects; the differences between the groups were significant at both T1 (P=0.019) and T2 (P=0.023). The time required for the RA movement considerably differed between the groups, and the difference was significant at both T1 (P=0.017) and T2 (P=0.010). Furthermore, the HTH movement duration was significantly different between the groups at T1 (P=0.005) and T2 (P=0.003). Table 3 shows the angular velocity at the elbow joint for the HTM (expected value, 58±21 °/s) and RA (expected value, 58±5 °/s) movements and at the shoulder joint for the HTH movement (expected value, 56±13 °/s). The values considerably differed between the 2 groups. Group B showed a positive trend in the angular velocity for all the movements, whereas patients who did not undergo the HEP exhibited a gradual decrease. Except for that in the HTH movement at T1 (P=0.127), the differences in the angular velocity between the groups were significant (HTM T1: P=0.013, HTM T2: P=0.002; RA T1: P=0.018, RA T2: P=0.001; HTH T2: P=0.043). Group A exhibited a gradual reduction in shoulder flexion. However, group B patients, who started from a similar condition at T0, experienced different modifications in the above-mentioned parameter. The differences between the groups were significant both at T1 (P=0.049) and T2 (P=0.011). With regard to shoulder abduction, the trend was similar to that observed for the shoulder flexion, except for the statistical significance at T2 (P=0.023) but not at T1 (P=0.076). With regard to elbow flexion/extension modifications, group A exhibited a gradual reduction in elbow RoM, whereas group B, who started from the same condition at T0, experienced an improvement in the RoM. The differences in the elbow RoM between the groups were significant at both T1 (P=0.035) and T2 (P=0.002).

Table 3. Angular velocity [º/s]

	T0		T1		T2	
	Group A (n=15)	Group B (n=15)	Group A (n=15)	Group B (n=15)	Group A (n=15)	Group B (n=15)
Hand to mouth (elbow)	*27 (3)*	*29 (4)*	*32 (4)*	*47* (4)*	*37 (3)*	*57* (4)*
Reaching arm (elbow)	*29 (2)*	*35 (7)*	*34 (4)*	*48* (2)*	*40 (2)*	*58* (2)*
Hand to head (shoulder)	*31 (3)*	*31 (4)*	*38 (4)*	*45 (5)*	*41 (5)*	*54* (6)*

Mean (st. dev.) **P value <0,05*

Lymphedema

Lymphedema was evaluated by assessing the arm circumference 10 cm above and 10 cm below the olecranon with a standard measuring tape (Lin et al., 1993). Lymphedema was defined if the difference between the sum of the 2 measurements among the affected and the unaffected arm was ≥4 cm (Paci et al., 1996). Accordingly, we evaluated the incidence rate (%) of arm lymphedema in our sample. At the 1-month follow-up, there was no significant difference between the 2 groups, although group B exhibited a more positive trend (lymphedema rate: group B, 20%; group A, 46.7%; P=0.121). However, after 3 months, we observed a significant difference in the incidence of arm lymphedema between the 2 groups (lymphedema rate: group B, 26.7%; group A, 66.7%; P=0.028).

Constant-Murley score

The Constant-Murley score is the most commonly used measure for assessing the outcomes of the treatment for shoulder disorders. All patients were evaluated using the Constant-Murley score at T0, T1, and T2. As reported in Table 4, although the trend in group B appears to be positive and that in group A appears to be almost stable, the differences in the Constant-Murley score between the groups were not significant.

Table 4. Rating scales

	T0		T1		T2	
	Group A	Group B	Group A	Group B	Group A	Group B
Brief fatigue inventory	*50.6 (27.46)*	*51.7 (17.79)*	*57 (20.78)*	*34.6 (5.13)*	*61.6 (17.93)*	*16.7* (12.50)*
EORTC QLQ–BR23	*43.3 (9.02)*	*46 (10.15)*	*50 (12.53)*	*40.7 (7.57)*	*57.4 (12.50)*	*35.3 (5.69)*
Costant score	*62.3 (5.03)*	*57 (7.55)*	*64.33 (5.03)*	*70.4 (6.03)*	*62.4 (8.62)*	*78.6 (9.29)*

Mean score (st. dev.) **P value <0.05*

Brief Fatigue Inventory score

The Brief Fatigue Inventory is used to rapidly assess the severity and impact of cancer-related fatigue. Table 4 shows a gradual decrease in this score in the patients who did not practice HEP, whereas group B patients experienced a progressive enhancement of the score. At T1 follow-up, the difference in this score between the groups was not significant, although this difference became significant at T2 (P=0.023).

EORTC QLQ-BR23 questionnaire

The EORTC QLQ-BR23 is a breast cancer-specific quality of life questionnaire. All the patients enrolled in the study were asked to fill the questionnaire at each follow-up. Results are shown in Table 4. Opposing trends were noted between the 2 groups; in particular, HEP patients exhibited a progressive improvement in their perceived quality of life, whereas control subjects exhibited a deterioration. Nevertheless, the differences between the groups were not significant.

DISCUSSION

In the present study, we demonstrated the efficacy of early HEP in preventing upper limb dysfunction in breast cancer survivors by using an objective and quantifiable tool—computerized 3D motion analysis.

Furthermore, we found that good upper limb performance, as a result of HEP completion, may be related to a smaller incidence of lymphedema and fatigue and to a better quality of life.

