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Lumbar range of motion in chronic low back pain is predicted by task-specific, but not by general measures of pain-related fear.

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Running head: Task-specific pain-related fear predicts lumbar ROM

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Significance: This is the first study to show that lumbar range of motion in CLBP is predicted by task-specific, but not by general measures of pain-related fear. This suggests that both in clinical practice and for research purposes, it might be recommended to use task-specific measures of pain-related fear when assessing the relationship with movement behavior. This may help to disentangle the complex interactions between pain-related fear, movement and disability in patients with CLBP.

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Abstract

Background: Most studies fail to show an association between higher levels of pain-related fear and protective movement behavior in patients with chronic low back pain (CLBP). This may be explained by the fact that only general measures of pain-related fear have been used to examine the association with movement patterns. This study explored whether task-specific, instead of general measures of pain-related fear can predict movement behavior.

Methods: Fifty-five patients with CLBP and 54 healthy persons performed a lifting task while kinematic measurements were obtained to assess lumbar range of motion (ROM). Scores on the Photograph Daily Activities Series-Short Electronic Version (PHODA-SeV), Tampa Scale for Kinesiophobia and its Activity Avoidance and Somatic Focus subscales were used as general measures of pain-related fear. The score on a picture of the PHODA-SeV, showing a person lifting a heavy object with a bent back, was used as task-specific measure of pain-related fear.

Results: Lumbar ROM was predicted by task-specific, but not by general measures of pain-related fear. Only the scores on one other picture of the PHODA-SeV, similar to the task-specific picture regarding threat value and movement characteristics, predicted the lumbar ROM. Compared to healthy persons, patients with CLBP used significantly less ROM, except the subgroup with a low score on the task-specific measure of pain-related fear, who used a similar ROM.

Conclusions: Our results suggest to use task-specific measures of pain-related fear when assessing the relationship with movement. It would be of interest to investigate whether reducing task-specific fear changes protective movement behavior.

1. INTRODUCTION

The fear-avoidance model postulates that catastrophic thoughts about pain can lead to pain-related fear, which in turn may result in avoidant behavior (Crombez et al., 2012; Vlaeyen et al., 2016). While the temporary avoidance of certain activities might be beneficial in case of acute injury, this behavior becomes maladaptive once the tissues have healed (Hodges & Smeets, 2015). This is relevant for patients with CLBP in particular, because in about 90% of this population no pathoanatomical cause can be detected to explain the pain (Maher et al., 2017). Despite the absence of clear tissue damage, a subgroup of patients with CLBP adopts a protective movement strategy by stiffening the spine, resulting in a reduced lumbar range of motion (ROM) during active movements (P. O'Sullivan, 2005).

Based on the fear-avoidance model, it has been hypothesized that especially patients with CLBP who are displaying higher levels of pain-related fear would show this protective behavior (Geisser et al., 2004). Although pain-related fear has been associated with a reduced active lumbar range of motion (Geisser et al., 2004; Thomas & France, 2008), most studies do not support such a relationship (Vincent et al., 2011; Demoulin et al., 2013; Vaisy et al., 2015; Marich et al., 2017; Karayannis et al., 2018). The discrepancy between the abovementioned hypothesis and the results from cross-sectional studies could possibly be explained by the fact that only general measures of pain-related fear, such as the Tampa scale for kinesiophobia (TSK) and the Fear-avoidance beliefs questionnaire (FABQ), have been used to examine the association with movement patterns. Although some patients with CLBP may present with a generalized fear of movement, others might be fearful of particular activities only, without achieving a high score on the TSK or the FABQ. As such, task-specific measures of pain-related fear could be more appropriate to assess the relationship with movement patterns (Leeuw et al., 2007; Oliveira et al., 2018).

If patients do not resume their normal movement patterns after an acute episode of LBP, but maintain a protective movement behavior, the latter can become a source of ongoing peripheral nociceptive input by loading the spine in a suboptimal manner, which in turn can contribute to the persistence of CLBP (P. O'Sullivan, 2005; Hodges & Smeets, 2015). Therefore, pain-related fear may not only influence central pain processing but also peripheral pain mechanisms. From a clinical perspective, it would be of interest to identify modifiable factors that are related to movement patterns which deviate from those of healthy persons. This would allow to specifically target therapy towards these sources of altered movement, potentially leading to improved treatment outcomes for patients with CLBP.

In this study, a standardized lifting task was used to examine the association between lumbar ROM and measures of pain-related fear in patients with CLBP. We hypothesized that lumbar ROM during a lifting task would be predicted by task-specific, but not by general measures of pain-related fear. Second, based on the observation that pain-related fear can generalize to movements that are proprioceptively similar to the initial painful movement (Meulders & Vlaeyen, 2013), we expected that patients who are fearful of activities similar to lifting would perform the lifting task with less lumbar ROM. Finally, the lumbar ROM of healthy persons and patients with CLBP was compared with each other. We hypothesized that patients with lower scores on the task-specific measure of pain-related fear would have a similar lifting pattern compared to healthy persons, whereas patients who self-report fear of lifting would use less lumbar ROM.

2. METHODS

2.1 Design

This cross-sectional study is a pre-planned analysis of baseline measurements of a randomized controlled trial (Matheve, Brumagne, et al., 2018). All the data presented in this paper were collected on the same day.

