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Review article

The role of emotion regulation in chronic pain: A systematic literature review

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ABSTRACT

Objective: Emotion regulation (ER) includes a set of cognitive and attentional processes used to change or maintain emotional state. A small but growing body of research suggests that maladaptive ER might be a risk factor for the development of chronic pain. This review aims to summarize existing literature on the association between ER and chronic pain, and to determine whether the construct of ER may further enhance our understanding of the risk and protective factors that may contribute to the onset and maintenance of chronic pain.
Methods: A systematic search was conducted using the search terms "chronic pain" and "emotion regulation." Studies that measured both constructs across all age groups were included.
Results: We found 15 studies that met our inclusion criteria. Nine studies were completed within the last five years, suggesting that the evaluation of ER as it relates to pain is a new line of research. Studies that measured "response-focused" ER found associations between maladaptive ER and pain. Studies that measured "antecedent-focused" ER strategies were less likely to show a direct association with pain.
Conclusion: Maladaptive response-focused ER may be an important risk factor in the development and maintenance of chronic pain, as it is associated with pain and psychological comorbidities. Adding ER to chronic pain investigations may help to further explain individual differences in the risk and protective mechanisms that are known to influence chronic pain. Importantly, this line of research has potential to directly inform future interventions for patients with chronic pain.

1. Introduction

Chronic pain is defined as any pain condition that exists for more than three months, either continuously or recurrently [14,48]. Chronic pain is estimated to effect 20% of the population and causes an enormous burden to both individuals and the healthcare system [25]. Current models of chronic pain illustrate the complex interplay of sensory, environmental, psychological, and pain regulatory risk factors that shape the pain vulnerability of an individual ([55]; see Fig. 1). Research on chronic pain seeks to disentangle the various risk and protective influences of biological, psychological, and environmental factors that are known to contribute to chronic pain disorders. Understanding these factors is critical to the development and implementation of targeted intervention.

Pain has long been defined as an "unpleasant sensory and emotional experience" ([40]). The recognition of the sensory and psychological components of pain have recently been strengthened by controlled laboratory studies that illustrate the link between emotional state and pain perception, both in healthy volunteers (e.g. [24,43]) and in patients with chronic pain (e.g. [50]). Additionally, research using fMRI has supported the notion that inducing negative mood can influence subsequent pain ratings [11]. Beyond the research linking the sensory and emotional experience of pain, patients with chronic pain have three times the risk of being diagnosed with anxiety and depression as compared to the general population [7,26,49]. Despite the multiple links between pain and negative emotions, surprisingly little is known about how emotion regulation styles may influence pain, pain-related disability, and psychological comorbidities in chronic pain populations.

Emotion regulation (ER) describes a person's ability to modulate his or her emotional state and expression, that includes influencing which emotions people have, when they have these emotions, and how emotions are experienced and expressed [1,31]. Assessment of ER thus encompasses measurement of cognitive, behavioral, and psychophysiological responses to an event or stressor [18,56]. The regulation of emotions has been the focus of various studies, among them studies in the field of stress and coping research [31]. However, ER is different

