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Altered upper limb motor behaviour in breast cancer survivors and its relation to pain: a narrative review

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Running title: Motor behaviour in breast cancer survivors
Abstract
Breast cancer is the most commonly diagnosed cancer among women and many women suffer from persistent physical and psychological complaints following their cancer treatment. Altered motor behaviour at the shoulder region and upper limb, i.e., alterations in movement patterns, spatiotemporal movement characteristics and muscle activation patterns, is a common physical consequence of breast cancer treatment, that can have a clear impact on daily life functioning and quality of life. Furthermore, altered upper limb motor behaviour is suggested to relate to upper limb pain, which is very commonly reported in breast cancer survivors (BCS). This review, prepared according to the SANRA guidelines, looks into the current understanding of alterations in motor behaviour at shoulder and upper limb in BCS, by discussing the factors related to this altered behaviour. In this, we specifically focus on the relation between motor behaviour and pain. Results of our search show that cancer treatment modality is predictive for shoulder range of motion. Furthermore, single prospective studies show depressive symptoms, living alone, being non-white and low physical activity levels as predicting factors for reduced shoulder range of motion. Pain as factor related to altered motor behaviour is only assessed in cross-sectional research, limiting its interpretation in context of being cause or consequence of motor behavioural adaptations, and on the underlying mechanism explaining their relation. It is concluded that studies which explain the mechanisms how and in which subgroup of BCS motor behavioural alterations are associated with pain at the upper limb, are necessary in future.

Key words (3-8): Arm; upper extremity; mastectomy; kinematics; fear of movement; subacromial
1. **Introduction**

Breast cancer is the most diagnosed cancer among women, with one in eight women who will be diagnosed with breast cancer at some point during lifetime\(^2\). Notwithstanding the currently favourable survival-prognosis, it is well known that many women suffer from persistent pain, and physical and psychological complaints following their cancer treatment. While not fatal, such complaints remain poorly treated and account for a great personal and societal burden as it clearly impacts daily life functioning and quality of life\(^3\).

Altered motor behaviour at the upper limb, including the shoulder region and trunk, is such a very common physical complaint following breast cancer treatment\(^3\). Examples of post-treatment alterations in upper limb motor behaviour are the reduced active shoulder range of motion (ROM) which is reported in up to 84% of the breast cancer survivors (BCS)\(^2\). These reductions in active shoulder ROM mainly occur in the short-term after medical treatment but persist in 10 to 21% of the BCS at the long-term after finishing breast cancer treatment\(^1\). Another example of motor behavioural changes in BCS following breast cancer treatment are specific alterations in scapulothoracic kinematics\(^7\), in spatiotemporal movement characteristics\(^6\), and in scapular muscle activation patterns\(^8\).

These alterations are observed on the symptomatic arm side in comparison to the asymptomatic arm side of BCS\(^7\) or in comparison to healthy controls\(^1\), or between different time points following treatment\(^5\).

Aforementioned alterations in upper limb motor behaviour are known to negatively affect the performance of work tasks and activities of daily living\(^6\). Thereby, they interfere with BCS’ mood and quality of life, work productivity and time to return to work, and thus ability to participate in society\(^6\). Furthermore, altered upper limb motor behaviour is also suggested to relate to upper limb pain, which is very commonly reported in BCS\(^6\). Since the modifiable factors associated with altered motor behaviour are currently not fully elucidated,
specific information for physical therapists on the value of addressing certain factors associated with upper limb motor behavioural changes in BCS is not available. This review intents to give an overview of the current knowledge on the factors associated with alterations in upper limb motor behaviour in BCS. Given this paper is part of the thematic issue ‘Persistent pain after cancer’, the relation between alterations in upper limb motor behaviour and shoulder pain, and the mechanisms underlying their potential association, is particularly discussed.
2. **Review methodology**