2.2 Participants

Fifty-four healthy persons and 55 patients with chronic non-specific LBP participated in this study. Participants were recruited via private GP and physiotherapy practices and via social media. To be included, participants needed to be between 18 and 65 years old, and patients had to be diagnosed with chronic non-specific LBP (> 3 months, ≥ 3 days/week). Exclusion criteria for both participant groups were signs and symptoms of nerve root involvement, a serious underlying disease, pregnancy, performance of lumbopelvic movement control exercises in the past year and musculoskeletal complaints other than LBP interfering with daily functioning (e.g. severe knee pain). Healthy participants were excluded when they experienced at least 1 day of self-reported LBP in the past year that interfered with daily life activities or sought professional help for their LBP in the past year (Sorensen et al., 2016). Persons willing to participate in the study were initially screened via a structured telephone interview, and eligibility was confirmed when participants arrived in the lab, prior to the start of the tests. Ethical approval was obtained from the Ethics Committees of Hasselt University and Jessa Hospital, Belgium. All participants gave written informed consent before being included in the study.

2.3 Procedures

First, participants completed a series of questionnaires after which a movement analysis was performed during a lifting task.

2.3.1 Questionnaires

2.3.1.1 Healthy participants and patients with CLBP

Sociodemographic variables: Age, sex, height and weight were collected. Patients were also asked to complete a question on the duration of the LBP.

2.3.1.2 Patients with CLBP

Numeric Pain Rating Scale (NPRS) (Chapman et al., 2011): Participants were asked to indicate the intensity of their present LBP and the average intensity of their LBP over the past 7 days on a 0 to 10 numeric rating scale (0= no pain, 10= worst imaginable pain).

Roland Morris Disability Questionnaire (RMDQ) (Roland & Morris, 1983): The RMDQ contains 24 questions about the effect of LBP on daily activities, which have to be answered with yes or no. A higher score (range 0-24) represents a higher level of disability.

Pain Catastrophizing Scale (PCS) (Sullivan et al., 1995): The PCS contains 13 questions relating to the patients' negative thoughts and feelings during pain. Each question has to be answered on a 5-point scale (0= not at all, 4= always), resulting in a score between 0 and 52. A higher score corresponds with a higher level of pain catastrophizing.

Tampa Scale for Kinesiophobia (TSK) (Vlaeyen et al., 1995): The TSK is a questionnaire containing 17 items to assess subjective ratings of fear of movement/re-injury due to physical activity. The total score (TSK-total) ranges between 17 and 68, with a higher score indicating a higher level of kinesiophobia. For patients with CLBP, two subscales can be discerned in the TSK. The activity avoidance subscale (TSK-AA) specifically measures activity avoidance and fear of re-injury, whereas the Somatic Focus subscale (TSK-SF) assesses to which extent patients believe that their LBP can be attributed to a serious underlying medical problem (Goubert et al., 2004). Because it has previously been hypothesized that the TSK-AA might be a better predictor for the lumbar ROM than the TSK-total or TSK-SF (Demoulin et al., 2013), a separate score for the TSK-AA (range 8 to 32) and for the TSK-SF (range 5 to 20) was also calculated.

The Photograph Series of Daily Activities—Short Electronic Version (PHODA-SeV) (Leeuw et al., 2007): The PHODA-SeV is a measure of perceived harmfulness of specific physical activities. Forty consecutive pictures of daily life activities are shown on a computer screen. Participants are asked to imagine themselves performing the activities, and to indicate to which extent they think the activities are harmful to their back on a 0 to 100 scale (0= not harmful at all, 100= extremely harmful). A total score (0 to 100) per participant is calculated by averaging the scores of the 40 pictures. The score (range 0 to 100) on picture number 3 of the PHODA-SeV, which displays a person lifting a flower pot with a bent back (see Supplementary Figure S1a), was defined a priori as a task-specific measure of pain-related fear (PHODA-lift), as this picture best resembles the task that participants in the current study had to perform.

Although the PHODA-SeV assesses the perceived harmfulness of specific activities, the total score on the PHODA-SeV (PHODA-total) gives a general rating of perceived harmfulness as it is the average of all scores on the individual tasks. As such, the PHODA-total does not specifically relate to the lifting task in this study. Therefore, the scores on the PHODA-total, TSK-total, TSK-AA and TSK-SF were considered as general measures of pain-related fear. Similar to other papers (Karayannis et al., 2013; Oliveira et al., 2018), the overarching term pain-related fear will further be used for both the TSK and PHODA-SeV. However, one should bear in mind that the TSK and PHODA-SeV might not measure exactly the same construct (Lundberg et al., 2011).

2.3.2 *Movement analysis*

2.3.2.1 Lifting task

The participants started from their habitual standing position. They were then asked to lift a box with handles from a platform, to remain in an upright standing position for one second and to put it down again (Supplementary Figure S1b). The task was performed five times at a self-selected pace. To standardize the lifting task for the participant's height, the top of the box was positioned 10 cm below the apex of the subjects' patella. Participants stood with both feet at a distance of 15cm from the box. The dimensions of the box were 40x30x23.5 cm, and it weighed 4 kg. The dimensions and weight of the box were chosen as they closely resemble the object in the picture of the PHODA-lift. Furthermore, we used this particular task because lifting is a highly relevant activity that patients with CLBP typically perceive as harmful (Leeuw et al., 2007; Stevens et al., 2016), and the lumbar ROM during this task can be assessed with excellent reliability (Bauer et al., 2015; Matheve, De Baets, et al., 2018).

