

**The effect of myofascial and physical therapy on trunk, shoulder, and elbow movement patterns in women with pain and myofascial dysfunctions after breast cancer surgery**

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1 **The effect of myofascial therapy in addition to physical therapy on trunk, shoulder and**  
2 **elbow movement patterns in women with pain and myofascial dysfunction on the long**  
3 **term after breast cancer surgery: secondary analyses of a randomized controlled trial**

4 *Myofascial therapy in breast cancer patients*

5

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7 Emmerzaal J, Devoogdt N.

8

9 **ABSTRACT**

10 **Introduction:** Secondary upper limb dysfunctions are common after breast cancer  
11 treatment. Myofascial treatment may be a valuable physical therapy modality for this  
12 problem.

13 **Objective:** To investigate the effect of myofascial therapy in addition to physical therapy on  
14 shoulder, trunk and elbow movement patterns in women with pain and myofascial  
15 dysfunctions at the upper limb on the long term after breast cancer surgery.

16 **Design:** A double-blinded randomized controlled trial

17 **Setting:** Rehabilitation unit of a university hospital.

18 **Participants:** Forty-eight women with persistent pain after finishing breast cancer treatment.

19 **Interventions:** Over three months, all participants received a standard physical therapy  
20 program. The experimental (n=24) and control group (n=24) received 12 additional sessions  
21 of myofascial therapy or placebo therapy, respectively.

22 **Main outcome measures:** Outcomes of interest were movement patterns of the  
23 humerothoracic joint, scapulothoracic joint, trunk and elbow, measured with an optoelectronic  
24 measurement system during the performance of a forward flexion and scaption task.  
25 Statistical parametric mapping (SPM) analyses were used for assessing the effect of  
26 treatment on movement patterns between both groups (group x time interaction effect).

27 **Results:** A significantly decreased protraction and anterior tilting was found post-  
28 experimental treatment. No beneficial effects on movement patterns of the humerothoracic  
29 joint, trunk and elbow were found.

30 **Conclusion:** Myofascial therapy in addition to a 12-week standard physical therapy program  
31 can decrease scapular protraction and anterior tilting (scapulothoracic joint) during arm  
32 movements. Given the exploratory nature of these secondary analyses, clinical relevance of  
33 these results needs to be investigated further.

34 **Keywords:** breast neoplasms, upper limb function, kinematics

## 35 INTRODUCTION

36 Breast cancer is the most frequently diagnosed cancer among women in the world <sup>1</sup>. Among  
37 the wide variety of breast cancer therapies, surgery and radiotherapy are usually the first  
38 treatment options. These therapies are known to frequently cause secondary upper limb  
39 problems <sup>2-4</sup>. Breast and axillary surgery as well as radiotherapy have a direct and profound  
40 effect on soft-tissue structures at the upper limb region, including skin, muscles and fascia <sup>5-7</sup>.  
41 As shown in previous studies, these soft-tissue restrictions may directly cause movement  
42 pattern alterations at the level of the shoulder joint <sup>8,9</sup>.

43 With reported prevalence rates up to 84%, the reduction of the active range of motion is thereby  
44 one of the most common morbidities at the upper limb region after finishing breast cancer  
45 treatment <sup>2,10-12</sup>. Kinematic studies in women after breast cancer treatment show alterations in  
46 humerothoracic movement patterns, including a reduced elevation and external rotation <sup>13-16</sup>.  
47 Regarding the scapulothoracic joint, an increased internal rotation and total joint excursion is  
48 reported <sup>13,16,17</sup>. For scapulothoracic lateral rotation, inconsistent results are seen. While an  
49 increased lateral rotation is reported in women post-mastectomy by Crosbie et al. (2010) <sup>17</sup>,  
50 Ribeiro et al (2019) found a reduction in lateral rotation in women post-surgery <sup>13</sup>.