To guarantee the quality of this narrative review, it was prepared with the aid of the SANRA scale which is developed for assessing the quality of narrative review articles. Relevant scientific studies were identified in Medline (Pubmed) using broad search terms for motor behaviour, breast cancer and the upper limb (Appendix 1). The database search was done in June 2022 by one person (LDB). Studies were selected for this narrative review if the study sample consisted of breast cancer survivors. Furthermore, studies had to assess the relation between upper limb, shoulder and/or trunk motor behaviour and another variable (e.g., medical treatment modality, lymphedema, pain, etc.), by performing a correlation analysis or regression analysis including the motor behavioural factor as the dependent variable, or studies in which motor behavioural factors were compared between groups of BCS (e.g., with high versus low levels of pain, with or without mastectomy, with or without lymphedema, etc.). Both cross-sectional and longitudinal study designs were considered. Regarding motor behaviour, we intended to include studies that objectively assessed upper limb, shoulder and/or trunk kinematics (e.g., joint angles, kinematic waveforms, range of motion), and/or muscular activation (e.g., by electromyography (EMG)) during active arm movements. Studies reporting outcomes on upper limb motor behaviour based on self-report measures were excluded. Also performance-based outcomes (e.g., grip strength, maximal shoulder strength) were not considered. Finally, papers only reporting on motor behaviour outcomes following breast reconstruction surgery were not included in this review.

To ensure the selection of high-quality evidence, we intended to rely primarily on evidence from systematic reviews and meta-analyses. However, we also aimed to cover the evidence that was not integrated in available reviews by including the results of recent prospective and cross-sectional studies, as well as high qualitative clinical trials.
The reference lists of the articles that we identified through the PubMed search and the articles citing the identified papers, were additionally checked for other relevant literature regarding this narrative review’s aim.
3. **Factors associated with upper limb movement behaviour**

Here, we synthesize the current scientific knowledge on the factors associated with alterations in upper limb motor behaviour in BCS, as identified by our literature search. Details are synthesised in Appendix 2. Associated factors are specifically referred to as predictive factors or predictors when the association between the factor and motor behaviour is assessed via regression analyses on longitudinal data, with the data collection of the predictor variable (i.e., the independent variable) being earlier than the data collection of the motor behavioural outcome (i.e., the dependent variable).

The investigated factors in relation to motor behavioural outcomes are various and multidimensional. They are structured for this review into structural (cancer treatment modalities, axillary web syndrome, chest tightness, lymphedema), personal (hand dominance), lifestyle (physical activity level, body mass index), psychosocial (depressive symptoms, negative affect, pain catastrophizing, ethnicity, living status), and functional factors (pain).

3.1. Structural factors

*Cancer treatment modalities*

Evidence from systematic reviews was identified on the association between cancer treatment modality and post-operative shoulder ROM\(^{35, 37, 80}\). Also, more recent individual studies assessing the relation between cancer treatment modalities and shoulder ROM were found\(^5, 28, 41, 75, 78, 81\)

Based on evidence from systematic reviews, it is concluded that mastectomy, axillary lymph node dissection and radiotherapy to the axilla and chest wall are predictors of reduced ROM towards shoulder abduction, flexion and external rotation\(^{35, 37}\), with more reductions in ROM apparent one month following surgery versus one year following surgery\(^{53}\). Additionally, Verbelen et al., (2014) describe in their systematic review that a sentinel lymph node biopsy
leads to a reduced shoulder abduction and flexion ROM, however to a lesser extent when compared to an axillary lymph node dissection\textsuperscript{80}. Though, this latter review’s results should be interpreted with caution since almost all women included in the original studies received breast-conserving surgery, mastectomy, radiation therapy, chemotherapy and/or hormone therapy. Therefore, the exclusive effect of the sentinel lymph node biopsy on shoulder ROM cannot be confirmed.

Several recent prospective studies, not included in the abovementioned systematic reviews, report additional results regarding the association between cancer treatment modalities and shoulder ROM\textsuperscript{28, 41, 78}. The cancer treatment-related predictors of poorer abduction ROM at one month post-operative in BCS are type of surgery (mastectomy), axillary lymph node dissection, and neo-adjuvant chemotherapy\textsuperscript{78}, which are also the cancer treatment-related predictors of inter-individual changes in postoperative abduction ROM over time\textsuperscript{78}. Also at 6 months following surgery, additional reported risk factors for decreased abduction ROM are more than three dissected lymph nodes, radiation, and the size of dissected tissue\textsuperscript{41}. However, at 5 years following surgery, no significant difference in shoulder flexion, abduction, external rotation, and internal rotation ROM is found between women undergoing a sentinel lymph node biopsy and women undergoing an axillary lymph node dissection\textsuperscript{5}.