2.3.2.2 Kinematic data acquisition

The Valedo®motion research tool (Version 1.2, Hocoma, Switserland) was used to obtain lumbopelvic kinematics in the sagittal plane. This tool consists of wireless inertial measurement sensors that have an accuracy of 0.1° and sampling rate of 50Hz. The reliability and validity of the system to asses lumbopelvic kinematics have been previously shown (Bauer et al., 2015; Matheve, De Baets, et al., 2018). First, the L1 and S1 levels were palpated in a standardized way (Tixa, 2015). Hereafter, the system was calibrated and the sensors were placed at the level of the spinous process of L1 and S1 using double sided tape. Both the palpation and sensor placement were performed with the participant in a relaxed standing position. The movement analysis started by recording the habitual standing position of the participants. For each repetition, the maximal deviation from the starting position was calculated and expressed in absolute values. Lumbar spine angles were calculated from the orientation of the L1-sensor relative to that of the S1-sensor. To obtain a more reliable measurement of the movement patterns, an average of the five repetitions was calculated. Further details on the data acquisition can be found elsewhere (Matheve, De Baets, et al., 2018).

2.4 Statistical analysis

A multiple linear regression was performed to examine the predictive value of pain-related fear for the lumbar ROM during the lifting task. First, a basic model was constructed that only contained the controlling variables age, sex, current pain, pain catastrophizing, duration of LBP and disability. These variables were controlled for as they might influence lumbar ROM (Intolo et al., 2009; Laird et al., 2014; Vaisy et al., 2015; Marich et al., 2017; Arshad et al., 2018). Next, for every measure of pain-related fear (i.e. TSK-total, TSK-AA, TSK-SF, PHODA-total, PHODA-lift), a separate regression analysis was made by adding the respective measure to the basic model. This resulted in 5 additional regression models, each containing the same set of controlling variables, but a different measure of pain-related fear.

Single correlation coefficients were used to analyze whether the lumbar ROM was associated with any of the scores on the individual pictures of the PHODA-SeV, other than the PHODA-lift. Because the Shapiro-Wilk test indicated that the lumbar ROM data were normally distributed, a Pearson or Spearman correlation coefficient was used depending on the distribution of the scores on the individual pictures of the PHODA-SeV. Scores of pictures showing a significant correlation with the lumbar ROM were entered in a regression analysis together with the same controlling variables as described above.

To compare the lumbar ROM of healthy persons with those of patients with CLBP, six regression analyses were performed, using age and sex as controlling variables. First, healthy persons were compared with the CLBP group as a whole. Second, to assess whether pain-related fear influenced this comparison, patients with CLBP were categorized into subgroups of low (n= 18), medium (n=18) or high (n= 19) levels of pain-related fear by using the lowermost, middle and uppermost thirds of the actual scores on the measure of pain-related fear (Karayannis et al., 2018). This subgroup analysis was performed for each of the pain-related fear measures. A Dunnett's post-hoc test was used to compare each subgroup of patients (low, middle or high level of pain-related fear) with the group of healthy persons.

3. RESULTS

Baseline characteristics of the participants can be found in Table 1. A total of 178 patients with CLBP and 56 healthy participants were screened for participation. Reasons for exclusion can be found in Supplementary Figure S2.

3.1 Prediction of lumbar ROM by pain-related fear

The results from the regression analyses are presented in Table 2. In all of the models, female sex was predictive for an increased lumbar ROM and current pain had a negative predictive value for lumbar ROM. Adding TSK-total, TSK-AA, TSK-SF or PHODA-total to the basic model, which contained only the control variables, did not explain an additional proportion of the variance in lumbar ROM (all p-values > 0.17). In contrast, adding PHODA-lift to the basic model explained an additional 11% of the variance in lumbar ROM (p= 0.003). PHODA-lift was negatively associated with lumbar ROM, indicating that patients who scored higher on the PHODA-lift used less lumbar ROM during the lifting task.

The correlations between each picture of the PHODA-SeV and the lumbar ROM can be found in Table 3. Besides the PHODA-lift, which was the picture with the highest correlation (ρ= -0.43, p= 0.0009), only the scores on picture 1 of the PHODA-SeV, showing a person shoveling soil with a bent back, were significantly correlated with lumbar ROM (ρ= -0.34, p= 0.01). When the scores on picture

1 were added to the basic regression model, they explained an additional 6% of the variance in lumbar ROM ($p= 0.02$, Table 4).

3.2 Comparison of lumbar ROM between healthy persons and patients with CLBP

In each of the regression analyses used to compare lumbar ROM between healthy persons and (subgroups of) patients with CLBP, the variable 'group' was significant (see Supplementary Table S1). Post-hoc tests indicated that the whole group and all the subgroups of patients with CLBP used significantly less ROM compared to the healthy subjects (all p-values ≤ 0.01), except the subgroup with a low score on the PHODA-lift (Table 5). No significant difference was present between the ROM of the healthy persons and the patients with a low score on the PHODA-lift ($p= 0.22$).

