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Cognitions and physical impairments in relation to upper limb function in women with pain and myofascial dysfunctions in the late stage after breast cancer surgery: an exploratory cross-sectional study

Upper limb function after breast cancer treatment

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ABSTRACT

Purpose: Upper limb (UL) function is one of the health outcomes that matters the most for women with breast cancer. However, a better understanding of the factors contributing to UL dysfunctions in the late stage after breast cancer surgery is needed. This study explores associations between impairment-related and cognition-related factors and UL function in women with pain and myofascial dysfunctions at the affected UL region in this late stage after breast cancer surgery.

Methods: In forty-one women, UL function (dependent variable) was evaluated by the Disabilities of Arm, Shoulder and Hand questionnaire. As independent impairment-related factors, relative excessive arm volume (perimetry), pain intensity (maximum score on the visual analogue scale past week) and humerothoracic elevation and scapular lateral rotation (kinematic analysis) were assessed. As independent cognition-related factors, pain catastrophizing (Pain Catastrophizing Scale) and pain hypervigilance (Pain Vigilance and Awareness Questionnaire) were evaluated. Bi-variable analyses and a stepwise regression analysis were used to explore associations.

Results: A higher pain intensity (r=0.52; p<0.001), more pain catastrophizing (r=0.49; p<0.001) and more pain hypervigilance (r=0.40; p=0.01) were related to more UL dysfunction. Pain intensity (p=0.029) and pain catastrophizing (p=0.027) explained furthermore 29.9% of variance in UL function.

Conclusion: Pain intensity and cognition-related factors are significantly associated with UL function in women with pain and myofascial dysfunctions, indicating the need of assessing pain beliefs in women in the late stage after breast cancer surgery.

Keywords: breast cancer, dysfunction, pain catastrophizing, pain intensity, myofascial dysfunctions

INTRODUCTION

Breast cancer is the most common form of cancer diagnosed in women worldwide, with one in nine women who will receive the diagnosis of breast cancer before the age of 75 [1]. As described by The International Consortium for Health Outcomes Measurement Initiative, upper limb (UL) function is one of the health outcomes that matters the most for women with breast cancer [2]. Decreased UL function can be defined as 'experiencing difficulties in performing activities of daily living with the upper limb' and is therefore situated at the 'activities level' of the International Classification of Functioning (ICF) [3]. More than one year after surgery, prevalence rates of UL dysfunctions range between 9-60%, depending on type of cancer treatment modalities patients received [4-6]. A long-lasting decreased UL function has a tremendous impact on a woman's quality of life [5,7,8]. Since survival rates of women diagnoses with breast cancer are increasing, it is essential to gain understanding in the factors which are associated with the potential chronic consequences of breast cancer treatment [1].

First of all, certain physical impairments at the UL region, including lymphedema, pain intensity and active range of motion limitations, have already been described as important contributors to UL function after breast cancer surgery [9,10]. **Lymphedema** occurs in about 20% of patients treated for breast cancer and is known to contribute to UL function [11-14]. However, with prevalence rates up to

79% after finishing primary treatments, even more women experience UL **pain** following breast cancer treatment, often in relation to myofascial dysfunctions [15-18]. Treatment modalities such as breast (including mastectomy or breast conserving surgery) and axillary (including axillary lymph node dissection or sentinel node biopsy) surgery as well as radiotherapy have a direct and profound effect on different soft-tissue structures at the UL region, including skin, muscles and fascia [17,19,20]. This scar tissue formation in and between the different soft-tissue layers, is likely to adapt UL movement behavior in women following breast cancer surgery [17,19,20]. Altered movement of the shoulder complex is indeed already described in women following breast cancer surgery with a reported **decrease in active range of motion** in up to 84% of breast cancer survivors [4,21-23]. In particular humerothoracic abduction and scapulothoracic lateral rotation motion can be affected [12,24-26]. The presence and impact of these impairments each individually have already been described before [10]. However, to our knowledge, no studies explored their combined contribution in a sample of women in the late stage after breast cancer treatment.