Concerning scapulothoracic kinematics and shoulder muscle activation patterns, no prospective research is identified. One cross-sectional study reports scapulothoracic movement deviations to be greater in women treated with mastectomy versus a breast-conserving surgery\textsuperscript{75}. Regarding shoulder muscle activation patterns, the prevalence of decreased muscle activity of the upper trapezius, deltoid and major pectoralis at 3 months after surgery is significantly greater in women undergoing a mastectomy plus axillary lymph node dissection compared to women undergoing a mastectomy plus sentinel lymph node biopsy\textsuperscript{81}. However, at 6 months after surgery, no significant differences in muscle activity are observed between groups\textsuperscript{81}. 
**Axillary web syndrome**

No evidence from systematic reviews is found regarding the relation between axillary web syndrome and upper limb motor behavioural outcomes. Shoulder flexion and abduction ROM is reported to be lower in women with axillary web syndrome at the short-term and long-term after surgery\(^43, 44, 53, 79\). One study describes axillary web syndrome at 2 and 4 weeks post-surgery as a risk factor for reduced shoulder abduction ROM at 5 years following medical treatment\(^43\), while this result is conflicted by another study that does not report a relation between the presence of cording and flexion and abduction ROM at more than 12 months post-surgery\(^53\). Another cross-sectional study that compares shoulder flexion and abduction ROM between BCS with axillary web syndrome and BCS without axillary web syndrome, also does not find differences in shoulder ROM between both groups at 2 months after surgery\(^2\).

**Chest tightness**

No evidence from systematic reviews or prospective studies is found regarding the relation between chest tightness and upper limb motor behavioural outcomes. One cross-sectional study reports a significant correlation between increased anterior chest tightness, and reduced shoulder range of motion\(^49\). More specifically, an increase in chest tightness assessed via the pectoralis minor muscle length is significantly correlated with decrease in shoulder extension and internal rotation ROM. When anterior chest tightness is defined by measuring the distance from the table to the posterior acromion in women when lying supine, a greater distance is significantly correlated with a decrease in shoulder adduction and internal rotation ROM\(^49\).

**Lymphedema**
No evidence from systematic reviews is found regarding the relation between lymphedema and upper limb motor behavioural outcomes. One prospective study indicates that the presence of lymphedema is not associated with shoulder abduction or flexion ROM at 12 months post-surgery\textsuperscript{53}. In cross-sectional research in BCS between 6 months and 5 years after surgery, less ROM in shoulder flexion, shoulder abduction, shoulder external rotation and elbow extension is observed in BCS with lymphedema as compared to BCS without lymphedema\textsuperscript{31}. Furthermore, a decreased shoulder abduction ROM, decreased scapulothoracic upward rotation and scapulothoracic increased anterior tilt is observed in BCS with severe lymphedema in comparison to BCS without lymphedema in the long-term following surgery\textsuperscript{4}.

3.2. Personal factors

Hand dominance

Three individual studies are identified reporting an association between the side of surgery (i.e., dominant versus non-dominant limb side) and shoulder ROM\textsuperscript{24, 39, 53}. Results seem conflicting, i.e., one prospective study reports surgery at the dominant limb side to be a risk factor for impaired shoulder flexion and abduction ROM at 3 months after surgery\textsuperscript{39}, while cross-sectional analyses report a reduced shoulder flexion and external rotation ROM\textsuperscript{24} and a reduced shoulder abduction ROM\textsuperscript{53} among BCS whose affected side was the non-dominant limb.

3.3. Lifestyle factors

Physical activity level
Two prospective cohort studies assessed the influence of physical activity level on shoulder ROM outcomes\textsuperscript{42, 53}. BCS who were moderate to vigorous physically active before surgery demonstrate more shoulder flexion and abduction ROM at 6 months post-surgery than BCS
who were inactive or light physically active before surgery\textsuperscript{42}. Furthermore, more physical activity at 1 month after surgery was significantly associated with improved shoulder ROM at 1 month\textsuperscript{53}. However, physical activity level at 12 months post-surgery seems not related to shoulder ROM at 12 months post-surgery\textsuperscript{53}.

\textit{Body mass index}

Prospective research indicates that a pre-surgical body mass index (BMI) \( \geq 25 \) is significantly related to a reduced flexion and abduction ROM at 12 months after surgery, and not to shoulder ROM at one month post-surgery\textsuperscript{53}. BMI \( \geq 25 \) at 12 months post-surgery seems only associated with reduced flexion ROM at 12 months post-surgery\textsuperscript{53}.

