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Prediction of persistent post-operative pain: Pain-specific psychological variables compared with acute post-operative pain and general psychological variables

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Abstract

Background: Psychological variables and acute post-operative pain are of proven relevance for the prediction of persistent post-operative pain. We aimed at investigating whether pain-specific psychological variables like pain catastrophizing add to the predictive power of acute pain and more general psychological variables like depression.

Methods: In all, 104 young male patients undergoing thoracic surgery for pectus excavatum correction were studied on the pre-operative day (T0) and 1 week (T1) and 3 months (T2) after surgery. They provided self-report ratings (pain-related: Pain Catastrophizing Scale, Pain Anxiety Symptoms Scale = PASS, Pain Vigilance and Awareness Questionnaire = PVAQ; general psychological: Screening for Somatoform Symptoms, State-Anxiety Inventory-X1, Center for Epidemiologic Studies Depression Scale = CES-D). Additional predictors (T1) as well as criterion variables (T2) were pain intensity (Numerical Rating Scale) and pain disability (Pain Disability Index).

Results: Three months after surgery, 25% of the patients still reported clinically relevant pain (pain intensity ≥ 3) and over 50% still reported pain-related disability. Acute post-operative pain as well as general psychological variables did not allow for a significant prediction of persistent post-operative pain; in contrast, pain-related psychological variables did. The best single predictors were PASS for pain intensity and PVAQ for pain disability.

Conclusions: Pain-related psychological variables derived from the fear-avoidance model contributed significantly to the prediction of persistent post-operative pain. The best possible compilation of these measures requires further research. More general psychological variables may become relevant predictors later in the medical history.

Significance: Our results suggest that pain-specific psychological variables such as pain anxiety and pain hypervigilance add significantly to the prediction of persistent post-operative pain and might even outperform established predictors such as acute pain and general psychological variables. Clinicians might benefit from the development of time-economic screening tools based on these variables.

1. Introduction

Chronic post-operative pain which is defined as pain persisting for 3 months or longer after surgery (Treede et al., 2015) develops in 10–50% of the cases and thus still constitutes a major complication of surgery (Chapman and Vierck, 2017). This high incidence underscores the need to identify pre-, peri- and post-operative risk factors to establish risk-minimizing prevention and intervention.

One of the most established predictors of chronic post-operative pain is the degree of acute pain after surgery (Katz et al., 1996; Perkins and Kehlet, 2000; Kehlet et al., 2006; Katz and Seltzer, 2009). However, it remains unclear whether this association is causal or can be explained by pre-operative factors predisposing patients to both acute and chronic pain (Katz and Seltzer, 2009; Brandsborg, 2012). Thus, optimizing post-operative acute pain management should certainly be one but not the only measure taken when aiming at reducing the incidence of chronic pain after surgery (Clarke et al., 2015); the identification of additional predictors is still of crucial importance.

The fear-avoidance model of chronic pain (Vlaeyen and Linton, 2000; Leeuw et al., 2007) proposes a decisive role of pain-specific psychological variables in the transition from acute to chronic pain. In case of high pain catastrophizing, which is characterized by anxious cognitions about pain (Sullivan et al., 1995), acute pain leads to heightened pain anxiety and hypervigilance which in turn trigger a vicious cycle of avoidance and chronification. In line with this, pre-operative catastrophizing has turned out to be a predictor of chronic post-operative pain (Edwards et al., 2009; Pinto et al., 2012; Theunissen et al., 2012; Masselin-Dubois et al., 2013). However, other pain-specific variables (e.g. pain anxiety, pain hypervigilance) have been rarely investigated and post-operative assessment of psychological variables is uncommon (Lautenbacher et al., 2010; Dimova et al., 2015). In addition, state-of-the-art reviews still stress the major importance of more general psychological variables such as anxiety and depression (Kehlet et al., 2006; Macrae, 2008; Hinrichs-Rocker et al., 2009; Katz and Seltzer, 2009; Voscopoulos and Lema, 2010; Chapman and Vierck, 2017) with neglect of the high predictive value of pain-specific psychological variables (Lautenbacher et al., 2009, 2010; Scheel et al., 2017).

The aim of our study was to assess the predictive power of pain-specific psychological variables for chronic post-operative pain in comparison to general psychological variables and acute pain. Correction of pectus excavatum was chosen as surgical model because patients are adolescents or young adults who are commonly healthy and pain-free prior to surgery. In addition, the incidence of chronic post-operative pain is particularly high after thoracic surgery (Katz et al., 1996; Perttunen et al., 1999; Pluijms et al., 2006) and in younger patients (Katz and Seltzer, 2009; Chapman and Vierck, 2017). Psychological variables were assessed as predictors pre-operatively and in the acute post-operative stage. The three groups of predictors (acute pain, general psychological variables, pain-specific psychological variables) were compared regarding their power to predict pain intensity and disability 3 months after surgery using a logistic regression model.