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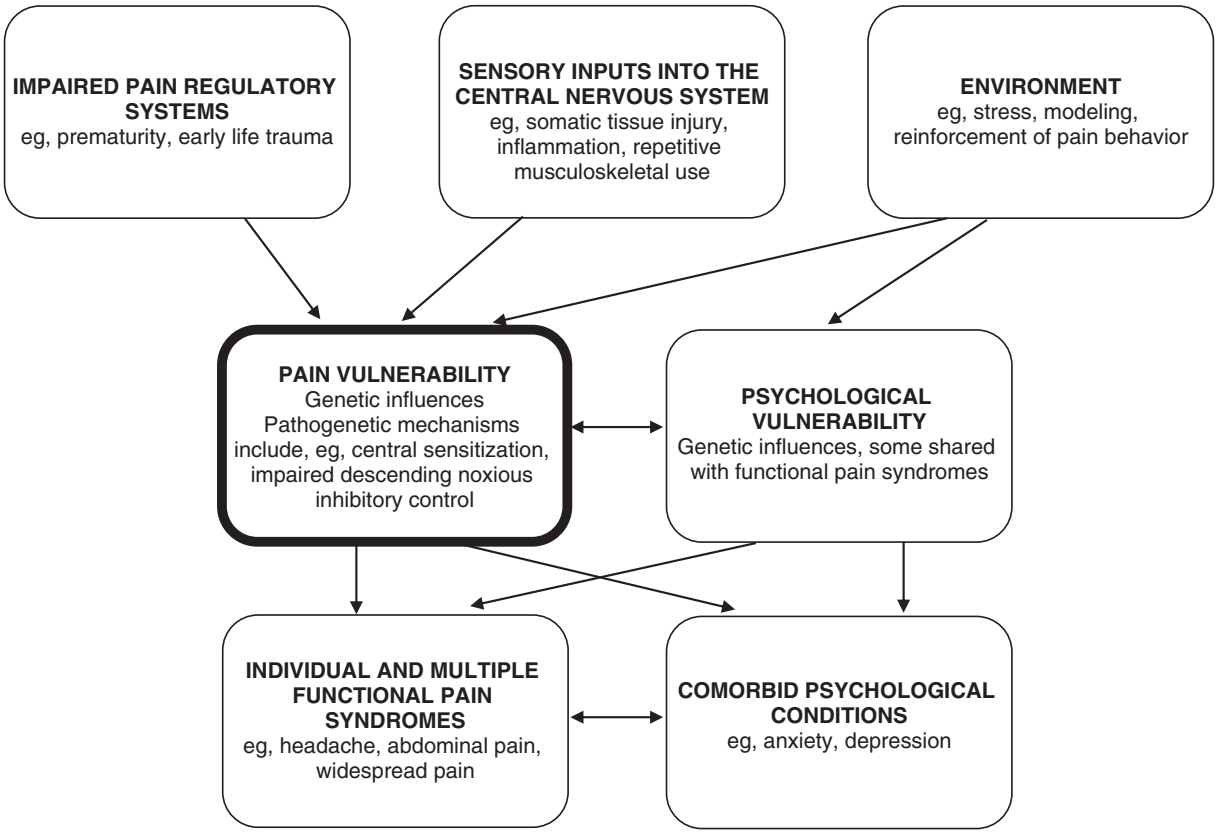

Fig. 1. Antecedents and consequences of pain vulnerability [55].
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from coping on the one hand in that coping includes non-emotional actions; ER on the other hand includes processes not traditionally considered in the coping literature, such as maintaining or up-regulating positive emotions [15].

A helpful model of organizing the diverse cognitive and behavioral strategies people use to regulate their emotions is the Process Model of ER [30,34]. The Process Model of ER is based on the modal model of emotion, which presents the core features of emotions and specifies that ER can set in at every step of the emotion generation process: Emotion arises in a *situation* that is meaningful to the individual and demands *attention*, has a particular *meaning* and gives rise to a multifaceted, embodied *response* (see Fig. 2). The Process Model broadly divides ER into antecedent- and response-focused strategies. Antecedent-focused strategies include situation selection, situation modification, attentional deployment, and cognitive change, that set in before the emotion is fully developed – hence their prospect of success is generally greater [3]. Strategies such as avoiding a situation that potentially elicits negative emotions or shifting one's attention to thoughts of an upcoming vacation to prevent boredom in a long work meeting are considered antecedent-focused. In contrast, response-focused strategies emphasize

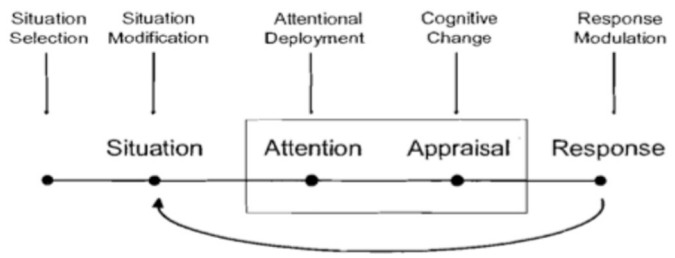

Fig. 2. The Process Model of Emotion Regulation [34].
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regulating the emotional response, especially its physiological and behavioral aspects, once the event has already onset [29,38]; holding back one's tears in public is one example.