4. DISCUSSION

The aim of this study was to investigate whether task-specific or general measures of pain-related fear were predictive for the lumbar ROM during a lifting task. The results supported our hypothesis that lumbar ROM was predicted by task-specific, but not by general measures of pain-related fear. Second, we expected that patients who were fearful of activities similar to lifting would perform the lifting task with less lumbar ROM. Only the scores on picture 1, displaying a person shoveling soil, were predictive for lumbar ROM during the lifting manoeuver. Finally, our results showed that all the subgroups (i.e. low, medium and high) based on the pain-related fear scores used significantly less ROM than the healthy control group, except the subgroup with low scores on the task-specific measure of pain-related fear, which used a ROM similar to the healthy subjects.

Higher levels of pain-related fear have consistently been associated with increased pain and disability in patients suffering from CLBP (Zale et al., 2013; Kroska, 2016). Moreover, the reduction of pain-related fear is predictive for a better treatment outcome in this population, which implies that this fear should be addressed when present (Wertli et al., 2014). To achieve this, Vlaeyen et al. developed a graded exposure in vivo treatment for patients with CLBP who are displaying elevated levels of pain-related fear (Vlaeyen et al., 2012). One of the key aspects of graded exposure therapy is to establish a personal fear hierarchy using the PHODA-SeV in order to gather information about which specific movements are feared and avoided (Leeuw et al., 2007). Based on this information, patients will (gradually) be exposed to feared movements and activities.

Although pictures of specific activities (including lifting) have previously been used to assess associations between implicit measures of danger and a bent back (Caneiro, O'Sullivan, et al., 2017; Caneiro et al., 2018), it had never been investigated whether the score on a specific item of the PHODA-SeV (e.g. lifting with a bent back) is indeed reflected in the actual movement behavior during a similar lifting task. This could be considered as a limitation of the construct validity of the PHODA-SeV, and therefore it has been recommended to relate PHODA-SeV scores with the performance on behavioral tests (Leeuw et al., 2007; Oliveira et al., 2018). Because the scores on the PHODA-lift were indeed predictive for the lumbar ROM during a lifting task, the results of this study suggest that the PHODA-SeV is a valid instrument for establishing a fear hierarchy and further support the use of task-specific behavioral assessments to investigate protective movement behavior (Holzapfel et al., 2016).

The general measures of pain-related fear were not related to the lumbar ROM, which is in line with the results from most (Vincent et al., 2011; Demoulin et al., 2013; Vaisy et al., 2015; Marich et al., 2017; Karayannis et al., 2018), but not all (Geisser et al., 2004; Thomas & France, 2008) of the studies on this topic. The reasons for these differences are unclear and may be explained by various factors, including differences in the task performed (e.g. flexion in standing versus a lifting task), the patient population (e.g. subacute versus chronic LBP) or the variables that have been controlled for in the analysis. In this respect, it could be argued that specifically including the PCS into the basic model of our study might have attenuated the predictive value of the pain-related fear measures because both variables are closely linked in the fear-avoidance model (Vlaeyen et al., 2016). However, there was no multicollinearity and removing the PCS from the basic regression model did not influence results.

A potential explanation for the lack of predictive value of the general pain-related fear measures is that some patients with CLBP might be afraid of particular movements only, without perceiving physical activity in general (e.g. walking or doing exercises) as harmful (Pincus et al., 2010). Fear-avoidance beliefs are shaped by many factors, including pain characteristics (e.g. predictability of pain), societal influences (e.g. family) and information from health care providers (Darlow et al., 2013; Bunzli et al., 2015). Especially the influence of the latter has gained more attention in recent years. While most health care practitioners regard exercises and staying active as beneficial for CLBP, many of them consider lifting with a bent back as harmful for the lumbar spine, although there is no good evidence to support this belief (Nolan et al., 2018). Because patients with CLBP are strongly influenced by the information provided by their health care provider (Darlow et al., 2013) it is plausible that misinformed patients will become fearful to perform this specific task, resulting in a protective movement behavior with a restricted lumbar ROM, without necessarily regarding general physical activity as harmful.

Besides the influence of the abovementioned factors, learning processes are fundamental for acquiring pain-related fear and avoidant behavior. When a lifting manoeuver is followed by an episode of LBP, lifting itself may become associated with pain. As a consequence, patients may develop a fear for lifting and avoid this activity (respondent conditioning). When the avoidance of lifting results in less pain, this behavior will be reinforced (operant conditioning) (Vlaeyen et al., 2016; Linton et al., 2018). A specific feature of respondent conditioning is stimulus generalization (Vlaeyen, 2015). This occurs when a stimulus that is similar to the original fear-eliciting stimulus will also provoke a fear-response. The strength of this response follows a gradient which depends on how closely these stimuli match with each other (Vlaeyen, 2015). Although these concepts were initially based on research in anxiety disorders (Dymond et al., 2015), Meulders et al. showed that in a predictable pain context, pain-related fear also spreads to movements that are proprioceptively similar to the original painful movement, and that this generalization does indeed follow a gradient (Meulders et al., 2013; Meulders & Vlaeyen, 2013). Therefore, we hypothesized that the lumbar ROM during lifting would also, but less strongly, be predicted by the scores on pictures of the PHODA-SeV that are proprioceptively related to a lifting manoeuver with a bent back.