51 Due to the tremendous impact of altered movement patterns on upper limb function and daily  
52 functioning in general in women after breast cancer treatment <sup>4</sup>, research into rehabilitation  
53 approaches targeting this movement capacity seems warranted. In this, it is of interest to  
54 assess whether targeting the soft tissue restrictions with myofascial therapy can break the  
55 vicious circle of decreased soft-tissue mobility, the consequent development and maintenance  
56 of specific movement alterations and upper limb dysfunctions in general <sup>18,19</sup>. A recent  
57 systematic review with meta-analysis described greater overall effects in support of the  
58 intervention with myofascial therapy for pain and functionality than other control groups/types  
59 of interventions<sup>20</sup>. For pain in particular, our own study results showed beneficial effects of  
60 myofascial therapy in addition to a standard physical therapy program at short term (i.e. after  
61 the 12-week intervention). No beneficial effects on other self-reported and clinical outcome  
62 measures, including shoulder range of motion, were found<sup>7,21</sup>. Besides these outcomes, we  
63 hypothesize that myofascial therapy has an effect on movement patterns of the shoulder by  
64 reducing soft tissue restrictions that may hamper certain movement patterns and/or reducing  
65 pain that may lead to avoidance of certain movements.

66 To fully assess the effect of myofascial therapy on movement patterns of the shoulder in the  
67 breast cancer population, objective three-dimensional motion capture of the shoulder joint, i.e.  
68 the scapulothoracic and humerothoracic joint, is needed. Furthermore, adjustments in

69 movement patterns at the level of the adjacent joints of the shoulder, i.e., trunk and elbow,  
70 might be of interest to evaluate as well. In addition, insights into the whole movement pattern  
71 (kinematic waveform) instead of gathering information of isolated joint angles at specific points  
72 in the movement (e.g. peak joint angle) may lead to a better understanding of this problem. To  
73 our knowledge, no previous studies have investigated this.

74 Therefore, the aim was to explore if myofascial therapy has an effect on the three-dimensional  
75 movement patterns of the humerothoracic joint, scapulothoracic joint, trunk and the elbow  
76 during the performance of active elevation tasks. More specifically, a combination of decreased  
77 scapulothoracic protraction, lateral rotation and anterior tilting, increased humerothoracic  
78 elevation and external rotation, decreased trunk movement in all dimensions and reduced  
79 elbow extension and/or supination are hypothesized. Objective opto-electronic motion analysis  
80 and kinematic waveform analyses were used for this purpose. The present study is a  
81 secondary analysis of a randomized controlled trial reported elsewhere <sup>7,21</sup>.

82

83

84

## 85 **METHODS**

86 This study was approved by the Ethical Committee [REDACTED]  
87 [REDACTED] All participants gave written informed consent before data collection  
88 began. The trial has been registered at [REDACTED]). The present  
89 manuscript presents secondary analyses of a randomized controlled trial, following the  
90 CONSORT guidelines. Results on the primary outcome and other secondary outcome  
91 measures of this trial can be found elsewhere <sup>7,21</sup>.

### 92 *Participants*

93 Patients were recruited in the Multidisciplinary Breast Centre and the Department of Physical  
94 Medicine and Rehabilitation of the University Hospitals in Leuven from March 2013 until  
95 February 2015. The inclusion criteria were (1) women after surgery for a primary breast cancer  
96 (2) whose surgery and/or radiation therapy was finished at least three months ago. These  
97 patients had to (3) score at least 40 out of 100 on the visual analogue scale (VAS) during the  
98 past week with more than three months of pain in the upper body region and (4) have presence  
99 of myofascial dysfunctions at the upper body region (yes/no). Evaluation of the myofascial  
100 dysfunctions were performed by a physical therapist through palpation for myofascial trigger  
101 points and/or adhesions between myofascial tissues. Patients were excluded if (1) they were  
102 not able to visit the hospital for the therapeutic sessions and measurements for the entire  
103 duration of the study, (2) had existing shoulder pathologies for which surgical indications are  
104 available (defined by ultrasound investigation) or (3) being in the presence of a current episode  
105 of cancer or metastasis.