3.4. Psychosocial factors

No evidence of systematic reviews on the association between psychosocial factors and upper limb motor behaviour is found. Few individual studies assessed different psychosocial constructs in relation to shoulder ROM. The investigated psychological factors are depressive symptoms in one prospective study\textsuperscript{9}, and pain catastrophizing and negative affect in two cross-sectional studies\textsuperscript{1,6}. The social factors investigated in prospective research are ethnicity and living status\textsuperscript{78}.

\textit{Depressive symptoms}

More depressive symptoms at baseline are associated with a reduced shoulder ROM at 12 months following breast cancer diagnosis. More specifically, it is reported that each unit
increase in depressive symptoms at baseline is associated with an 8% decreased odds of having a full shoulder ROM, even after controlling for relevant patient and treatment factors.

**Pain catastrophizing**

In women with shoulder ROM limitations, significantly higher scores on the Pain Catastrophizing Scale are found in comparison to women without shoulder ROM limitations at 6 months or longer after surgery. Also, the prevalence of women with limited shoulder ROM was higher in women with a higher score on the Pain Catastrophizing Scale.

**Negative affect**

Regarding negative affect, this factor is significantly associated with limited shoulder abduction and external rotation ROM at the short- and long-term following surgery in BCS. Furthermore, perceived disability is identified as a mediator on the relationship between shoulder ROM and negative affect.

**Ethnicity and living status**

Ethnicity (being non-white) is one of the five predictors of inter-individual changes in reduced shoulder abduction ROM at 1 month post-operative (next to three medical treatment-related factors and pre-operative shoulder ROM). Furthermore, living alone is one of the four predictors of inter-individual changes in postoperative abduction ROM over time (next to three medical treatment-related factors).

3.5. Functional factors
Pain

No systematic review or prospective research evidence on the association between pain and upper limb motor behaviour in BCS is found. Few cross-sectional research is identified in which motor behavioural outcomes are compared between in BCS with shoulder pain and BCS without shoulder pain or a healthy control group\textsuperscript{25, 45-48, 69, 70, 76}. In these studies, reduced ROM (for shoulder flexion, horizontal abduction, shoulder abduction, and external shoulder rotation)\textsuperscript{45, 70}, kinematic alterations at the scapulothoracic joint (reduced scapulothoracic upward rotation post-mastectomy\textsuperscript{45, 47, 48}; increased scapulothoracic internal rotation post-mastectomy\textsuperscript{48}), alterations in scapulohumeral rhythm\textsuperscript{47} and changes in shoulder muscle activation\textsuperscript{46, 69} are reported in the BCS experiencing subacromial pain in comparison to a control group or BCS without pain. Regarding these changes in muscle activity in BCS with subacromial pain, an increased post-mastectomy peak force of pectoralis major, upper trapezius, and supraspinatus is reported\textsuperscript{46}. Furthermore, during shoulder abduction and flexion, an increased upper trapezius and deltoideus EMG amplitude\textsuperscript{25, 69}, and decreased lower trapezius, infraspinatus and serratus anterior EMG amplitude\textsuperscript{69} are observed. Regarding muscular timing, an earlier activation of upper and lower trapezius, together with a delayed activation of deltoideus and serratus anterior is recorded during shoulder abduction and flexion. During shoulder external rotation, early upper trapezius and delayed posterior deltoideus, infraspinatus, lower trapezius and serratus anterior muscular activation is recorded\textsuperscript{69}. 
4. Discussion, including future research

In this discussion, we first outline the factors associated with altered upper limb motor behaviour, as evident from prospective research, followed by the factors associated with altered upper limb motor behaviour reported in cross-sectional research.