Our results showed that besides the PHODA-lift, only the scores on picture 1, depicting a person shoveling soil, predicted the lumbar ROM. In line with our hypothesis, the scores on picture 1 were a less strong predictor for the lumbar ROM than the scores on the PHODA-lift. Interestingly, the lifting and shoveling task share similarities regarding the threat value and movement characteristics, that is, both tasks were perceived as highly harmful and the person in both pictures is handling a load with a clearly flexed spine and extended knees. Potentially, not only the proprioceptive relatedness is of importance to predict movement behavior, but also the threat value of the activity. This hypothesis is supported by two observations. First, pictures showing activities in a clearly flexed position (i.e. proprioceptively similar), but which were rated as significantly less harmful than the PHODA-lift, were not related to the lumbar ROM. For example, picture 4 shows a person in a fully flexed position who is picking up a pair of shoes with one hand, while taking support on a cupboard with the other hand. For some patients, simply flexing the spine might already be seen as a harmful movement, whereas others might only perceive this as harmful when heavier loads are being handled or when they cannot use an external support. Second, a movement that was perceived as equally harmful to the PHODA-lift, but which was proprioceptively different (i.e. falling backward on the grass), was also not associated with the lumbar ROM. For the same reason, it can be explained that the scores on picture 10, displaying a person lifting a crate from the trunk of a car, were not correlated with the lumbar ROM. Although this activity was also regarded as highly harmful, the person's spine is only slightly flexed, limiting the proprioceptive relatedness. Taken together, these results suggest that both the proprioceptive similarity (e.g. activities with a flexed spine) as well as the perceived harmfulness are important in order to predict the lumbar ROM.

Compared to healthy persons, only the patients with a low score on the PHODA-lift used a similar lumbar ROM during lifting. From a clinical perspective, the question thus arises whether reducing the task-specific fear will automatically lead to a 'normalization' of the lumbar ROM during that task. This question is pertinent, because it has been well established that both peripheral (e.g. altered movement patterns) and central (e.g. maladaptive beliefs) pain mechanisms are associated with CLBP (Sheeran et al., 2012; P. O'Sullivan et al., 2016; Meier et al., 2017). While a particular mechanism may be dominant in certain persons, many individuals present themselves with a mixed pattern of peripherally and centrally mediated pain (Nijs et al., 2015).

Despite its overall effectiveness, a substantial number of patients with CLBP does not achieve a clinically meaningful reduction in disability after exposure therapy (Glombiewski et al., 2018), which suggests that other factors than pain-related cognitions and emotions might be responsible for the patient's problem. Furthermore, changes in subjective measures of fear do not necessarily lead to synchronous changes in behavior (Rachman & Hodgson, 1974). If subjective measures of fear diminish but the protective movement behavior is maintained, the latter may become an underlying mechanism contributing to persistence of CLBP by loading the spine in a suboptimal manner. Therefore, it would be valuable to assess whether movement patterns change after (exposure) treatment and, if so, whether these changes mediate the improvements in pain and disability.

In this respect, a treatment called 'cognitive functional therapy' (CFT) has been recently developed in the physical therapy field (P. B. O'Sullivan et al., 2018). CFT is a multidimensional behavioral approach combining graded exposure therapy with physical treatments (e.g. targeting maladaptive movement patterns). It has been shown that CFT improves pain-related cognitions and emotions (Vibe Fersum et al., 2013; K. O'Sullivan et al., 2015), as does exposure therapy (Leeuw et al., 2008), but it is unclear whether CFT influences movement behavior. Clinical trials have shown that standard tasks such as sitting posture and lumbar ROM during forward bending did not change after CFT (Vibe Fersum et al., 2013; K. O'Sullivan et al., 2015). In contrast, several case studies that evaluated patient-specific activities showed that an improvement in pain and disability was associated with a less protective movement behavior after CFT (Caneiro et al., 2013; Meziat Filho, 2016; Caneiro, Smith, et al., 2017). Therefore, it might be more appropriate to evaluate the specific movements that were targeted during treatment instead of using standardized tasks.

Study limitations

Several limitations apply to this study. First, to compare the lumbar ROM of healthy participants and patients with CLBP, the patient group was divided into three subgroups based on the actual scores on the measures of pain-related fear. Categorizing participants into subgroups may limit the power to detect smaller differences. However, this problem is mainly present when a median split is used to categorize a predictor, but is largely avoided by discretizing it into thirds, as we did in the current study (Gelman & Park, 2009). Furthermore, using a certain cut-off for categorizing patients is somewhat arbitrary. The scores on the PHODA-SeV, TSK and its subgroups in our study were slightly lower compared to the normative data for patients with CLBP (Leeuw et al., 2007; Nicholas et al., 2008). However, these normative data are mainly based on severely disabled patient populations that were referred to specialized pain clinics. Therefore, they might not be representative for the patients seen in primary care, such as the ones in the current study (Leeuw et al., 2007; Nicholas et al., 2008). Moreover, cut-off values on the TSK that have been used to include patients with either moderate (>34/68) (Leeuw et al., 2008) or high (>39/68) (Vlaeyen et al., 2012) levels of pain-related fear into graded exposure interventions correspond very well with the scores of the moderate (range 33-38/68) and high (range 40-53/68) groups of the TSK-total in the present study.