However, from musculoskeletal research, it is known that other factors than physical impairments at the UL region, including cognitions, can contribute to persistent UL dysfunction and pain in the late stage following injury or surgery as well [27,28]. People with persistent musculoskeletal pain tend to have an increased attention towards pain (pain hypervigilance) and might worry and feel helpless about their pain (pain catastrophizing) [29]. However, at this moment it is not clear to which extent these cognitions (i.e. pain catastrophizing and pain hypervigilance) as well as impairment-related factors (i.e. lymphedema, pain intensity and active range of motion) are associated with a decrease in UL function in women who experience pain and myofascial dysfunctions in the UL region in the late stage after breast cancer surgery. It is of interest to investigate the factors related to UL dysfunction in these women with persistent consequences of breast cancer surgery in order to enhance clinical decision making and treatment planning targeting the mechanisms underlying these chronic complaints and ultimately improve their quality of life. This study therefore aims to explore the extent to which pain intensity, lymphedema, shoulder motion, pain hypervigilance and pain catastrophizing explain the variance in UL function in women in the late stage after breast cancer surgery who experience pain and myofascial dysfunctions in the UL region.

METHODS

The present study is a secondary analysis on the baseline data of the participants of a randomized controlled trial that took place at the University Hospital in Leuven [30], on the effect of myofascial techniques in the treatment of persistent arm pain after breast cancer treatment. Participants included in the original study had to meet the following inclusion criteria: (1) women after treatment for primary breast cancer (mastectomy or breast conserving surgery and axillary lymph node dissection or sentinel node biopsy), (2) radiation treatment finished at least 3 months prior to the research, (3) pain at the UL for a period longer than 3 months, with a visual analogue scale score of more than 40 out of 100 during the last week, (4) the existence (yes/no) of myofascial dysfunctions (defined by palpation for myofascial trigger points and adhesions) at the upper body region. Women were excluded if: (1) other shoulder pathologies were present, for which a surgical intervention was needed (confirmed by ultrasound and a physician), (2) metastasis or current episodes of cancer were present [30].

Participants were recruited from the Multidisciplinary Breast Centre during and the Department of Physical Medicine and Rehabilitation of the University Hospital in Leuven. If patients reported they experienced pain complaints after their breast cancer treatment, they were referred to the study team to screen for eligibility. The recruitment and the measurements took place from March 2013 until February 2015. The study was approved by the Ethical Committee of the University Hospitals Leuven (ref number: s54579). All participants gave written informed consent before data collection.

Measurements took place at the Department of Physical Medicine and Rehabilitation of the University Hospital of Leuven (campus Gasthuisberg), except for the kinematic analyses which took place at campus Pellenberg of the University Hospital of Leuven. All outcome measures were assessed by one of three skilled assessors with a physiotherapy background (ADG, EC, RVH).

1) Dependent variable: UL function

UL function was measured by the Disabilities of Arm, Shoulder and Hand questionnaire (DASH). The DASH is a questionnaire consisting of 30 items on daily life activities, which have to be scored from 1 (no difficulties) to 5 (impossible). The total score ranges from 0 to 100, with a higher score indicating more dysfunction. This questionnaire is recommended for use in women after breast cancer surgery given its appropriate construct validity and responsiveness [31].

2) Independent variables: physical impairment-related factors

- **Relative excessive arm volume** as indicator for arm lymphedema was assessed by the perimeter. The perimeter is a valid device to quantify limb volume by measuring each 4 cm of both arms, starting at the olecranon. The volume within each segment was calculated by the formula of the truncated cone. Arm volume was defined by the sum of the segments. Relative excessive arm volume was calculated as follows: ((volume of the edematous limb – volume of the non-edematous limb) / volume of the non-edematous limb) x 100. The perimeter shows good to excellent validity in a population of women treated for breast cancer [32].