2. Materials and methods

2.1 Subjects

2.1.1. Surgical procedure and exclusion criteria

In all, 104 male patients with congenital malformations of thorax (mostly pectus excavatum) between the ages of 13 and 33 years (mean age: 19.3 ± 4.5 year) participated in this study. Age was distributed as follows: 13–15 years: $N = 28$ (26.9%), 16–18 years: $N = 35$ (33.7%), 19–21 years: $N = 12$ (11.5%), 22–24 years: $N = 17$ (16.3%), 25–27 years: $N = 7$ (6.7%), 28–30 years: $N = 2$ (1.9%), 31–33 years: $N = 3$ (2.9%). 58.7% of the participants were under the legal age of 18 years. Typically, about 80% of the patients undergoing this surgical procedure are children or adolescents (Park et al., 2004), thus explaining the limited age range of our sample. In addition, as males are affected more often (Brochhausen et al., 2012) and only very few female patients were operated during data collection for our study, we decided to include only male patients. Participants were recruited among consecutive inpatients of the Department of Pediatric Surgery of the University of Erlangen. This department is specialized in the surgical correction of thorax malformations; patients from all over Germany are treated here. Weber et al. (2006) have described the surgical technique for correction of this thorax malformation, the so-called Erlangen technique of funnel chest correction in detail. Therefore, only a brief description is given here. The lower part of the sternum is freed through an interior incision. Mobilization of the sternum begins with freeing of the xiphisternum. A spring balance is attached to the sternum with a hook; afterwards, the sternum is moved into the desired position. The chest wall is then stabilized with a lightweight transsternal metal implant. After placing wound drains, the chest wall is closed. Patients are discharged from the hospital after 7–10 days post-surgery. The metal plate is removed after 1 year. Exclusion criteria regarding our study were as follows: (1) Chronic pain conditions, (2) major surgical interventions in the past, (3) current or previous psychological disorders other than mood or anxiety disorders (as diagnosed with the Mini-DIPS diagnostic interview based on DSM-IV and ICD-10) and (4) strong levels of discomfort or pain due to functional limitations associated with the chest malformation. Relating to (3), none of our patients presented with a current diagnosis of any mood or anxiety disorder. The study protocol was approved by the ethics committee of the medical faculty of the University of Erlangen. All participants gave written informed consent. In case of not having attained legal age, written informed consent was obtained from participants' parents and written assent was obtained from participants.

2.1.2. Post-operative analgesic medication

All patients included in the study received thoracic Patient Controlled Epidural Analgesia (PCEA). Before the induction of general anaesthesia, an epidural catheter was inserted through the interspinous space at Th6/Th7 or Th7/Th8. The proximal end of the catheter was tunnelled subcutaneously. After the induction of general anaesthesia, 0.375% ropivacaine (0.2 mL/kg) was given via epidural route. During surgery, alfentanil was administered intravenously. Thirty minutes before the end of the surgery, patients again received ropivacaine via epidural route (one-third of their first dose). Additionally, patients either received 0.5 mg/kg dexketoprofen or 20 mg/kg paracetamol intravenously. Post-operative PCEA was provided using a standard PCA pump. The pump was set to deliver 0.2% ropivacaine plus 1.0-mg/mL sufentanil at a basal rate of 6–8 mL/h. The patient could additionally administer a bolus dose of 3 mL, with a lock-out interval of 30 min. Nonopioids were available as rescue analgesia on demand. The epidural catheter was removed after 3 or 4 days post-surgery. The number of requested PCEA boluses (pump calls, including those during lock-out periods) ranged from 1 to 885 (M = 128.2, SD = 141.7).

2.2 Materials and procedure

This study focused on the prediction of chronic pain after funnel chest (pectus excavatum) correction by acute post-surgical pain complaints and psychological variables. There were three sessions altogether: one pre-operative session which was scheduled on the afternoon prior to surgery and two post-operative sessions which took place approximately 1 week and 3 months after surgery, respectively. Psychological variables were assessed by questionnaires in the pre-operative session (T0) and the first post-operative session (T1). Thus, two scores (pre- and post-surgery) for each questionnaire were entered as predictors. This approach was chosen as we assumed that the psychological state in the acute post-operative phase might be an important additional predictor which might have been missed by previous studies only including pre-operative assessment. Self-rated pain intensity and pain-related disability were assessed in the first post-operative session (T1; acute pain, predictor) and again in the second post-operative session (T2; chronic pain, outcome). This study was part of a larger prospective study also including additional predictors such as experimental pain testing and cortisol levels which are not reported here (Lautenbacher et al., 2009, 2010; Dimova et al., 2015).

2.2.1 Assessment of psychological variables

2.2.1.1. Pain-related variables. Pain catastrophizing, pain-related anxiety and pain hypervigilance were assessed by self-rating questionnaires [Pain Catastrophizing Scale (PCS; Sullivan et al., 1995), Pain Anxiety Symptom Scale (PASS; McCracken et al., 1992), Pain Vigilance and Awareness Questionnaire (PVAQ; McCracken, 1997)].

The PCS (Sullivan et al., 1995) was developed as a measure of catastrophizing related to pain. It contains 13 items that can be divided into three subscales, namely rumination, magnification and helplessness. The items (e.g. 'I worry all the time about whether the pain will end.') are rated on a 5-point scale. For further analyses, we used the combined sum score of the PCS (range: 0–52). The PCS showed good internal consistency (Cronbach's $\alpha = 0.95$) for the general scale (Sullivan et al., 1995).

The PASS (McCracken et al., 1992) is composed of four subscales – cognitive anxiety, escape/avoidance, fearful appraisal and physiological anxiety – and is designed to measure fear of pain across cognitive, behavioural and physiologic domains. The items (e.g. 'When I feel pain I am afraid that something terrible will happen.') are rated on a 6-point scale. For further analyses, we used the combined sum score (40 items) of the PASS. PASS total score (range: 0–240) showed good internal consistency: Cronbach's $\alpha = 0.94$ (McCracken et al., 1992).