ER is considered maladaptive if it shows a negative short- and/or long-term outcome, antagonizes personal goals or shows a lack of ER flexibility (i.e., is inappropriate to contextual or social demands [5]). Research on ER has studied how ER affects the individuals as well as the people around them. This has yielded results linking maladaptive ER to psychopathology (for a review see [4]), negative affect [9], learning difficulties [17], memory deficits [19,42], and physiological stress reactions [13]. Importantly, research has demonstrated that training in adaptive ER is effective for treating a range of psychological and psychosocial difficulties. As a result, these skills and strategies are often incorporated as a component part of cognitive behavioral therapy treatment [10,27].

This systematic review synthesizes the existing body of research that explores the relationship between ER and chronic pain. To our knowledge, this is the first review to examine the ER – chronic pain relationship. Our goal is to investigate whether the construct of ER may enhance the existing theoretical frameworks of chronic pain, to increase our understanding of individual-level risk and protective influences that contribute to development and maintenance of chronic pain conditions. Further, we seek to explore the associations between the two categories of ER, antecedent- and response-focused strategies, and chronic pain. Based on our understanding of the process model of ER, we hypothesize that response-focused ER is more likely to have negative associations with chronic pain as compared to antecedent-focused ER.

2. Methods

For this systematic review, we searched PubMed, Embase, PsychInfo, Web of Science, CINAHL, and the Cochrane Central Database

Table 1
Search terms.

PubMed	(emotion regulat*[tiab] OR emotional regulat*[tiab] OR emotion dysregulat*[tiab] OR emotional dysregulat*[tiab] OR emotional modulat*[tiab] OR emotion modulat*[tiab] OR emotion management[tiab] OR emotional management[tiab] OR emotional competenc*[tiab] OR emotion comptetenc*[tiab] OR emotional expression[tiab] OR emotion expression[tiab] OR emotional control[tiab] OR emotion control[tiab] OR emotional self-efficacy[tiab] OR emotional suppression[tiab] OR emotion suppression[tiab] OR affect regulat*[tiab] OR affect dysreg*[tiab] OR effortful control[tiab] OR situation selection[tiab] OR situation modification[tiab] OR attentional deployment[tiab] OR cognitive change[tiab] OR response modulation[tiab]) AND ("pain"[mesh] OR "Pain Measurement"[mesh] OR pain[tiab])
Embase	((emotion* NEXT/1 (regulat* OR dysregulat* OR modulat* OR management OR competenc* OR expression OR control OR 'self efficacy' OR suppression)):ab,ti OR (affect* NEXT/1 (regulat* OR dysregulat*)):ab,ti OR 'effortful control':ab,ti OR 'situation selection':ti,ab OR 'situation modification':ti,ab OR 'attentional deployment':ti,ab OR 'cognitive change':ti,ab OR 'response modulation':ti,ab) AND ('pain'/exp. OR 'pain measurement'/exp. OR pain:ab,ti) AND [embase]/lim
PsycINFO	DE ("Emotional Regulation" OR DE "Emotional Control") OR TI ((emotion* W1 (regulat* OR dysregulat* OR modulat* OR management OR competenc* OR expression OR control OR "self efficacy" OR suppression)) OR (affect* W1 (regulat* OR dysregulat*)) OR "effortful control" OR "situation selection" OR "situation modification" OR "attentional deployment" OR "cognitive change" OR "response modulation") OR AB ((emotion* W1 (regulat* OR dysregulat* OR modulat* OR management OR competenc* OR expression OR control OR 'self efficacy' OR suppression)) OR (affect* W1 (regulat* OR dysregulat*)) OR 'effortful control' OR 'situation selection' OR 'situation modification' OR 'attentional deployment' OR 'cognitive change' OR 'response modulation') AND DE ('Pain Measurement' OR 'Pain' OR "Back Pain" OR 'Chronic Pain' OR "Headache" OR "Myofascial Pain" OR "Neuralgia" OR "Neuropathic Pain" OR "Pain Perception" OR "Pain Thresholds") OR TI pain OR AB pain
CINAHL	TI ((emotion* W1 (regulat* OR dysregulat* OR modulat* OR management OR competenc* OR expression OR control OR 'self efficacy' OR suppression)) OR (affect* W1 (regulat* OR dysregulat*)) OR 'effortful control' OR 'situation selection' OR 'situation modification' OR 'attentional deployment' OR 'cognitive change' OR 'response modulation') OR AB ((emotion* W1 (regulat* OR dysregulat* OR modulat* OR management OR competenc* OR expression OR control OR 'self efficacy' OR suppression)) OR (affect* W1 (regulat* OR dysregulat*)) OR 'effortful control' OR 'situation selection' OR 'situation modification' OR 'attentional deployment' OR 'cognitive change' OR 'response modulation') AND MH ("Pain+" OR 'Pain Measurement') OR TI pain OR AB pain
Web of Science	TS = ("emotion regulat*" OR "emotional regulat*" OR "emotion dysregulat*" OR "emotional dysregulat*" OR "emotional modulat*" OR "emotion modulat*" OR "emotion management" OR "emotional management" OR "emotional competenc*" OR "emotion comptetenc*" OR "emotional expression" OR "emotion expression" OR 'emotional control' OR "emotion control" OR "emotional self-efficacy" OR "emotional suppression" OR "emotion suppression" OR "affect regulat*" OR "affect dysreg*" OR 'effortful control' OR 'situation selection' OR 'situation modification' OR 'attentional deployment' OR 'cognitive change' OR 'response modulation') AND TS = pain
Cochrane Central Database of Controlled Clinical Trials	('emotion regulat*' OR 'emotional regulat*' OR 'emotion dysregulat*' OR 'emotional dysregulat*' OR 'emotional modulat*' OR 'emotion modulat*' OR 'emotion management' OR 'emotional management' OR 'emotional competenc*' OR 'emotion comptetenc*' OR 'emotional expression' OR 'emotion expression' OR 'emotional control' OR 'emotion control' OR 'emotional self-efficacy' OR 'emotional suppression' OR 'emotion suppression' OR 'affect regulat*' OR 'affect dysreg*' OR 'effortful control' OR 'situation selection' OR 'situation modification' OR 'attentional deployment' OR 'cognitive change' OR 'response modulation') AND pain