- **Maximum UL pain intensity during the past week** was measured with a Visual Analogue Scale (VAS). The VAS is a unidimensional measurement of pain intensity. Participants had to indicate the maximal pain intensity, experienced in the last week, on a continuous line from 0 to 100. Zero indicating no pain and 100 indicating the worst possible pain. The VAS is considered a reliable and valid measure of pain intensity [33].

- Active shoulder motion was captured by 15 infrared cameras sampling at 100 Hz (Vicon, Oxford Metrics, UK) and filtered with spline-interpolation [34]. Clusters of three or four markers were placed on the sternum, scapula (flat part of the acromion) and upper arm (proximal, lateral) (Figure 1). Anatomical landmarks were digitized during static trials, were defined within their respective segmental marker cluster (CAST-procedure),[35] and were then used to construct anatomical coordinate systems and calculate joint kinematics, according to the ISB-guidelines [36]. Humerothoracic kinematics were defined for the following three rotations: humerothoracic elevation plane, humerothoracic elevation and humerothoracic rotation. Scapulothoracic kinematics were described for following three rotations: protraction/retraction, medial/lateral rotation, anterior/posterior tilting.

Kinematic data collection took place at the Clinical Motion Analysis Laboratory of the University Hospital Pellenberg (Leuven, Belgium). While seated on a chair with low back support, marker clusters were mounted on the participant's upper body. Static calibration trials were first collected to digitize the anatomical landmarks. Participants were subsequently instructed to perform an arm elevation task in the scapular plane (30° in front of the frontal plane) and to touch a bar (which was located at 120° of humerothoracic elevation) with the radial side of the index finger (Figure 2). This bar was placed by the researchers at the correct height (i.e. 120° elevation) before the dynamic trials started. Therefore, one researcher passively elevated the arm of the participant, with an extended elbow and without allowing forward flexion, lateral flexion or rotational movements of the trunk, until 120° of humerothoracic elevation. At this height, a second researcher placed the bar. All participants familiarized with the requested movement task during several practice trials, after which three dynamic trials consisting of four repetitions each were recorded. From the recorded trials, only the second and third repetition were selected for data analysis (as these were not interrupted by initiation/completion strategies), resulting in six cycles per participant for data-analysis. Movement cycles were visually defined from movement start to highest arm position (elevation phase). Kinematic data was further processed with Matlab®, using U.L.E.M.A.[37]. Each movement cycle was time-normalized. The parameters of interest of interest for this study were the humerothoracic elevation angle (i.e. humerothoracic abduction angle while moving in the scapular plane) and the scapulothoracic lateral rotation angle at the highest arm position (when the hand was touching the bar).

[insert figure 1 and 2 here]

3) Independent variables: cognition-related factors

- **Pain catastrophizing** was assessed using the Pain Catastrophizing Scale (PCS). The PCS is a questionnaire which consists of 13 statements about feelings and thoughts people can experience while having pain. Each statement can be scored from 0 (not at all) to 4 (all the time) [38]. A higher total score on the PCS, with a maximum of 52, on the PCS indicates more pain catastrophizing. This questionnaire has good validity and reliability for clinical and non-clinical populations [39].

- Pain-related attention was assessed by the Pain Vigilance and Awareness Questionnaire (PVAQ). This questionnaire measures a person's attention to pain and to changes in pain. It consists of 16 statements, which are scored from 0 (never) to 5 (all the time) [40]. A higher total score on the PVAQ, with a maximum of 100, indicates more pain vigilance. The PVAQ shows good internal consistency in a chronic pain population [41].

To describe the study population, following personal and disease-related data were collected: age, body mass index (BMI), tumor size (pT) and lymph node stage (pN). Treatment-specific information was collected as well, i.e. date of the surgery, type of surgery (breast conserving/mastectomy and sentinel lymph node biopsy/axillary lymph node dissection) and subsequent treatment (chemotherapy, radiotherapy, hormone therapy and/or target therapy).