The PVAQ (McCracken, 1997) was developed as a comprehensive measure of attention to pain and has been validated for use in chronic pain and non-clinical samples (McCahon et al., 2005). It consists of 16 items (e.g. 'I am quick to notice changes in pain intensity') that are rated on a 6-point scale and that assess awareness, vigilance, preoccupation and observation of pain. For further analyses, we used the combined sum score of the PVAQ (range: 0–80). The PVAQ demonstrated good internal consistency: Cronbach's $\alpha = 0.86$ (McCracken, 1997).

With the exception of the PASS (which had been translated into German and validated by Walter et al. 2002), we had to translate the other two questionnaires into German, using a standard 'forward-backward' procedure. Only if the resulting backward English version was very similar to the original version according to the evaluation of an English native speaker, translation accuracy was considered sufficient. The German version of the PVAQ has recently been validated in clinical and non-clinical samples (Kunz et al., 2016). The intercorrelation of the three German questionnaires ranged between $r = 0.48$ and $r = 0.71$, which is in accordance with intercorrelations reported in the literature for English and Dutch versions (Burns et al., 2003; Roelofs et al., 2003, 2004; Moss-Morris et al., 2007). In addition, Cronbach's alpha coefficients ranged from 0.87 to 0.93 for the German versions (Baum et al., 2011) and from 0.86 to 0.94 for the original English versions (McCracken et al., 1992; Sullivan et al., 1995; McCracken, 1997). Thus, the German versions showed good internal consistency and high similarity to the original English questionnaires.

2.2.1.2 General psychological variables: affective and bodily distress. The affective and bodily distress variables were assessed with three different questionnaires (self-rating scales), namely the German version of the Screening for Somatoform Symptoms (SOMS; Rief et al., 1997), the German version of the State-Anxiety Inventory (STAI-X1; Laux et al., 1981) and the German version of the Center for Epidemiologic Studies Depression Scale (CES-D; German version: ADS; Hautzinger and Bailer, 1992).

The SOMS (Rief et al., 1997) is a self-rating scale of somatization, which assesses 53 organically unexplained physical symptoms (e.g. headache, low back pain, nausea). In our sample, only 48 of the total 53 items were of relevance as the remaining five assess symptoms which are specific to females (e.g. menstrual pain). The state version of the SOMS was applied where subjects are asked to rate the intensity of each symptom during the last 7 days on a 5-point Likert scale; this version has demonstrated good internal consistency (Cronbach's $\alpha = 0.88$; Rief et al., 1997). For further analyses, we used the sum of the 48 relevant items which indicates number and severity of symptoms ('somatization severity index'; range: 0–192).

The STAI-X1 (Laux et al., 1981) is a self-rating scale and contains 20 items that were designed to measure transitory anxiety states – that is, subjective feelings of apprehension, tension and worry that vary in intensity and fluctuate based on the situation. The STAI-X1 showed good internal consistency (Cronbach's $\alpha = 0.90$; Laux et al., 1981). Items are rated on a 5-point rating scale; total scores range from 20 to 80.

The CES-D (Hautzinger and Bailer, 1992) is a self-rating scale that was designed to assess emotional, somatic and cognitive symptoms of depressive mood during the last week. It contains 20 items that are rated on a 4-point Likert scale and has good internal consistency (Cronbach's $\alpha = 0.89$); total scores range from 0 to 60.

2.2.2 Assessment of surgical outcome

Surgical outcome in terms of self-rated pain intensity and pain-related disability was measured 1 week after surgery (T1) to assess acute post-surgical pain (which was used as predictor variable for persistent pain) and again 3 months after surgery (T2) to assess persistent post-surgical pain (which was used as criterion variable).

2.2.2.1 Pain intensity. Patients were asked to rate the average intensity of their pain during the last week (T1) or during the last 4 weeks (T2) on an 11-point numerical rating scale (NRS). The NRS was labelled with the verbal anchors 'no pain' (corresponding to 0) and 'strongest pain imaginable' (corresponding to 10).

2.2.2.2 Pain-related disability. For the assessment of pain-related disability, patients were asked to complete the German version of the Pain Disability Index (PDI; Tait et al., 1987, 1990; German version: Dillmann et al., 1994) questionnaire. The PDI was designed to assess subjective pain-related disability and consists of seven items measuring the degree to which pain interferes with functioning across a range of activities (e.g. social, recreational and job-related activities). Scores of each item may range from 0 (no interference) to 10 (total interference). Thus, the maximum PDI score is 70. Cronbach's alpha for the German version ranged between 0.83 and 0.90, thus proving good internal consistency (Dillmann et al., 1994).

2.2.2.3 Classification of outcome groups. As most of the patients reported very low pain intensity or even being pain-free 3 months after surgery, the distribution of pain intensity scores was positively skewed, with skewness of 0.94 (SE = 0.24). Significant deviation from normality was confirmed by a Kolmogorov–Smirnov Test [D (104) = 0.20; $p < 0.001$]. The same was observed for pain disability (PDI scores), with a skewness of 1.04 (SE = 0.24) and also a significant deviation from normality [D (104) = 0.15; $p < 0.001$].