Second, because we only included a lifting task to assess the predictive value of pain-related fear, we cannot make any statements concerning other movements. On the other hand, lifting is a highly relevant activity that patients with CLBP typically perceive as harmful (Leeuw et al., 2007; Stevens et al., 2016). As a consequence, reducing the fear for lifting an object is often one of the treatment goals in this patient population.

Third, we only used the maximal lumbar ROM as a measure of movement behavior and we did not differentiate between ROM of the lower and upper lumbar spine. The latter can be considered as a limitation because regional differences in lumbar spinal movement have been previously reported (Mitchell et al., 2008; Hemming et al., 2018). In addition, other measures of movement behavior, such as muscle activity patterns and movement speed might also be of interest, especially because differences in these parameters have been shown between healthy persons and patients with CLBP (Laird et al., 2014; Lima et al., 2018). Furthermore, the lumbar ROM during a functional task is sometimes expressed as a percentage of the individual's total available ROM, instead of using absolute values (Bible et al., 2010). In this case, the total available ROM is typically measured using a flexion in standing, when a person is asked to bend forward as far as possible (Bible et al., 2010). However, some people might have a fear of bending, irrespective whether this is a simple flexion or a lifting task (Caneiro, O'Sullivan, et al., 2017). Consequently, the ROM during flexion in standing might not be a good indication of the total available ROM because it could also be limited due to the protective behaviour (Geisser et al., 2004). Furthermore, it has been shown that the lumbar flexion ROM during functional activities sometimes exceeds the maximal lumbar ROM measured during flexion in standing (Wade et al., 2012). In our opinion, the latter measure cannot be considered to be the golden standard for measuring the maximal physiological ROM. Therefore, we used absolute instead of relative values to express the ROM, and controlled for various factors (e.g. sex and age) that could influence this outcome.

Finally, the measurements were performed in a laboratory setting. Because the context in which activities are performed can influence (avoidant) movement behavior (Claes et al., 2016), it would be valuable to evaluate how people move during daily life activities in their personal context. Considering the limitations of the currently available measurement systems, however, this would be very challenging from a technical point of view.

Conclusions

The present study confirmed our hypothesis that the lumbar ROM during a lifting manoeuver was predicted by task-specific, but not by general measures of pain-related fear. We also expected that scores on pictures showing activities which were proprioceptively similar to the lifting task would predict the lumbar ROM. However, our results suggest that besides the proprioceptive relatedness, also the threat value should be similar to predict the lumbar ROM. Finally, only the patients with a low score on the task-specific measure of pain-related fear had a similar lumbar ROM compared to healthy persons. Based on these results, we recommend to use task-specific measures of pain-related fear when assessing the relationship with movement behavior. Furthermore, it would be of interest to investigate whether reducing task-specific fear changes protective movement behavior, and whether these potential changes mediate the improvements in pain and disability.

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Author contributions

T.M. conceptualized the study, collected and analyzed the data, and wrote the manuscript. All authors interpreted the findings, commented on and revised the manuscript. All authors approved the final version of the manuscript.

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Figure caption list

FigureS1 – (a) The PHODA-Lift picture of the PHODA-SeV, (b) the lifting task participants had to perform in the current study.

FigureS2 – Flowchart of participants through the study

Table 1 Sociodemographic data and baseline questionnaires

	Patients with CLBP (n=55)		Healthy persons (n=54)		p-value
Sociodemographic variables					
Age (years)	41.1	(13.6)	36.9	(13.1)	0.11
Sex (n female, %)	26	(47)	34	(62)	0.10
BMI (kg/m²)	24.2	(3.4)	23.2	(3.5)	0.13
LBP Questionnaires					
Duration LBP (years)[a]	5	(2-11)			
Pain 7 days (0-10)	4.6	(1.7)			
Current pain (0-10)	3.3	(2.0)			
RMDQ (0-24)[a]	7	(5-11)			
PCS (0-52)	15.9	(8.4)			
TSK-total (17-68)	36.5	(6.9)			
TSK-AA (8-32)[a]	16	(13-20)			
TSK-SF (5-20)	10.0	(3.2)			
PHODA-total (0-100)	41.0	(13.6)			
PHODA-lift (0-100)[a]	77	(60-89)			

Data are mean (SD), unless otherwise stated. BMI= Body Mass index, LBP= low back pain, Pain 7 days= average pain in the past 7 days, PCS= Pain catastrophizing scale, PHODA-lift= score on the task-specific picture of the PHODA-SeV, PHODA-total= total score on the PHODA-SeV, RMDQ= Roland Morris Disability Questionnaire, TSK-total= total score on the Tampa Scale for Kinesiophobia, TSK-AA= score on the Activity Avoidance subscale of the TSK, TSK-SF= score on the Somatic Focus subscale of the TSK.