Statistical analysis

All the data analyses were executed in SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Given that the present study is a secondary analysis

of a data collect at the baseline assessment of a randomized controlled trial [30], no sample size calculation was performed for the current study aim. Bi-variable analyses were done to investigate a possible association between UL function and the following variables: relative excessive arm volume, pain intensity, humerothoracic elevation, scapulothoracic lateral rotation, pain catastrophizing and pain hypervigilance. Pearson Correlation Coefficients were calculated in case of normal data distribution and spearman rho coefficients in case of non-normal data distribution. Arbitrary guidelines for interpretation of the correlations as formulated by Evans were followed [42]. Correlation coefficients between 0 and 0.19 were considered 'very weak', between 0.20-0.39 'weak', between 0.40-0.59 'moderate', between 0.60-0.79 'strong' and between 0.80-1.00 'very strong'.
Second, a stepwise backwards linear regression analysis was performed using the variables with a bi-variable association with a p-value < 0.05 as independent variables and UL function as dependent variable. Through this regression model, the effect size was obtained by the measure of adjusted R^2. The assumptions for linear regression were checked.

RESULTS

In the original study, all patients referred by doctors as based on reporting pain complaints were screened for eligibility (n=169). Eighty-two patients were eligible and 50 (61%) agreed to participate [30]. For the present secondary analysis, four participants were excluded because of missing data for the DASH. In addition, one person had missing data for PCS and PVAQ and four other persons were excluded because kinematic data was not available as a result of erroneous signals due to artefacts caused by marker occlusion. This resulted in a final study population of 41 participants.
Mean age of this sample was 54.37 years (SD 7.50) and mean time since surgery was 3.36 years (SD 3.66). Detailed information regarding the patient characteristics can be found in Table 1.
Given the mean DASH score of 34.36%, UL function of this sample can be considered as impaired since the mean DASH was three times higher than the mean norm value (11.96%) for the American female population [43]. Twenty (49%) and sixteen (39%) participants were diagnosed with lymphedema based on the 5% and 10% increase of arm volume difference compared to pre-surgical values, respectively.
Data was not normally distributed so spearman rho coefficients were calculated. The coefficients revealed moderate significant associations between UL function and weekly maximum pain intensity (r=0.52; p<0.001), level of pain catastrophizing (r=0.49; p<0.001) and level of pain vigilance and awareness (r=0.40; p=0.01) (Table 2). This indicates that more UL dysfunction is related to more pain, more pain catastrophizing or more pain vigilance. No significant correlations were found between UL

function and relative excessive arm volume (as measure of lymphedema), humerothoracic elevation and scapular lateral rotation.

In the stepwise backwards linear regression model, pain intensity, pain catastrophizing and pain vigilance were entered and together explained 29.8% of variance in the DASH, with a significant contribution of pain intensity (p=0.044). When excluding the variable with the highest p-value, i.e. pain vigilance (p=0.338), 29.9% of variance was explained by pain intensity (p=0.029) and pain catastrophizing (p=0.027), with both variables being significant (Table 3).

DISCUSSION

The purpose of this study was to investigate the variables associated with UL function in women in the late stage after breast cancer surgery who experienced pain and myofascial dysfunctions in the UL region.

The results indicated that pain intensity and cognition-related factors, i.e. pain catastrophizing and pain hypervigilance, were related to UL function. This contrasted to impairment-based variables, i.e. lymphedema and shoulder motion, which did not relate to UL function in this sample.

The women assessed in this study were on average 3.3 years after treatment. Considering this is beyond the time needed for local tissue healing [44], it was expected that other factors than impairments related to acute injury serving a protective function, would relate to UL dysfunction in this study sample. The study results confirm that pain intensity and cognition-related factors (i.e. pain catastrophizing and pain hypervigilance) are significantly associated with UL function. This finding is in line with the available literature, which indicate that pain intensity significantly explain variance in UL function in breast cancer surviors [6,11,45]. In addition to pain, the included women also suffered from myofascial dysfunctions (i.e. myofascial trigger points and/or adhesions between myofascial tissue layers) which is hypothesized to contribute to UL function, given their potential influence on normal shoulder motion [20,30]. Contrasting to this hypothesis, the present study found that humerothoracic elevation and scapulothoracic lateral rotation were less (and non-significantly) related to UL function in this study sample.