Due to these statistical limitations, we decided on classifying patients into good and poor outcome groups according to their self-reported pain intensity and disability, resulting in two groups for Pain Intensity ('no pain' vs. 'pain') as well as two groups for Pain Disability ('no disability' vs. 'disability'). For pain intensity, patients were required to provide a rating of 3 or higher on the NRS (0–10) to be classified into the 'pain' group. For pain disability, patients were required to have PDI total scores of 9 or higher to qualify for the 'disability' group. The cut-off for pain intensity was based on findings suggesting that at least two scale units on a NRS are needed to represent meaningful changes in pain intensity (Farrar et al., 2003) and that surgery patients regard pain therapy as successful if their pain intensity is reduced to about 25 points on a Visual Analogue Scale (VAS) scale (Lempa et al., 2000). In line with this, a cut-off score of 3 has been used in several publications on post-operative pain (Pavlin et al., 2005; Althaus et al., 2012; Masselin-Dubois et al., 2013; Fletcher et al., 2015; Hoofwijk et al., 2015). The cut-off for pain disability was derived from a report stating that 95% of chronic pain patients score higher than 8 on the PDI (Dillmann et al., 1994). The same cut-offs were already used in one of our previous publications (Lautenbacher et al., 2010).

2.2.3 Statistical analysis

To test the predictive value of (1) acute post-surgical pain intensity and disability, (2) general psychological variables relating to affective and bodily distress and (3) specific variables relating to pain for the development of chronic post-surgical pain intensity and disability, we computed two separate logistic regression analyses with (1) pain intensity group ('no pain' vs. 'pain') or (2) pain disability group ('no disability' vs. 'disability') as criterion variable. As we aimed to investigate whether acute pain would be sufficient to predict chronic pain or adding general or pain-specific psychological variables would significantly increase the explanatory value of our model, the predictors were entered in three blocks: Acute pain intensity (NRS rating) and acute pain disability (PDI score) as a first block, general psychological variables relating to affective and bodily distress (SOMS, STAI-X1 and CES-D; T0 and T1) as a second block and pain-specific psychological variables (PCS, PASS and PVAQ; T0 and T1) as a third block. For a descriptive analysis of relationships between psychological predictors and between acute and chronic post-surgical pain, correlation analyses were computed. IBM SPSS 23 SPSS (IBM, Armonk, North Castle, New York, United States) was used for all calculations; significant effects were assumed at $\alpha = 0.05$.

3. Results

3.1 Descriptive statistics

3.1.1 Predictor variables

3.1.1.1 Acute pain. In the acute post-operative state, patients reported on average a moderate level of pain intensity (NRS rating: $M = 3.90$, SD = 2.04). Individual scores ranged from 0 to 9, with 73.1% of the patients ($N = 76$) reporting pain intensities of ≥3. Likewise, patients reported on average a moderate level of pain disability (PDI score: $M = 36.17$, SD = 15.98). Individual scores ranged from 0 to 65, with 93.3% of the patients ($N = 97$) presenting with PDI scores of ≥9. Thus, the majority of patients showed a clinically significant level of pain intensity and pain disability in the acute post-operative state.

3.1.1.2 Psychological variables. Descriptive statistics for the psychological variables assessed on the pre-operative day (T 0) and 1 week after surgery (T 1) are displayed in Table 1. With exception of the STAI, all questionnaire scores increased significantly from the pre-operative to the post-operative measurement (PCS: $t = 3.019$, $p = 0.003$; PASS: $t = 3.559$, $p = 0.001$; PVAQ: $t = 6.311$, $p < 0.001$; CES-D: $t = 11.070$, $p < 0.001$; SOMS: $t = 5.822$, $p < 0.001$; STAI: $t = 1.917$, $p = 0.058$).

Table 1 Descriptive statistics (mean, SD) and internal consistency (Cronbach's α) of psychological variables for both measurement points (T0 and T1).

	Mean	SD	Cronbach's α
Pain-related questionnaires			
PCS_{T0}	16.34	6.51	0.79
$PASS_{T0}$	71.38	25.64	0.90
$PVAQ_{T0}$	32.94	11.88	0.84
PCS_{T1}	18.35	8.21	0.88
$PASS_{T1}$	79.75	27.16	0.90
$PVAQ_{T1}$	39.40	9.62	0.74
Affective and bodily distress			
$SOMS_{T0}$	9.50	8.14	0.82
$STAI\text{-}X1_{T0}$	43.70	9.42	0.91
$CES\text{-}D_{T0}$	11.26	6.28	0.79
$SOMS_{T1}$	22.58	25.01	0.96
$STAI\text{-}X1_{T1}$	41.56	9.69	0.90
$ES\text{-}D_{T1}$	21.23	7.70	0.72

PCS, Pain Catastrophizing Scale; PASS, Pain Anxiety Symptoms Scale; PVAQ, Pain Vigilance and Awareness Questionnaire; SOMS, Screening for Somatoform Disorders; STAI-X1, State-Anxiety Inventory; CES-D, Center for Epidemiologic Studies Depression.

With regard to the three pain-related questionnaires (PCS, PASS and PVAQ), mean values indicated that the level of pain catastrophizing, pain-related anxiety and pain vigilance was heightened in our sample in the acute post-operative state compared to scores normally reported for healthy adults (Osman et al., 1994; Roelofs et al., 2002; Lee et al., 2010). The mean PASS score at T1 was even higher than mean scores reported for two chronic pain samples (Roelofs et al., 2004). Likewise, mean values of questionnaires assessing anxiety and depression (STAI state and CES-D) at T1 were very close to cut-off scores recommended for distinguishing clinically significant symptoms (STAI-X1: cut-off score 40; CES-D: cut-off score 23) and the mean SOMS score at T1 indicated moderate number and severity of somatization symptoms (Hiller et al., 2006).