From the literature summarized in this narrative review, it is concluded that mainly *structural factors* are assessed today in prospective research in relation to altered upper limb motor behaviour in BCS. There is an influence of cancer treatment modality on shoulder ROM, scapulothoracic kinematics, and scapulothoracic muscle activation, with mastectomy, axillary lymph node dissection, neo-adjuvant chemotherapy and radiotherapy to the axilla and chest being associated with reduced or deviated upper limb motor behaviour. The factor ‘cancer treatment modality’ appears to have its main effect in the early post-operative stage. Regarding other than structural factors, prospective research reports distinct *psychosocial factors*, i.e., depressive symptoms, being non-white, and living alone, as risk factors for decreased shoulder ROM on the longer term. The *lifestyle factors* ‘physical activity’ and ‘BMI’ also influences upper limb motor behaviour, with a moderate to vigorous physical activity level before surgery being related to more shoulder flexion and abduction ROM at 6 months after surgery, and baseline BMI >25 related to decreased shoulder ROM at one year after surgery. This clearly illustrates that upper limb motor behaviour after surgery in BCS is not only dependent on structural aspects or factors related to medical treatment, but that motor behaviour is influenced by biopsychosocial and lifestyle factors as well. Therefore, a multidimensional examination, including abovementioned factors related to upper limb motor behaviour, is required before and after surgery in women diagnosed with breast cancer.

Other structural factors (i.e., chest tightness and lymphedema), psychological factors (i.e., pain catastrophizing, negative affect), and functional factors (i.e., the presence of subacromial pain) are currently only cross-sectionally related to motor
behavioural outcomes, without further assessment of moderating mechanisms explaining their relationship. Since only prospective research can clarify the role of these factors on the development of altered motor behaviour, there is a clear gap in current knowledge around their effective contribution to upper limb motor behaviour. Indeed, it is unknown whether chest tightness, lymphedema, pain catastrophizing, negative affect and the presence of upper limb pain are precipitating factors, perpetuating factors or consequences of altered motor behavioural outcomes of the upper limb in BCS. However, given their cross-sectional association with upper limb motor behaviour it is of interest to also take these factors into account in the patient examination.

Especially regarding upper limb pain, it is remarkable and unfortunate that the potential bi-directional relationship between the presence and intensity of pain and altered motor behaviour at the upper limb is yet to be unravelled. Indeed, BCS are, with a reported prevalence up to 60%\(^6\), at high risk for developing persistent pain and subsequently a reduced quality of life. Therefore, unravelling the pain – motor behaviour relationship, together with the mechanisms explaining this relationship, from pre- to post-surgical time points is urgently needed to clearly define treatment targets and develop individualized treatment plans for BCS with suffering pain, influenced by their upper limb motor behaviour.

*Considering pain-related and lymphedema-related beliefs as moderating mechanisms on the path between upper limb motor behaviour and pain in BCS*

Given (1) the first evidence on the role of pain catastrophizing and negative affect on shoulder ROM limitations in BCS (reported in point 3.4)\(^1\), (2) the known association between pain catastrophizing/fear-avoidance beliefs and pain, dysfunction, lymphedema, depression, decreased physical activity participation and quality of life in BCS\(^1, 13, 22, 27, 63\), (3) the
resemblance between typical protective motor behavioural adaptations based on pain-related beliefs in chronic musculoskeletal pain populations and the reported upper limb motor behavioural alterations in BCS with pain (reported in point 3.5) and (4) the fact that structural factors mainly explain motor behavioural adaptation in the short-term following surgery, there is a rationale to explore the role of cognitions (i.e., pain catastrophizing) and emotions (i.e., fear of movement) in the association between persistent alterations in upper limb motor behavioural outcomes and persistent shoulder pain in BCS.

Different mechanisms can underlie persistent pain in BCS. Apart from neuropathic pain that is typically a consequence of surgery, chemotherapy or radiotherapy and provides pain in the region of the peripheral nerve, persistent posture and movement-related pain can occur as well. This pain is based on continuous nociceptive peripheral input, with trapezius myalgia and movement dysfunctions as examples of sources of nociception. It is typically mechanical in nature, and localized in the area of (referred pain of) the source of nociception. From such persistent posture and movement-related pain conditions in non-cancer populations, it is known that pain catastrophizing, pain-related fear of movement and protective motor behaviour (i.e., avoidance behaviour) have a main role in the transition from acute to chronic pain. While such avoidance behaviour might be protective in the acute stage after surgery when tissues are healing, it can have negative consequences when it lasts beyond the time needed for tissue-healing. Indeed, only seldom, avoidance behaviour is overt, meaning that a patient avoids every activity which is related to pain (and thus unloads the musculoskeletal system). Mostly, avoidance behaviour is subtle, and characterized by muscle guarding, stiffening, decreased range of motion of the affected region, altered inter-joint coordination, and/or altered spatiotemporal movement characteristics during activities. Thereby, avoidance behaviour may lead to suboptimal loading of specific musculoskeletal
structures and subsequent be a source of ongoing nociceptive peripheral input, making tissues more sensitive and contribute to the persistence of pain\textsuperscript{23, 36, 66}.