Rehabilitation following breast cancer surgery has been found to be beneficial in several clinical trials and systematic reviews; the rehabilitation programs include exercise therapy to reduce shoulder and upper limb dysfunction (Lauridsen et al., 2005), exercise for treatment-related physical changes during adjuvant treatment (Markes et al., 2006), and physical therapy for managing lymphedema (Bergmann et al., 2014; Johansson et al., 2014). In particular, HEP has been proposed as a good alternative to supervised standard exercise in many clinical trials (Blair et al., 2014; Cornette et al., 2015; Demark-Wahnefried et al., 2012; Gautam et al., 2011; Jeffs et al., 2013; Letellier et al., 2014; Rogers et al., 2015; Spector et al., 2014; van Waart et al., 2015; Vincent et al., 2013; Wenzel et al., 2013). Nevertheless, in all the studies, the quality of upper limb movement has been based only on observational and subjective analysis. According to a Cochrane 2010 study (McNeely et al., 2010), assessments conducted following surgery should include the measurement of shoulder movement (RoM) and function. Motion analysis offers an objective method for quantifying the movement of the upper limb, even if this task is technically difficult due to the non-cyclical nature of functional use and the increased range and complexity of motion at the shoulder joint. Therefore, only few researchers have used motion analysis to characterize upper limb kinematics. Based on our experience with computerized motion analysis of the lower limb, we hypothesized that this procedure can also be used for the assessment of upper limb dysfunction in breast cancer survivors after major surgery. Hence, we decided to evaluate the total amount of shoulder and elbow RoM and the function of the above-named joints, by making the patient perform some tasks that simulated the activities of daily living. Patients who practiced HEP, starting immediately after the surgery, experienced a gradual recovery of shoulder and elbow RoM, whereas patients who decided to not undergo the home rehabilitation protocol developed a disability of the upper limb. In fact, group B patients performed all the functional tasks in a shorter time and at a greater angular velocity, as compared to the group A patients. Thus, our results are consistent with those in the literature, but to our knowledge, this is the first study to derive these findings by using an objective validation tool—3D motion analysis.

The Constant-Murley score is one of the most used, validated, and reliable outcome measures for the assessment of the shoulder (Bonaiuti, 2011). This scoring system consists of subjective variables, such as pain, activities in daily living, arm positioning, and objective variables, such as RoM and strength. In the present study, we found that exercise improves the Constant-Murley score in breast cancer survivors, consistent with that in previous studies (Morone et al., 2014).

Lymphedema is a chronic condition characterized by the accumulation of fluid in tissues as a result of reduced lymph drainage routes. Approximately one-third of women undergoing axillary breast cancer treatment will develop ipsilateral arm swelling with significant physical and psychological consequences (Gartner et al., 2010). Breast cancer-related lymphedema (BCRL) has a significant impact on cancer survivorship, and thus affects work, social, and leisure activities and causes psychological distress (Ridner, 2005). As observed in several previous studies, early HEP markedly reduced the incidence of lymphedema in the present study as well.

Fatigue is frequently reported by cancer patients and survivors, regardless of the tumour type or treatment (Prue et al., 2006). Fatigue can be highly distressing and can have a profound impact on daily functioning (Minton et al., 2010). Breast cancer survivors frequently experience clinically significant levels of fatigue for months or years after successful treatment (Bower et al., 2000). Supervised exercises have a favourable effect on cancer-related fatigue, as compared to conventional care, and can be considered safe therapy for the management of fatigue in breast cancer survivors (Meneses-Echávez et al., 2015). In the present study, we found that HEP has a positive effect on fatigue in breast cancer survivors, as compared to usual care.

The quality of life issues for breast cancer patients include factors such as pain, fear of recurrence, fatigue, altered sense of femininity, feelings of decreased attractiveness, anxiety, and problems associated with treatment-related arm swelling. Studies have found that exercise is an effective intervention for improving the quality of life in breast cancer survivors (McNeely et al., 2006). Aerobic exercise programs significantly improve the overall quality of life and physical functioning in breast cancer survivors (Murtezani et al., 2014). In the present study as well, we found that HEP can improve the quality of life of breast cancer survivors (Spector et al., 2014).

This study is clinically relevant because it is the first such study to objectively and quantifiably assess the efficacy of early home-based exercises in the prevention of upper limb dysfunction in breast cancer survivors.

Nevertheless, the study has certain limitations, including the small sample size and its retrospective nature. However, the underpowered nature of the study could be explained by the fact that computerized motion analysis of the upper limb is technically very difficult and only a few cancer survivors are willing to undergo long-lasting medical procedures. With regard to the study design, it might be problematic to conduct a prospective trial due to the ethical nature of the study, as it would be necessary to intentionally exclude some cancer patients from rehabilitation treatment after surgery.

CONCLUSIONS

Patients who underwent 14-day HEP immediately after major breast surgery showed significantly wider shoulder and elbow RoM in accordance with 3D motion analysis, along with greater upper limb comfort and a reduced incidence of lymphedema. We can conclude that this physical state positively influenced the vitality and mood of breast cancer survivors, despite the several factors involved. Early HEP should be recommended and prescribed to all patients who undergo surgery for breast cancer, particularly for those who are scheduled to undergo risky surgical procedures. Moreover, due to its low cost and simplicity, and because it can be performed at home with less stress, as compared to standard exercises, this rehabilitative procedure is always favourably considered by patients. Furthermore, the reduction in postoperative complications of the upper limb limits the healthcare costs. Hence, further clinical trials with larger samples and higher levels of evidence are necessary to confirm our data.

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