[a] Median (IQR)

Table 2 Regression models predicting lumbar range of motion during the lifting task

Regression model	Variables	Std Beta	p-value	R^2	R^2 adj	ΔR^2 adj
Basic model with control variables	Sex [F]	0.34	0.008	0.39	0.31	
	Age	-0.24	0.13			
	Duration LBP	0.02	0.87			
	Current pain	-0.29	0.04			
	RMDQ	-0.24	0.10			
	PCS	0.02	0.86			
Basic model +	Sex [F]	0.38	0.006	0.40	0.31	-0.01
TSK-total	Age	-0.27	0.10			
	Duration LBP	0.05	0.73			
	Current pain	-0.29	0.04			
	RMDQ	-0.26	0.08			
	PCS	-0.03	0.82			
	TSK	0.14	0.35			
Basic model +	Sex [F]	0.38	0.004	0.41	0.32	0.01
TSK-AA	Age	-0.28	0.08			
	Duration LBP	0.07	0.62			
	Current pain	-0.30	0.03			
	RMDQ	-0.28	0.06			
	PCS	-0.02	0.87			
	TSK-AA	0.19	0.17			
Basic model +	Sex [F]	0.35	0.009	0.39	0.29	-0.02
TSK-SF	Age	-0.25	0.12			
	Duration LBP	0.02	0.87			
	Current pain	-0.29	0.04			
	RMDQ	-0.24	0.10			
	PCS	<0.01	0.99			
	TSK-PFS	0.04	0.76			
Basic model +	Sex [F]	0.34	0.01	0.39	0.29	-0.02

PHODA-total	Age	-0.24	0.14			
	Duration LBP	0.02	0.89			
	Current pain	-0.29	0.04			
	RMDQ	-0.24	0.11			
	PCS	0.02	0.87			
	PHODA-total	0.01	0.93			
Basic model + PHODA-lift	Sex [F]	0.37	0.003	0.49	0.42	0.11
	Age	-0.26	0.07			
	Duration LBP	0.05	0.70			
	Current pain	-0.30	0.02			
	RMDQ	-0.13	0.33			
	PCS	0.06	0.68			
	PHODA-lift	-0.35	0.003			

LBP= low back pain, PCS= Pain catastrophizing scale, PHODA-lift= score on the task-specific picture of the PHODA-SeV, PHODA-total= total score on the PHODA-SeV, RMDQ= Roland Morris Disability Questionnaire, TSK= Tampa scale for kinesiophobia, TSK-AA= Activity avoidance subscale of the TSK, TSK-SF: Somatic focus subscale of the TSK. ΔR^2 adj= difference in R^2 adj relative to R^2 adj of the model with control variables only. Due to rounding, ΔR^2 adj might not add up precisely to R^2 adj of the model with control variables only.

Sex [F]: a positive Std. Beta indicates that female sex is associated with a larger range of motion.

Table 3 Correlations between scores on individual pictures of the PHODA-SeV and lumbar range of motion during lifting.

Picture	Description	Score on item		Correlation with ROM	p-value
		Median (IQR)	Mean (SD)		
3	Lifting pot. bent back	77 (60-89)	72.9 (18.9)	-0.43[a]	0.0009
1	Shovelling soil	84 (70-92)	79.4 (18.6)	-0.34[a]	0.01
5	Picking up shoes. squatting	16 (5-30)	21.7 (23.1)	-0.26[a]	0.06
7	Ironing while standing	30 (15-50)	31.3 (21.5)	0.21	0.12
39	Mowing lawn	60 (33-71)	53.8 (25.3)	-0.19[a]	0.17
31	Lifting toddler from cot	59 (43-70)	56.9 (22.2)	-0.19	0.16
19	Back twisting	33 (20-50)	36.1 (22.2)	-0.18	0.19
32	Carrying child on hip	50 (37-65)	49.8 (21.7)	-0.18	0.18
26	Getting out of bed	35 (15-55)	37.2 (25.3)	-0.15[a]	0.28
2	Lifting pot. squatting	16 (5-26)	17.0 (13.7)	-0.14[a]	0.29
30	Riding bike bumpy street	10 (0-25)	14.9 (16.6)	-0.14[a]	0.30
14	Clearing out dishwasher	54 (34-70)	50.6 (26.4)	-0.14	0.31
25	Making bed	50 (24-70)	50.4 (27.4)	-0.13	0.36
12	Carrying two shopping bags. both hands	26 (15-44)	30.8 (21.9)	-0.12[a]	0.36
23	Rope skipping	31 (13-56)	34.6 (22.4)	-0.10[a]	0.48
34	Running through forest	25 (14-40)	28.7 (21.6)	-0.09[a]	0.54
37	Cycling. looking aside	12 (5-35)	23.8 (23.4)	0.09[a]	0.50
4	Picking up shoes. bent back	55 (27-70)	49.7 (26.9)	0.09	0.52
35	Walking through forest	5 (1-15)	10.5 (15.3)	-0.08[a]	0.34
40	Drilling hole above head	60 (35-80)	59.2 (26.7)	0.07[a]	0.59
11	Carrying shopping bag. one hand	52 (37-70)	53.7 (23.3)	0.07	0.62
18	Leg stretching	27 (19-41)	32.5 (22.1)	-0.06[a]	0.66
36	Cycling from kerb	20 (9-40)	26.4 (22.8)	-0.06[a]	0.67
38	Falling backwards	80 (57-90)	70.7 (24.5)	-0.06[a]	0.64
15	Taking box from cupboard	27 (15-55)	36.3 (27.0)	-0.05[a]	0.71
8	Ironing while sitting	14 (5-25)	18.9 (19.4)	0.05[a]	0.69
28	Walking down stairs	12 (5-23)	16.8 (16.5)	0.05[a]	0.75
17	Mopping floor	50 (30-61)	46.6 (22.2)	-0.05	0.73
9	Lifting basket. walking up stairs	45 (22-64)	44.4 (25.4)	-0.04	0.76
16	Vacuum cleaning	60 (40-75)	58.2 (23.4)	0.04	0.76
6	Taking book. twisted back	35 (12-70)	39.7 (29.5)	-0.04[a]	0.79
22	Trampoline jumping	30 (14-60)	34.8 (26.0)	-0.03[a]	0.83