As first part of this discussion explanatory models for these findings are proposed. First, results of the present study can be interpreted by referring to the **fear-avoidance model of pain**, which postulates that inappropriate catastrophic thoughts about pain following a painful experience might initiate pain-related fear and lead to avoidance behavior, in an attempt to decrease pain or to prevent further injury [46]. In context of the present study, this may as such lead to decreased UL function in general. Although this avoidance behavior can be overt, i.e. a person completely avoids an activity which he/she links to pain, it is often more subtle, such as muscle guarding, decreased range of motion of the affected region and/or altered spatiotemporal movement characteristics during activities and thus a decreased UL function [47-49]. In the acute stage following surgery, protective posturing of the shoulder and motor adaptations to avoid further tissue damage are adaptive because they enhance the recovery of damaged tissues [50]. However, avoidance behavior is not helpful when it persists based on pain-related fear even when the tissues are healed. In this case it might leads to a vicious circle of decreased UL function, increased pain, increased pain-related fear and subsequent avoidance behavior on the long term [51]. One could also argue that the active arm elevation assessment in the present study could be considered an assessment of avoidance behavior, i.e. altered movement behavior based on pain-related fear. Nonetheless, it is known that, to provoke avoidance behavior, the requested movement task should be challenging and resemble a fearful activity [48]. Therefore, the arm elevation in the scapular plane as used in the present study may not be fearful or challenging enough to effectively capture potential avoidance behavior.

Second, when results are interpreted from a **pathomechanical perspective**, one could argue whether the standardized unloaded scapular plane arm elevation until 120°, as performed in in this study, is sensitive enough to detect potential alterations in shoulder motion based on the present myofascial dysfunctions in this study sample. Indeed, the structural and functional limitations in myofascial tissues at the UL region may not have been provoked by this movement task and therefore result in only weak and non-significant associations. Furthermore, the fact that information on the total passive range of shoulder motion is absent, limits a full result interpretation. Assessing kinematics during more functional tasks, challenging the different degrees of freedom in the shoulder complex which might be prone to myofascial dysfunctions (e.g. rotational movements and movements in the transversal plane like horizontal adduction / abduction) might have given different insights into the relation between shoulder motion and UL function in women with pain and myofascial dysfunctions in the late stage after surgery. On the other hand, the acromion marker cluster, applied in this study to record scapulothoracic kinematics, is only considered valid until 120° of humerothoracic elevation, and rotational movement are generally least reliably measurable, which are general limitations of the used kinematic analysis approach [52-54].

Third, when we approach the reported results from **a pain physiological perspective**, we should consider the presence of different pain mechanisms in this study sample. Given the late stage after surgery and chronicity of the pain experience in this sample, getting better insight in the underlying mechanisms of the women's pain experience (nociceptive/neuropathic/nociplastic mechanisms) may be relevant to have a better understanding of the relationship of pain with UL function. To which extent acute effects of the different treatment modalities are still present at this stage and cause mainly nociceptive and/or neuropathic pain versus to which extent the pain experience is dominated by nociplastic changes, needs to be further explored.

Other factors that can be considered to further clarify the limited explained variance in the regression model described in this study (29.9%), relate to the (1) applied patient-reported assessment instruments, (2) potentially relevant variables not assessed in this study, and (3) the specific sample characteristics.

First, regarding the used **patient-reported assessment** instruments, it is possible that the DASH, which is a self-report questionnaire with general items on activities in daily living, is not context- and individual-specific enough to capture real UL function in each individual. Therefore, the reported UL function might not be an adequate reflection of the function of the UL in each woman in real life. The same holds for the cognitive factor 'pain catastrophizing' which is assessed by self-report. Recently, it was indicated that the construct of pain catastrophizing, as defined in the cognitive-behavioral literature, was not captured by commonly used patient-reported instruments for pain catastrophizing like the Pain Catastrophizing Scale [55]. Instead, it was advised to rate pain catastrophizing by taking contextual information into account, together with expert judgment [55].