3.1.2 Chronic post-operative state (outcome variables)

Three months after surgery, patients reported significantly lower pain intensity (NRS rating: $M = 1.63$, $SD = 1.63$) and disability (PDI score: $M = 12.80$, $SD = 12.47$) compared to the acute post-operative state as verified by a Wilcoxon signed-rank test (NRS rating: $z = -7.038$, $p < 0.001$; PDI score: $z = -7.954$, $p < 0.001$). NRS ratings ranged from 0 to 6, with 30.8% of the patients ($N = 32$) providing a score of 0. PDI scores ranged from 0 to 55, with 19.2% of the patients providing a score of 0.

Patients were allocated to the outcome groups (see 2.2.2) as follows. For pain intensity, 25% of the patients were classified into the 'pain' group (NRS rating ≥3) and the remaining 75% were classified into the 'no pain' group (NRS rating <3). For pain disability, 52.9% of the patients were allocated to the 'disability' group (PDI score ≥9) and the remaining 47.1% were allocated to the 'no disability' group. NRS ratings ranged between 3 and 6 in the 'pain' group ($M = 3.9$, $SD = 1.1$) and PDI scores ranged between 10 and 55 in the 'disability' group ($M = 21.9$, $SD = 10.6$).

Thus, although 75% of the patients reported no pain or very low pain intensity 3 months after surgery, over 50% reported that they still experienced considerable pain-related disability. This divergence between the two measures suggests that perceived disability related to pain is influenced also by additional factors besides pain intensity.

3.2 Correlation between psychological predictors

Intercorrelations (Spearman's Rho) between the psychological predictors, that is, the three pain-related questionnaires (PCS, PASS and PVAQ) and the three questionnaires assessing affective and bodily distress (SOMS, STAI-X1 and CES-D), are given in Table 2. Spearman correlations were used as the distribution deviated from normality for three of the questionnaires (SOMS, STAI-X1 and CES-D) at T0 and T1. With exception of $PASS_{T0} \times STAI\text{-}X1_{T0}$ and $PVAQ_{T0} \times SOMS_{T0}$, all of the psychological measures were significantly correlated. Correlations ranged between 0.111 and 0.687 at T0 and between 0.204 and 0.695 at T1. This means that shared variance varied considerably from 1% to 48% between psychological predictors although nearly all correlations were significant. Supporting tentatively the assumption of a differentiation between general and pain-related psychological variables is the fact that PCS and PASS (within pain-related variables) as well as STAI-X1 and CES-D (within general variables) had 48% common variance at both time points, whereas the highest score of common variance between the two sets of variables was only 30% at T1 and even only 13% at T0. Test–retest correlations were significant for all questionnaires with exception of STAI-X1 and CES-D.

3.3 Correlation between acute and chronic pain intensity and disability

The association between self-rated pain intensity (NRS rating) and pain disability (PDI score) in the

Table 2 Intercorrelations (Spearmans's Rho) between psychological predictors.

	1	2	3	4	5	6	7	8	9	10	11	12
1.PCS_{T0}		0.687**	0.374**	0.356**	0.212*	0.330**	**0.511****	0.560**	0.386**	0.242*	0.033	0.189
2.$PASS_{T0}$			0.552**	0.320**	0.111	0.250*	0.286**	**0.577****	0.426**	0.218*	−0.055	0.154
3.$PVAQ_{T0}$				0.189	0.243*	0.238*	0.235*	0.359**	**0.514****	0.093	0.065	0.204*
4.$SOMS_{T0}$					0.217*	0.313**	0.264**	0.265**	0.122	**0.494****	0.204*	0.286**
5.STAI-$X1_{T0}$						0.434**	0.113	0.087	0.187	0.323**	**0.319**	0.292**
6.CES-D_{T0}							0.167	0.156	0.165	0.164	0.166	**0.174**
7.PCS_{T1}								0.694**	0.463**	0.380**	0.325**	0.507**
8.$PASS_{T1}$									0.627**	0.417**	0.358**	0.545**
9.$PVAQ_{T1}$										0.204*	0.289**	0.401**
10.$SOMS_{T1}$											0.384**	0.466**
11.STAI-$X1_{T1}$												0.691**
12.CES-D_{T1}												

PCS, Pain Catastrophizing Scale; PASS, Pain Anxiety Symptoms Scale; PVAQ, Pain Vigilance and Awareness Questionnaire; SOMS, Screening for Somatoform Disorders; STAI-X1, State-Anxiety Inventory; CES-D, Center for Epidemiologic Studies Depression.
*$p < 0.05$; **$p < 0.01$. Test–retest correlations are marked in bold script.

acute phase and the chronic phase was analysed by computing correlations. As in the regression analyses, continuous scores were used for measures of acute pain (NRS_{T1}, PDI_{T1}; predictors) and dichotomous scores were used for measures of chronic pain (NRS_{T2}, PDI_{T2}; outcome groups). The following correlations were computed: $NRS_{T1} \times PDI_{T1}$, $NRS_{T1} \times NRS_{T2}$, $NRS_{T1} \times PDI_{T2}$, $PDI_{T1} \times PDI_{T2}$ and $PDI_{T1} \times NRS_{T2}$. The Pearson correlation coefficient was used for all correlations as it has been shown to be mathematically equivalent to the point-biserial correlation coefficient which is needed for analysing associations between continuous variables and dichotomous variables (i.e. all but $NRS_{T1} \times PDI_{T1}$) (Tate, 1954).