21	Taking heavy box from shelf above head	60 (30-85)	56.8 (30.0)	0.02[a]	0.91
27	Walking up stairs	10 (5-20)	16.1 (18.8)	-0.01[a]	0.94
29	Cleaning windows above head	41 (20-71)	44.5 (30.6)	0.01[a]	0.91
24	Abdominal exercises	26 (11-49)	33.9 (26.9)	<0.01[a]	0.95
10	Lifting beer crate. slightly bent back	69 (49-81)	64.4 (23.0)	<0.01[a]	0.96
13	Carrying rubbish bag. one hand	50 (30-70)	49.6 (23.2)	<0.01	0.96
20	Back bending	40 (21-58)	41.1 (23.7)	<0.01	0.95
33	Doing dishes	44 (27-59)	44.2 (24.7)	<0.01	0.97

ROM= range of motion. Compared to the PHODA-lift (item 3). picture 1 was rated significantly more harmful ($p< 0.001$) whereas item 38 was rated equally harmful ($p= 0.51$). All of the other tasks were rated less harmful ($p< 0.05$).

[a] Spearman correlation

Table 4 Regression model with picture 1 of PHODA-SeV predicting lumbar range of motion during the lifting task

Regression model	Variables	Std Beta	p-value	R^2	R^2 adj	ΔR^2 adj
Basic model +	Sex [F]	0.34	0.006	0.45	0.37	0.06
picture 1 of PHODA-SeV	Age	-0.28	0.07			
	Duration LBP	0.04	0.74			
	Current pain	-0.26	0.046			
	RMDQ	-0.14	0.34			
	PCS	0.02	0.85			
	Picture 1 PHODA-Sev	-0.28	0.02			

LBP= low back pain, PCS= Pain catastrophizing scale, PHODA-SeV= The Photograph Series of Daily Activities—Short Electronic Version, RMDQ= Roland Morris Disability Questionnaire, TSK= Tampa scale for kinesiophobia. ΔR^2 adj= difference in R^2adj relative to R^2 adj of the model with control variables only. Sex [F]: a positive Std. Beta indicates that female sex is associated with a larger range of motion.

Table 5 Mean estimates and comparison of healthy persons with subgroups of patients with CLBP categorized into low, medium and high levels of pain-related fear

Group		Mean (range) score on PRF-measure	Mean ROM (°)		Post-hoc Dunnett's test – difference with healthy (°)		
			Estimate	SE	Difference	SE	p-value
Whole group	Healthy		37.1	1.5			
	CLBP		27.9	1.4	9.3	2.1	<0.001
TSK-total	Healthy		37.1	1.5			
	Low	26.6 (23-32)	27.6	2.5	9.5	2.9	0.001
	Medium	34.8 (33-38)	29.8	2.5	7.3	2.9	0.01
	High	44.7 (40-53)	26.1	2.5	11.0	3.0	<0.001
TSK-AA	Healthy		37.1	1.5			
	Low	11.8 (9-13)	28.5	2.7	8.6	3.0	0.005
	Medium	15.2 (14-17)	27.8	2.3	9.2	2.8	0.001
	High	22.2 (18-27)	27.3	2.5	9.8	3.0	0.001
TSK-SF	Healthy		37.1	1.5			
	Low	6.4 (5-8)	28.9	2.5	8.2	2.9	0.006
	Medium	9.9 (9-11)	27.9	2.5	9.3	2.9	0.002
	High	13.4 (12-18)	26.7	2.5	10.4	2.9	<0.001
PHODA-total	Healthy		37.1	1.5			
	Low	26.3 (6.2-36.4)	27.8	2.5	9.3	2.9	0.002
	Medium	41.6 (36.5-45.1)	27.3	2.5	9.8	2.9	0.001
	High	54.3 (46.4-80.1)	28.5	2.5	8.6	3.0	0.005
PHODA-lift	Healthy		37.1	1.4			
	Low	50.8 (10-69)	33.7	2.4	3.4	2.8	0.22
	Medium	76.1 (70-80)	26.8	2.4	10.3	2.8	<0.001
	High	90.7 (81-100)	23.3	2.3	13.8	2.7	<0.001

LBP= low back pain, PHODA-lift= score on the task-specific picture of the PHODA-SeV, PHODA-SeV= The Photograph Series of Daily Activities—Short Electronic Version, PHODA-total= total score on the PHODA-SeV, PRF= pain-related fear, TSK-AA= Activity avoidance subscale of the TSK, TSK-SF= Somatic focus subscale of the TSK, TSK-total= total score on the Tampa Scale for Kinesiophobia.

The number of participants in each subgroup of the PRF-measure was as follows: Low (n= 18), Medium (n= 18), High (n=19), except for the TSK-AA subgroups: Low (n= 16), Medium (n= 20), High (n= 19).