Second, **not all potential associated factors were evaluated**. In persons with musculoskeletal shoulder pain, psychological factors including pain self-efficacy together with expectations of recovery were identified as predictors of UL function, in contrast to structural or clinical factors [27,28]. Similar relations can be expected in cancer patients, although this needs to be confirmed. On the other hand, a recent systematic review revealed that handgrip strength as impairment after breast cancer is consistently associated with UL function, together with higher number of comorbidities [10]. This should be confirmed as well. At last, more specific for the cancer population, a relation between UL function and fear of cancer recurrence, can been expected to explain variance in UL function. It has been described that patients often interpret bodily symptoms as a sign of cancer recurrence [56]. It may be worthy to investigate to which extent fear of cancer recurrence and the experienced threat of bodily symptoms, including pain, relate to dysfunctions in breast cancer patients.

Third, in the present study a **specific sample of breast cancer patients** with persistent pain and myofascial dysfunctions was recruited. Presence of myofascial dysfunctions was determined by palpation for myofascial trigger points and/or adhesions between myofascial tissues because at that moment, no standardized assessment method was available to evaluate the severity of myofascial dysfunctions. One could argue whether the included women effectively had myofascial dysfunctions and to which extent they contributed to their persistent pain complaint and subsequent UL dysfunctions [30]. Also, although mean relative excessive arm volume was above the cut-off of 5% for diagnosis of arm lymphedema, this impairment-related factor was not associated with UL function either [57]. It should be noted that only 20 (49%) participants were actually diagnosed with lymphedema based on the 5% increase of arm volume difference compared to pre-surgical values. Although sixteen (39%) women even had a volume difference of $\geq$ 10%, possibly, the severity of their lymphedema was not enough to contribute to UL function. To unravel the contribution of lymphedema to UL function, a different sample with women with confirmed lymphedema should be studied.

Clinical implications

Based on the results of this study, some careful recommendations can be formulated. It is advised to assess pain catastrophizing and pain hypervigilance in women following breast cancer surgery with pain and myofascial dysfunctions in the UL region in the late stage after breast cancer surgery. In addition to self-report, these cognitive constructs are best judged based on expert opinion [55]. Specific attention towards the movement of the scapulothoracic joint and the degree of humeral elevation during simple active tasks such as an arm elevation movement and towards the degree of lymphedema, seem of less priority in the clinical examination of women with the same characteristics as the women in the included sample.

Limitations

Given the cross-sectional nature of this study, the predictive value of variables, nor casual relationships, could be considered. Furthermore, no sample size calculation specifically for this study's purposes was performed, since this study is a secondary exploratory analysis on the baseline data of a randomized controlled trial [30], resulting in a fairly low number of available participants for this study aim. At last, no information was available on the care participants received for their upper limb dysfunctions in the past.

Future research

First, alternative and more objective measures of UL function should be considered instead of self-reported questionnaires such as the DASH. Accelerometry-based assessments have already been found to be highly feasible and valid in other populations and may be worth to use in breast cancer patients as well [58]. More specific, it may also be interesting to compare self-reported measures with accelerometry-based assessments as measure of UL function and their relationship with other factors. Second, our results suggest the importance of psychological factors to explain functioning in breast cancer patients. Relevant constructs we recommend to investigate in future in this population are movement avoidance behavior and fear of cancer recurrence in particular. In addition, considering the late stage after surgery, the contribution of different pain mechanisms to UL dysfunctions should be further explored.

Conclusion

In women following breast cancer surgery with pain and myofascial dysfunctions in the UL region in the late stage following surgery, pain intensity and cognitive factors, i.e. pain catastrophizing and pain hypervigilance, were related to UL function. This contrasted to physical impairment-based variables, i.e. shoulder motion and lymphedema, which did not relate to UL function in this sample.

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Declaration of interest

The authors report no conflicts of interest.