### 106 *Procedure*

107 The patients were randomized into two groups. The experimental group received a standard  
108 physical therapy program and additional myofascial therapy. The control group received the  
109 same standard physical therapy program, but with additional placebo therapy instead of  
110 myofascial therapy.

### 111 *Interventions*

112 A standard physical therapy program of twelve weeks was planned for all participants. The first  
113 eight weeks, two one-on-one sessions were given per week. During week nine to twelve only  
114 one one-on-one session per week was provided. The sessions lasted 30 minutes and  
115 consisted of different physical therapy modalities, including: (1) passive mobilizations of the  
116 shoulder to improve the active and passive range of motion; (2) stretching of pectoral muscles  
117 to improve muscle flexibility and active and passive shoulder range of motion; (3) scar tissue  
118 massage to improve flexibility of the scar(s) and (4) exercise therapy to improve muscle

119 flexibility, endurance and strength, posture, scapulothoracic movement patterns and active  
120 shoulder range of motion.

121 Immediately after the standard physical therapy session, the *experimental group* received  
122 additionally, **myofascial therapy** including manual myofascial release techniques on (1) active  
123 myofascial trigger points and (2) on myofascial adhesions in the pectoral, axillary and cervical  
124 region, diaphragm and scars. In short, the pressure applied by the therapist's hands proceed  
125 from the superficial to the deep layers of the myofascial tissue. Where a resistance is felt, the  
126 barrier is softly maintained until a release is felt. This approach is repeated until a soft end-feel  
127 is reached in every direction and layer. Patients in the *control group* received a **placebo**  
128 **treatment** consisting of static bilateral hand placements. While the previous group received  
129 more firm and dynamic techniques, the control group received a technique where myofascial  
130 tissues were not moved and where minimal pressure was given. One session of  
131 myofascial/placebo therapy lasted 30 minutes with a frequency of once a week for twelve  
132 weeks. All interventions were performed by physical therapists with a Master of Science in  
133 Rehabilitation Sciences. More details on the interventions can be found elsewhere <sup>21</sup>.

134

#### 135 *Outcome measures*

136 The outcome measures described in this manuscript are the three-dimensional movement  
137 patterns of the humerothoracic and scapulothoracic joint, trunk, and elbow at the affected side.  
138 The movement analysis was performed using 15 infrared cameras sampling at 100 Hz (Vicon,  
139 Oxford Metrics, UK) and filtered with spline-interpolation<sup>22</sup> during the performance of two active  
140 arm movements: an arm elevation in the scapular plane, defined as 30° in front of the frontal  
141 plane (scaption task) and an arm elevation in the sagittal plane (forward flexion task). All  
142 measurements took place at the Clinical Motion Analysis Laboratory of the University Hospitals  
143 Leuven in campus Pellenberg (Belgium) 1 to 10 days prior and after the 12-week intervention  
144 period. Assessors were blinded for treatment allocation.

145

146 The movement analysis was preceded by three preparatory steps. First, while seated on a  
147 chair with low back support, clusters of three or four markers were placed on the sternum,  
148 scapula (flat part of the acromion), the upper arm (proximal, lateral) and lower arm (just  
149 proximal of ulnar and radial styloid processes), as visualized in Figure 1.

150

151 [insert Figure 1 here]

152

153 Second, the elevation distance and height were standardized (Figure 2). A bar, which indicated  
154 the elevation height, was installed by one researcher while another researcher passively

155 elevated the arm of the participant. This was performed with an extended elbow and without  
156 allowing flexion, lateral bending or axial rotation of the trunk, until 120° of humerothoracic  
157 elevation was achieved, both for the scaption and forward flexion task.

158 Third, participants were asked to perform the scaption and forward flexion task actively, until  
159 they touched the bar - that was located at 120° of humerothoracic elevation - with the radial  
160 side of their index finger (Figure 2). Speed of movement was controlled by ... Several practice  
161 trials were performed to make sure participants understood the requested task. After the  
162 preparations, three recordings of four repetitions each were recorded per task.