We found significant correlations between pain intensity and disability at T1 ($r = 0.244$, $p = 0.012$) as well as between pain disability at T1 and T2 ($r = 0.195$, $p = 0.048$). All other correlations failed to pass the level of significance. Thus, there was no significant association between acute pain intensity and chronic pain intensity or disability and also no significant association between acute pain disability and chronic pain intensity or disability.

For analysing the association between chronic pain intensity and chronic pain disability ($NRS_{T2} \times PDI_{T2}$; dichotomous outcome groups), a χ^2 test was used. As expected, a significant association between the distribution of patients to the intensity and disability groups was detected [χ^2 (1) = 8.040, $p = 0.005$; Phi = 0.278, $p = 0.005$]. Of the 78 patients still reporting pain 3 months after surgery, 43 (55.1%) also reported pain-related disability. Vice versa, of the 26 patients reporting pain, 20 (76.9%) also reported pain-related disability at this time point.

3.4 Prediction of chronic pain by acute pain and psychological variables

3.4.1 Prediction of chronic pain intensity

Results of the logistic regression analysis for the prediction of chronic pain intensity ('no pain' group vs. 'pain' group), that is, NRS rating 3 months after surgery, are summarized in Tables 3 and 4. The logistic regression model reached significance only after adding the third block, that is, pain-related psychological variables (pain catastrophizing, pain anxiety and pain vigilance; see Table 3).

Thus, neither acute pain intensity and disability nor general psychological variables relating to affective and bodily distress led to satisfactory prediction of persistent pain 3 months post-surgery. Only the inclusion of the pain-related variables led to a significant increase in explanatory power. Pain anxiety (PASS) at T1 clearly proved to be the best single predictor in the final logistic regression model according to the Wald statistics and the Odds Ratio (see

Table 3 Fit of the overall logistic regression model for the prediction of pain intensity and disability after inclusion of block 1, block 2 and block 3.

	Model X^2	df	*p*
Prediction of pain intensity			
Block 1 (acute pain)	3.619	2	0.164
Block 2 (affective and bodily distress)	5.349	8	0.720
Block 3 (pain-related questionnaires)	26.084	14	**0.025**
Prediction of pain disability			
Block 1 (acute pain)	4.015	2	0.134
Block 2 (affective and bodily distress)	7.234	8	0.512
Block 3 (pain-related questionnaires)	23.265	14	0.056

Significant predictors ($p < 0.05$) are marked in bold script

Table 4 Regression coefficient *B* (±standard error), Wald statistic and odds ratio (95% confidence interval) for all predictors included in the final logistic regression model for the prediction of pain intensity.

			95% CI for odds ratio		
	B (SE)	Wald	Lower	Odds ratio	Upper
Block 1 (acute pain)					
NRS_{T1}	−0.092 (0.175)	0.274	0.648	0.913	1.285
PDI_{T1}	0.034 (0.019)	3.038	0.996	1.034	1.074
Block 2 (affective and bodily distress)					
$SOMS_{T0}$	0.017 (0.038)	0.189	0.943	1.017	1.096
STAI-$X1_{T0}$	−0.024 (0.037)	0.412	0.908	0.977	1.050
CES-D_{T0}	−0.007 (0.053)	0.016	0.838	0.937	1.047
$SOMS_{T1}$	0.006 (0.015)	0.148	0.977	1.006	1.035
STAI-$X1_{T1}$	−0.021 (0.042)	0.241	0.902	0.980	1.064
CES-D_{T1}	−0.079 (0.063)	1.531	0.816	0.924	1.047
Block 3 (pain-related questionnaires)					
PCS_{To}	0.108 (0.080)	1.808	0.952	1.114	1.303
$PASS_{T0}$**	**−0.075 (0.027)**	**7.654**	**0.880**	**0.928**	**0.978**
$PVAQ_{T0}$	0.058 (0.032)	3.323	0.996	1.060	1.128
PCS_{T1}*	**−0.157 (0.064)**	**6.015**	**0.753**	**0.854**	**0.969**
$PASS_{T1}$**	**0.091 (0.026)**	**12.102**	**1.040**	**1.095**	**1.153**
$PVAQ_{T1}$	−0.018 (0.044)	0.176	0.902	0.982	1.069

NRS, Numerical rating scale; PDI, Pain Disability Index; PCS, Pain Catastrophizing Scale; PASS, Pain Anxiety Symptoms Scale; PVAQ, Pain Vigilance and Awareness Questionnaire; SOMS, Screening for Somatoform Disorders; STAI-X1, State-Anxiety Inventory; CES-D, Center for Epidemiologic Studies Depression. R^2 = 0.22 (Cox & Snell), 0.33 (Nagelkerke).
*$p < 0.05$; **$p < 0.01$.
Significant predictors (p < 0.05) are marked in bold script

Table 5 Regression coefficient *B* (±standard error), Wald statistic and odds ratio (95% confidence interval) for all predictors included in the final logistic regression model for the prediction of pain disability.