Data availability statement

The data that support the findings of this study are available from the corresponding author [ADG] upon reasonable request.

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Table 1. Patients Characteristics (n=41). Mean (SD) or frequency (%) is given.

Age (years)	54.37 (7.50)
BMI (kg/m²)	26.03 (4.14)
Time after surgery (years)	3.36 (3.66)
Surgery at dominant side	24 (58.5%)
Type of breast surgery	
Mastectomy	31 (75.6%)
Breast Conserving	10 (24.4%)
Type of axillary surgery	
Sentinel lymph node biopsy	10 (24.3%)
Axillary lymph node dissection	31 (75.7%)
Tumour size:	
pTis	2 (4.9%)
pT1	13 (31.7%)
pT2	20 (48.8%)
pT3	6 (24.6%)
Lymph node stage:	
pN0	22 (53.7%)
pN1	13 (31.7%)
pN2	4 (9.8%)
pN3	2 (4.9%)
Radiotherapy	38 (92.7%)
Hormone therapy	39 (95.1%)
Chemotherapy	26 (63.4%)
Trastuzumab	6 (14.6%)
Upper limb function (DASH 0-100)	37.76 (17.18)

SD=Standard deviation; BMI=Body Mass Index; pT=Pathological Tumor Stage; pN=pathological Lymph Node Stage; DASH=Disability of Arm, Shoulder and Hand questionnaire

Table 2. Overview of the independent variables and their relation to upper limb function (DASH) through correlation analysis

	Mean	SD	Spearman Correlation Coefficient (p-value)
Relative excessive arm volume (%)	8.53	13.13	0.03 (p=0.86)
Maximum pain intensity past week (VAS 0-100)	67.44	15.37	0.52 (p<0.001)*
Humerothoracic elevation (°)	90.07	8.49	0.16 (p=0.33)
Scapular lateral rotation (°)	48.91	12.40	0.06 (p=0.71)
Pain Catastrophizing (PCS 0-52)	14.17	8.09	0.49 (p<0.001)*
Pain Vigilance (PVAQ 0-100)	37.39	11.52	0.40 (p=0.01)*

SD: standard deviation; VAS: visual analogue scale; PCS: pain catastrophizing scale; PVAQ: pain vigilance and awareness questionnaire; DASH: disabilities of arm, shoulder and hand questionnaire
*significant p-value < 0.05

Table 3. Overview of the independent variables and their relation to upper limb function (DASH) through stepwise backwards linear regression analyses

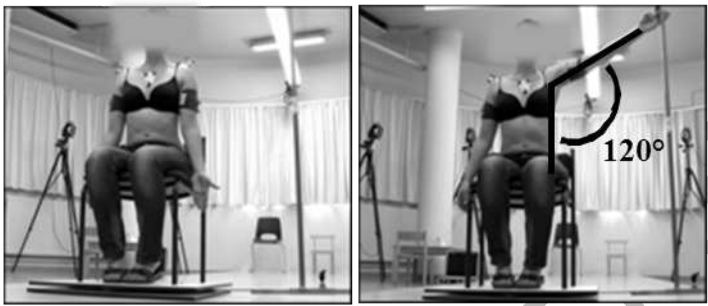
Independent variables	**adjusted R^2 (%)**	**Significance***
Weekly maximum VAS, PCS, PVAQ	29.8%	0.001
Weekly maximum VAS, PCS	29.9%	0.000

VAS: visual analogue scale; PCS: pain catastrophizing scale; PVAQ: pain vigilance and awareness questionnaire; *significant p-value < 0.05

Figure 1. Marker cluster placement

Clusters of three or four markers, placed on the sternum, scapula (flat part of the acromion) and upper arm (proximal, lateral) for humerothoracic and scapulothoracic kinematic analysis

Figure 2. Arm elevation task in the scapular plane until 120°



Performance of an arm elevation task in the scapular plane (30° in front of the frontal plane) and to touch a bar (which was located at 120° of humerothoracic elevation) with the radial side of the index finger