163

164 [insert Figure 2 here]

165 After these movement trials, static trials were recorded in which anatomical landmarks were  
166 digitized and defined within their respective segmental marker cluster (CAST procedure) <sup>23</sup>.  
167 The anatomical landmarks were then used to construct anatomical coordinate systems and to  
168 calculate joint kinematics, according to the ISB-guidelines <sup>24</sup>. The recorded movement data in  
169 this study were movement patterns of the humerothoracic joint (elevation/lowering,  
170 internal/external rotation), scapulothoracic joint (pro/retraction, lateral/medial rotation,  
171 ant/posterior tilting), trunk (flexion/extension, ipsilateral/contralateral lateral bending,  
172 ipsilateral/contralateral axial rotation) and elbow (flexion/extension, pro/supination).

173 Information about the cancer and its treatment was collected from the medical file of the  
174 patient. Other baseline characteristics were questioned including age, body mass index and  
175 time since surgery. Active humerothoracic forward flexion and abduction range of motion (°)  
176 was also measured with an inclinometer as part of the clinical examination. This was done in  
177 sitting position before and after the intervention <sup>25</sup>.

### 178 *Movement data analysis*

179 Recorded movement data was processed with Matlab®, using U.L.E.M.A. <sup>26</sup>. Movement cycles  
180 were time-normalized and visualized from start to end point (from the moment the hand was  
181 moving until the hand was again placed next to the thigh). Out of the four repetitions (for each  
182 of the three recordings), the first and the last trial were eliminated because of potential  
183 interruption by initiation/completion strategies. Therefore, six repetitions per task were  
184 analyzed. The parameter of interest in this study was the complete movement pattern for each  
185 degree of freedom. Time-normalized kinematic waveforms (joint angles from start to end point  
186 of the task) of the humerothoracic joint, scapulothoracic joint, trunk and elbow were visually  
187 checked for erroneous signals due to artefacts caused by marker occlusion. Erroneous  
188 recordings were excluded from the statistical analysis.



189 Statistical parametric mapping (SPM) was used to statistically analyze pre-post intervention  
190 differences in movement patterns at the level of the four joints between the groups (SPM<sub>1D</sub>  
191 version 0.4 - MATLAB-based open-source software, available for download at  
192 <http://www.spm1d.org/>)<sup>27</sup>. The advantage of SPM<sub>1D</sub> is that it allows hypothesis testing on  
193 continuous data without neglecting the interdependence between measures across different  
194 joint angles/time points. It uses Random Field Theory to estimate (1) the critical threshold  
195 above which only 5% (i.e.,  $\alpha = 0.05$ ) of equally smoothed random continuous data would be  
196 expected to cross, and (2) the probability that this would occur (i.e., p-value). For each task  
197 (scaption/ forward flexion), a two-way ANOVA (group x time) with one repeated measure was  
198 performed for each degree of freedom. A significant interaction effect would indicate that the  
199 two groups have responded differently to their respective interventions.

200

201

202

203

204 **RESULTS**

205 All women (n=169), referred by doctors, were screened for eligibility. A total of 82 women were  
206 eligible and 50 women (61%) agreed to participate. These women were randomized to an  
207 experimental group receiving myofascial therapy in addition to a standard physical therapy  
208 program (n=25) and a control group receiving placebo therapy in addition to the same standard  
209 physical therapy program (n=25). For the present secondary analyses, four participants were  
210 excluded because of erroneous signals in the kinematic data. This resulted in an experimental  
211 group of 22 participants and a control group of 24 participants. Baseline characteristics of the  
212 intervention and control group are given in Table 1.

213 The kinematic waveforms of the humerothoracic joint, scapulothoracic joint, trunk and elbow  
214 are graphically represented for the scaption task in Figure 3 and for the forward flexion task  
215 in Figure 4.