			95% CI for odds ratio		
	B (SE)	Wald	Lower	Odds ratio	Upper
Block 1 (acute pain)					
NRS_{T1}	0.014 (0.145)	0.009	0.763	1.014	1.347
PDI_{T1}*	**0.035 (0.016)**	**4.548**	**1.003**	**1.035**	**1.069**
Block 2 (affective and bodily distress)					
$SOMS_{T0}$	−0.037 (0.034)	1.218	0.902	0.964	1.029
STAI-$X1_{T0}$	0.015 (0.031)	0.248	0.956	1.015	1.078
CES-D_{T0}	−0.051 (0.045)	1.337	0.870	0.950	1.036
$SOMS_{T1}$	0.010 (0.012)	0.627	0.986	1.010	1.035
STAI-$X1_{T1}$	0.032 (0.035)	0.798	0.963	1.032	1.106
CES-D_{T1}	−0.071 (0.052)	1.877	0.841	0.931	1.031
Block 3 (pain-related questionnaires)					
PCS_{To}	0.045 (0.060)	0.558	0.930	1.046	1.177
$PASS_{T0}$	−0.003 (0.017)	0.036	0.965	0.997	1.030
$PVAQ_{T0}$*	**0.068 (0.029)**	**5.582**	**1.012**	**1.070**	**1.132**
PCS_{T1}	−0.091 (0.049)	3.462	0.829	0.913	1.005
$PASS_{T1}$	0.029 (0.018)	2.686	0.994	1.029	1.065
$PVAQ_{T1}$	−0.022 (0.037)	0.368	0.910	0.978	1.051

NRS, Numerical rating scale; PDI, Pain Disability Index; PCS, Pain Catastrophizing Scale; PASS, Pain Anxiety Symptoms Scale; PVAQ, Pain Vigilance and Awareness Questionnaire; SOMS, Screening for Somatoform Disorders; STAI-X1, State-Anxiety Inventory; CES-D, Center for Epidemiologic Studies Depression. R^2 = 0.20 (Cox & Snell), 0.27 (Nagelkerke).
*$p < 0.05$; **$p < 0.01$.
Significant predictors (p < 0.05) are marked in bold script

Table 4). To clarify the specific relevance of pain anxiety as predictor of chronic pain intensity, we excluded the PASS as predictor and then reran the regression analysis with only PCS and PVAQ scores included in the third block. Interestingly, this time the regression model did not reach significance after inclusion of the third block [Model χ^2 (12) = 8.293; p = 0.762]. Thus, pain catastrophizing and pain vigilance did not contribute significantly to the prediction of chronic pain intensity, stressing the robustness of the finding that only pain anxiety was a relevant predictor.

3.4.2 Prediction of chronic pain disability

Results of the logistic regression analysis for the prediction of chronic pain disability ('no disability' group vs. 'disability' group), that is, PDI score 3 months after surgery, are summarized in Tables 3 and 5. Similarly to the prediction of chronic pain intensity, the regression model reached marginal significance only after inclusion of the pain-related psychological variables in block 3 (see Table 3). The only two single predictors reaching significance in the final regression model were pain disability (PDI) at T1 and pain vigilance (PVAQ) at T0 (see Table 5).

4. Discussion

The aim of the present study was to investigate the relevance of pain-specific psychological variables for the prediction of chronic post-operative pain in a sample of young males undergoing pectus excavatum correction. Pain catastrophizing, pain anxiety and pain hypervigilance were assessed on the preoperative day and again in the acute post-operative stage. Their predictive value was evaluated in comparison to two other well-established groups of predictors: acute post-operative pain and general psychological variables. For the latter, we selected three variables which are regarded as important predictors of post-operative pain: depression, state anxiety and somatization (Kehlet et al., 2006; Macrae, 2008; Hinrichs-Rocker et al., 2009; Katz and Seltzer, 2009; Theunissen et al., 2012).

The intensity of acute post-operative pain did not turn out to be a significant predictor of chronic pain intensity or disability, which is in contrast to previous findings (Katz et al., 1996; Perkins and Kehlet, 2000; Kehlet et al., 2006; Katz and Seltzer, 2009; Chapman and Vierck, 2017). Only acute pain-related disability emerged as significant single predictor of chronic disability. The general psychological variables had no predictive value for both outcome measures. Prediction of chronic pain intensity and disability was provided only after inclusion of the pain-specific psychological variables, with pain anxiety and pain hypervigilance as best single predictors.

We are not the first to find a predictive role of pain-specific psychological variables for chronic post-operative pain. Pain catastrophizing has turned out as relevant predictor in several studies (Edwards et al., 2009; Theunissen et al., 2012; Masselin-Dubois et al., 2013; Schreiber et al., 2013; Burns et al., 2015) and is also increasingly acknowledged as psychological risk factor in comprehensive reviews (Niraj and Rowbotham, 2011; Chapman and Vierck, 2017). However, pain anxiety and pain hypervigilance have to date rarely been tested (Lautenbacher et al., 2010; Dimova et al., 2015). In addition, depression and anxiety are still highlighted as the main psychological factors implicated in the transition from acute to chronic post-operative pain (Hinrichs-Rocker et al., 2009; Chapman and Vierck, 2017). Challenging this view, some evidence for a superior predictive power of pain-specific compared to general psychological variables is provided by a review on prediction of chronic post-operative pain by pain catastrophizing and anxiety (Theunissen et al., 2012) and by a recent study on prediction of acute pain after hysterectomy (Scheel et al., 2017). The present study adds to these findings and brings up the need for large-scale studies comparing the predictive value of pain-specific and general psychological variables in various surgical models.

As nearly 60% of our patients were below the age of 18 years, our study also contributes to research on the prediction of post-operative pain in children and adolescents. Despite prevalence estimates similar to those reported in adult samples (Batoz et al., 2016; Rabbitts et al., 2017), the search for predictors of chronic post-operative pain in paediatric samples is still an emerging field. A recent meta-analysis (Rabbitts et al., 2017) identified only three studies investigating the prediction of chronic post-operative pain by pre-surgical variables in paediatric patients. The only predictors identified by these studies were pre-surgical pain intensity, general anxiety, pain coping efficacy and parental pain catastrophizing. Our results indicate that child's and adolescent's pain anxiety as well as child's and adolescent's pain hypervigilance might also be relevant predictors which should be considered in future studies in paediatric samples.