Applying this reasoning to BCS and the results of this review, protective posturing of the shoulder and reducing the shoulder ROM might be adequate in the acute stage after the breast surgery to promote wound healing and avoid seroma formation. This is reflected in our results, which indicate a higher EMG amplitude in the upper trapezius and deltoideus in BCS\textsuperscript{25, 69} and ROM reductions that relate to the extent of medical treatment modality, mainly in the first post-operative stage\textsuperscript{35, 36}. When such protective behaviour persists after adequate healing has occurred, as based on inappropriate beliefs (e.g. the reduced shoulder ROM seen in BCS at the long term after surgery with high levels of pain catastrophizing), it may be a potential source of nociceptive peripheral input and contribute to the development of persistent pain in BCS. However, apart from the fact that we know that a subgroup of the BCS shows reduced shoulder ROM at the long term after surgery which is not linked to the medical treatment modality\textsuperscript{53}, the association between motor behaviour of the upper limb and pain-related beliefs (pain catastrophizing and fear of movement) and the presence of pain is not studied in BCS today.

Next from pain-related fear of movement, fear of lymphedema related to arm movement and arm use is reported in BCS, and is found to be associated with reduced arm function and arm weakness\textsuperscript{50, 52}. In contrast, lymphedema itself is not associated with arm weakness\textsuperscript{50}, emphasizing the importance of assessing beliefs. This reported reduced arm function and arm weakness as based on lymphedema-related fear of movement can be interpreted as a protective behavioural reaction. This is unnecessary protective behaviour as it is known that arm use is not increasing the risk of lymphedema\textsuperscript{33}, and is therefore considered unhelpful as it potentially contributes to persistent shoulder pain in BCS due to inappropriate musculoskeletal loading.
Typical motor adaptations related to avoidance behaviour in persons with pain are reported. Examples of such motor adaptations are, amongst others, decreased movement at the (initial) painful area (i.e., reduced shoulder ROM as found in this review), compensatory movement in non-painful body regions (i.e. altered scapulothoracic movement as found in this review), increased muscle activation (i.e., increased upper trapezius activity as found in this review), slower movements, etc. This indicates that the assessment of the shoulder ROM during a simple arm elevation task, as is today the most often assessed motor behaviour outcome, might not be specific enough to assess altered motor behavioural outcomes as based on pain-related or lymphedema-related fear of movement. Indeed, it is known that, to be able to assess avoidance behaviour, the requested movement task should be challenging and resemble a fearful activity.

**Conclusion and future research**

Today, we know that in the first stage after surgery, shoulder ROM is reduced, with the main contributing factor to this reduced ROM being the medical treatment modality. Regarding persistent motor behavioural adaptations in BCS, our knowledge on associated factors is limited since most assessed variables are only assessed once, in small, mainly cross-sectional studies. Taking the knowledge of the mechanisms underlying motor behavioural adaptations in non-cancer persistent pain populations into account, it seems of interest to assess how much of the variance of motor behavioural outcomes in BCS at the long term after surgery is due to pain-related or lymphedema-related cognitions and emotions leading to altered motor behaviour in BCS. Also, whether such avoidance behaviour is contributing to the transition from acute to persistent upper limb pain in (specific subgroups of) BCS is of high interest to study. In this, it is of relevance to explore which motor behavioural outcomes can be identified as markers of avoidance behaviour based on fear of movement. Therefore, future research should additionally
focus on a thorough examination of motor behaviour, with clear investigation of the beliefs underlying alterations in motor behaviour (i.e., fear of pain, fear of injury, fear of lymphedema, …). This way, it can be identified in which BCS (e.g., with a higher level of catastrophic beliefs, or with higher levels of anxiety) which beliefs regarding arm movement exist, and how behavioural responses look like. Furthermore, it is of interest to investigate whether beliefs and behavioural adaptations are related to persistent upper limb pain and disability. Only based on such information, clear targets, including unhelpful beliefs and perceptions, for behavioural management can be identified.

References

conserving surgery depending on the type of intervention in the axillary fossa. *Contemp Oncol (Pozn).* 2018;22:240-246.