216 A significant group x time interaction effect for scapulothoracic protraction/retraction was found  
217 during scaption, with a significantly reduced protraction post-experimental treatment at the  
218 mid-range of the arm elevation ( $p=0.049$ ) and lowering phase ( $p = 0.043$ ) (Figure 3). A  
219 significant group x time interaction effect was also found for scapulothoracic anterior/posterior  
220 tilting during forward flexion, with a significantly reduced anterior tilting post-experimental  
221 treatment at the beginning of the arm lowering phase ( $p = 0.049$ ) (Figure 4). No significant  
222 interaction effects were found for other scapulothoracic movement patterns, humerothoracic  
223 joint, trunk and elbow movement patterns in the scaption nor forward flexion task.

224 [insert Figure 3 and 4 here]

225 In Appendix A, the mean (SD) joint angles at each percentage of the movement cycle are  
226 additionally provided for both groups and both time points, for all degrees of freedom, for the  
227 scaption task. In Appendix B, this information is provided for the forward flexion task.

228

229 **DISCUSSION**

230 The aim of the present study was to explore if targeting soft-tissue restrictions with myofascial  
231 therapy, resulted in alterations in the movement patterns of the humerothoracic joint,  
232 scapulothoracic joint, trunk and elbow, on the long term after breast cancer treatment. The  
233 results show, in line with our hypothesis, a decreased scapulothoracic protraction and anterior  
234 tilting in women who received myofascial therapy in addition to a standard physical therapy in  
235 comparison to women who received a placebo treatment in addition to the same standard  
236 physical therapy program. In contrast to our hypothesis, no differences in the movement  
237 patterns of the humerothoracic joint, trunk and elbow between both groups were found.

238 **For humerothoracic movements**, a recent review with meta-analyses showed conflicting  
239 results for range of motion, assessed with clinical methods (e.g. goniometer) <sup>20</sup>. Beneficial  
240 effects of myofascial therapy were seen for abduction range of motion, but not for flexion,  
241 compared to placebo treatment or other interventions <sup>20</sup>. These results should be interpreted  
242 with caution since the low-methodological quality of the included studies and the wide variety  
243 in myofascial techniques used. **For scapulothoracic movements**, results in the same sample  
244 of the present study (published elsewhere) showed no beneficial effects of myofascial therapy  
245 on clinical scapular static and dynamic outcome parameters <sup>7</sup>. The present study moves  
246 beyond traditional clinical range of motion parameters by using objective three-dimensional  
247 motion data and kinematic waveform analyses, in order to improve understanding of these  
248 upper limb problems. Using this methodology, a decreased scapulothoracic protraction and  
249 anterior tilting after myofascial therapy was found. Possibly, the objective three-dimensional  
250 motion capture is a more sensitive and/or valid assessment method. **A differentiation has to**  
251 **be made between the significant results in scapulothoracic protraction during scaption**  
252 **and scapulothoracic posterior tilting during forward flexion.** For scapulothoracic  
253 protraction, we see that both groups had similar values at baseline. Post-intervention, we see  
254 that the protraction angle has decreased in the experimental group, while it has increased in  
255 the control group. For scapulothoracic posterior tilting however, the experimental and control  
256 group showed large differences at baseline. Post-intervention, the posterior tilting angle of the  
257 experimental group has increased to values comparable to the control group. Despite these  
258 differences in the interpretation of the significant results, the evolution of the experimental  
259 group can be considered beneficial in both cases.

260

261 Results of the present study should be interpreted considering the following: First, regarding  
262 the included breast cancer population, women were on the long term after breast cancer  
263 treatment. Potentially, soft-tissue stiffness/restrictions were present for too long to be resolved