Another innovative aspect of our study is that psychological predictors were assessed not only pre-operatively (T0) – as in the majority of prospective studies – but also in the acute post-operative phase (T1). Pain-specific psychological variables turned out to be predictors of chronic pain at both time points (T0 and T1), suggesting that the acute post-operative psychological state might also be of importance. In line with this, Pinto et al. (2012) were able to show a predictive role of post-operative anxiety for chronic pain after hysterectomy. We found no clear evidence for a superiority of either pre-operative or post-operative measurement of psychological predictors; the contribution of these predictors at different time points (pre vs. post-surgery) and the separation of state vs. trait components remain important topics to be elucidated in future research.

As regard the comparison of different pain-specific psychological variables, pain anxiety and pain hypervigilance seemed to be the best predictors in the present study. However, it seems very likely that all variables implicated in the fear-avoidance model (Vlaeyen and Linton, 2000, 2012) show considerable empirical overlap as indicated by high inter-correlations (e.g. Roelofs et al., 2004; Lautenbacher et al., 2009, 2010). At the moment, it might be better to state that pain-specific psychological variables seem to be relevant predictors instead of proposing one of these variables as the one and only predictor which sometimes appears to be the for case pain catastrophizing (Khan et al., 2011; Pinto et al., 2012; Burns et al., 2015).

Two questions still to be answered are why the acute post-operative pain as well as the general psychological variables had that little power for the prediction of persistent post-operative pain in our study. The acute post-operative pain was assessed 1 week after surgery; patients were asked to retrospectively rate the days after surgery. It might be that the acute pain is underrated under these conditions because pain was always well controlled by PCEA and additional medication at the end of the first post-operative week. The moderate acute pain ratings support this assumption. Findings of some previous studies indicate that only strong acute post-operative pain can contribute to the prediction of persistent post-operative pain (Poleshuck et al., 2006; VanDenKerkhof et al., 2013; Bjørnholdt et al., 2015; Fletcher et al., 2015). Therefore, either the surgical model allowing for sufficient acute pain management or the way of acute pain assessment might have been responsible for only moderate levels of acute pain, which in turn may have limited its predictive power.

The patients were young males with often long-standing dissatisfaction with their body which resulted in the decision to undergo cosmetic surgery. Nevertheless, the psychopathological load of the patients was likely smaller than in many other studies on post-operative pain because an exclusion criterion in the present study was major pain prior to surgery. Thus, medical histories of chronic pain and other serious illnesses which are often associated with increased depression, anxiety and somatization (Bair et al., 2003; Tsang et al., 2008; Yalcin and Barrot, 2014) were very unlikely. It might be that these variables need to reach clinically relevant levels to exert relevant influence on the course of post-operative pain which might not have been the case in our patient group.

Our regression model allowed for the significant prediction of chronic pain intensity; in contrast, the model for prediction of chronic pain disability was only marginally significant. Associations between the two variables were significant but only moderate, stressing that there is some commonality but also a lot of different influences. The PDI as indicator of pain disability reflects by definition a more multidimensional construct by asking for functional limitations in various areas of life, whereas the NRS as indicator of pain intensity is a unidimensional measure. Therefore, it is likely that the PDI scores 3 months after surgery are influenced by many more factors than the acute post-operative situation, which may principally lower the relative potency of predictors assessed in this situation.

There are also some limitations worth mentioning. First, the age of our participants ranged from 13 to 33 years; some questionnaire items might have been less suitable for the youngest participants. However, we deemed it as most feasible to use the standard adult versions for all participants to ensure comparability to other post-surgical samples; in addition, validated child versions in German language are not yet available for most of the questionnaires. Second, our sample size was relatively small which might have led to insufficient statistical power to detect a predictive value of acute pain. However, the statistical contribution of acute pain intensity to our regression model was close to 0 so that a disproportionately large sample would have been necessary to detect an effect. Third, the specific sample of the present study does not allow for generalization to other samples and surgical models. Large-scale studies are needed to further evaluate the predictive power of pain-specific and general psychological variables in various surgical models. Finally, pain intensity at T2 was assessed by a retrospective rating of the previous 4 weeks which might have led to memory bias in some participants.

In conclusion, the transition from acute to chronic post-operative pain can be predicted by pain-specific psychological variables. For theoretical and economic reasons, it should be clarified which of the three variables derived from the fear-avoidance model qualifies best as predictor. Alternatively, aggregation of these variables into a meta-tool might be promising. Given that these self-report measures are easy to assess, even in clinically pressing situations, a focus of further research should lie on the optimization and validation of such tools with the aim of developing one comprehensive tool providing high predictive power with a minimal number of items.

Author contributions

All authors discussed the results and commented on the manuscript. Also, all authors have read and approved the paper. The contribution of each author for this paper is as follows: C.H.-H.: Study design/data analyses/interpretation of results/writing of the manuscript. J.S: Data collection/data input/data analyses/helpful input regarding discussion of results in the context of literature. V.D.: Data collection/data input. A.P.: Data collection/data input/patient diagnostics and treatment. R.C.: Patient treatment. N.G.: Patient diagnostics and treatment. Reinhard Sittl: Patient diagnostics and treatment. S.L.: Study design/interpretation of results/writing of the manuscript.

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