264 by myofascial techniques. Since the average time post-surgery was 3.03 (2.65) years, it can  
265 be assumed that the scars were fully healed and in the maturation phase, making it more  
266 difficult to influence elasticity and other soft tissue characteristics <sup>28</sup>. The participants also  
267 experienced pain and myofascial dysfunction in the affected upper limb region. However, the  
268 assessment of myofascial dysfunction was arbitrary assessed, i.e. yes or no. Since the severity  
269 of the myofascial restriction and their contribution to the patient's pain experience and altered  
270 movement patterns was not considered, these broad inclusion criteria could have resulted in  
271 a large number of non-responders to the myofascial therapy. Furthermore, large within-  
272 treatment group variability in movement patterns is observed. This might be due to the natural  
273 highly variable nature of movement patterns of the shoulder between individuals and the  
274 inconsistencies in shoulder movement patterns in persons with shoulder pain <sup>29,30</sup>, but it might  
275 also rely on the different medical treatments that participants within one group received. Given  
276 the potential different impact of axillary and breast surgery or radiotherapy on soft-tissue  
277 structures and thus movement patterns of the shoulder, the medical treatment-related effect  
278 within each group can be larger than a potential between-group effect of the myofascial  
279 treatment. Second, regarding the applied methodology to assess the movement patterns, we  
280 adhered to the ISB standards for motion capture of the upper limb <sup>24</sup>. However, we only  
281 measured analytical tasks, i.e. scaption and forward flexion until 120 degrees. This upper limit  
282 was chosen because the applied acromion marker cluster only returns valid data until 120° of  
283 elevation <sup>24</sup>. This is clearly a shortcoming of the used methodology as a noteworthy treatment  
284 effect on movement patterns could possibly be observed only at higher ranges of motion. The  
285 applied physical therapy and myofascial techniques focused on improving range of motion at  
286 the end of the available range of motion. As seen from the baseline characteristics (Table 1),  
287 the women included in this research were generally able to elevate the arm more than 120°. It  
288 is possible that additional treatment effects occur beyond 120° of arm elevation. Third,  
289 although the present analysis provides novel insights in movement patterns in a sample of  
290 women after breast cancer, one could furthermore critically question whether it is possible to  
291 assess natural movement behavior in a motion laboratory environment. Furthermore, the used  
292 analytical tasks in the present study may not capture the complexity of shoulder movement  
293 behavior during daily life activities. Other motion capture systems, that are less obtrusive, like  
294 inertial sensors, might be more able to effectively capture natural movement patterns during  
295 the performance of functional tasks <sup>31</sup>. Indeed, the disadvantage of functional tasks related to  
296 marker occlusion in a movement laboratory environment, are excluded by using inertial  
297 sensors.

298

## 299 **Strengths and limitations**

300

301 **The strengths** of this research should be pointed out. The patients were randomized into two  
302 groups. This randomization was computer-generated. The distribution of the patients into the  
303 two groups was blinded for the therapists, assessors and the patients. The patients in these  
304 two groups received the same amount of the individual standard physical therapy program,  
305 which was 20 sessions in total. The intervention group received 12 sessions of myofascial  
306 therapy and the patients in the control group received 12 sessions of placebo therapy.  
307 Treatment programs were therefore similar between two groups. Furthermore, this is the first  
308 study that made use of SPM for the statistical analysis of the movement patterns. Not only  
309 does SPM allow to analyze the entire waveform at once, it is also statistically more robust than  
310 the analysis of discrete values extracted from the waveform <sup>27</sup>. However, also SPM comes with  
311 its limitations. Although it is well suited to grasp the interaction between the different timepoints  
312 of the kinematic waveforms, it can only analyze one degree of freedom at the time. In order to  
313 fully grasp the interdependency between different degrees of freedom within a joint and  
314 between joints, more complex statistical approaches might be used in future research. As  
315 limitation, it has to be noted that these were exploratory secondary analyses with no sample  
316 size calculation and possibly not enough power to detect differences between group. Further,  
317 limitations related to the 3D-assessment method and laboratory setting discussed above  
318 should be considered as well.

319

## 320 **Clinical implications**

321 In the sample of women used for this secondary analysis, a short-term effect of additional  
322 myofascial therapy was found on pain intensity after three months. These effects however did  
323 not persist on the long-term <sup>21</sup>. With the knowledge of the beneficial effects on scapulothoracic  
324 motion in mind, it should be explored to which extend the alterations in movement patterns at  
325 the level of the scapula contribute to the short-term decrease in pain intensity, or vice versa.  
326 While some evidence suggests an interaction between pain and movement patterns <sup>32,33</sup>, other  
327 research in musculoskeletal shoulder pain showed that alterations in scapulothoracic  
328 kinematics are not related to alterations in pain intensity following a physical therapy  
329 intervention <sup>34,35</sup>. Also in the (breast) cancer population, pain is considered to be a complex  
330 and multifactorial experience <sup>36</sup>. Given this, psychosocial contributors, including anxiety,  
331 depression and stress among other, to (persistent) pain have to be considered, drawing  
332 attention to a shift from a biomedical explanation of persistent pain to a comprehensive  
333 biopsychosocial approach <sup>37</sup>.

334 **Conclusion**

335 This research has collected an extensive dataset on 3D humerothoracic, scapulothoracic,  
336 trunk and elbow movement patterns. Based on these data, myofascial therapy in addition to a  
337 12-week standard physical therapy program seems to have beneficial effects on  
338 scapulothoracic movement patterns in women with pain and myofascial dysfunctions at the  
339 affected upper limb region on the long term after breast cancer surgery. Movement patterns at  
340 the humerothoracic joint, trunk and elbow did not change after myofascial therapy. The clinical  
341 relevance of this finding needs to be further explored considering the complex nature of  
342 shoulder kinematics and pain and the exploratory character of the reported analyses.  
343

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347 **DECLARATION OF INTEREST**

348 Declarations of interest: none

349

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## 467 TABLES

468

Table 1. Baseline characteristics of women according to treatment allocation. Mean (SD) and frequency (%) are given.

	Experimental group (n=22)	Control group (n=24)
Mean (SD) age (years)	54.81(7.74)	52.62 (7.20)
Mean (SD) BMI (kg/m <sup>2</sup> )	28.81(4.66)	25.42 (4.15)
Mean (SD) time since surgery (years)	3.03 (2.65)	3.05 (3.52)
Operated on dominant side (%)	10 (46%)	10 (42%)
Lymph node stage (%)		
pN0	11 (50%)	15 (63%)
pN1	7 (32%)	8 (33%)
pN2	3 (14%)	0 (0%)
pN3	1 (5%)	1 (4%)
Tumor size (%)		
pT0	0	2 (8%)
pT1	12 (55%)	6 (25%)
pT2	9 (41%)	11 (46%)
pT3	1 (4%)	3 (13%)
pT4	0	2 (8%)
Type of cancer therapy (%)		
Breast surgery		
<i>Mastectomy</i>	14 (64%)	18 (75%)
<i>Breast conserving surgery</i>	8 (36%)	6 (25%)
Axillary surgery		
<i>Level I</i>	4 (18%)	6 (25%)
<i>Level I-II</i>	8 (37%)	7 (29%)
<i>Level II-III</i>	9 (41%)	11 (46%)
Radiotherapy	22 (100%)	23 (96%)
Chemotherapy	14 (64%)	15 (63%)
Neoadjuvant chemotherapy	2 (9%)	3 (13%)
Hormonal therapy	19 (85%)	22 (92%)
Targeted therapy	3 (14%)	3 (13%)
Active humerothoracic range of Motion (inclinometry)		
Mean (SD) Forward flexion – pre(°)	148 (13)	133 (25)
Mean (SD) Forward flexion – post(°)	155 (14)	146 (22)
Mean (SD) Abduction – pre(°)	125 (20)	115 (29)
Mean (SD) Abduction - post(°)	143 (16)	133 (28)

*BMI: body mass index, SD: standard deviation*

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470

471 **FIGURES**

472 **Figure 1. Cluster placement**

473 **Figure 2. Standardization of the participants and the forward flexion task execution**

474 **Figure 3. Kinematic waveforms of A) the trunk, B) the humerothoracic joint, C) the**  
475 **scapulothoracic joint and D) elbow for the scaption task**

476 **Figure 4. Kinematic waveforms of A) the trunk, B) the humerothoracic joint, C) the**  
477 **scapulothoracic joint and D) elbow for the forward flexion task**

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