of Controlled Clinical Trials using the key words "emotion regulation" and 'chronic pain'. For additional information on search terms, see Table 1. In total, our search returned 2893 articles, of which 1041 duplicates were removed. The screening and selection process was conducted by two authors independently (HK and CW). We included studies that measured both ER and chronic pain using a cross-sectional, observational, longitudinal, or interventional design across all age groups and pain conditions, published from the earliest available record from 1923 through November 2016. We excluded studies of acute and/or experimentally induced pain, studies that did not report on the associations between ER and pain measures, and studies that assessed coping or alexithymia instead of ER. Reviews, meta-analyses, dissertations, posters, and conference abstracts were also excluded. Based on abstract and title search, 48 papers were included in full text review (see Fig. 3). We extracted information on study sample, pain diagnosis, pain measure, ER measure, and statistical associations between pain and ER measures. Further, we reviewed questionnaire items on each measure of every study and categorized measures into antecedent- or response-focused ER.

3. Results

The study selection procedure is summarized in Fig. 3. Our search identified fifteen studies including a total of 2065 patients who met our criteria. Two studies included pediatric populations, six studies had a female-only population, and only one study had a majority of male participants. The studies included in this review assessed patients with one or more of the following pain conditions: fibromyalgia (n = 5), rheumatoid arthritis (n = 4), back pain (n = 4), multiple pain sites (n = 3), juvenile idiopathic arthritis (n = 1), pelvic pain (n = 1), and sickle cell disease (n = 1). Characteristics of the included studies are shown in Table 2. All measures of ER were classified as either antecedent (n = 4)- or response (n = 5)-focused ER. Several studies (N = 5) used both antecedent- and response-focused measures and one study used a measure that could not clearly be classified. The statistics and the multivariate and bivariate associations for the studies are reported in the supplement (Table S1).

3.1. Antecedent-focused emotion regulation

Four studies measured ER strategies that were classified as antecedent-focused (see Table 2). This included cognitive ER strategies such as thought suppression or cognitive reappraisal.

This group of studies sought to determine how pain intensity or pain-related functioning was influenced by cognitive ER strategies that are typically employed prior to the full-blown emotional response. For example, one study that was interested in participants' tendency to employ cognitive change strategies, asked them to rate statements such

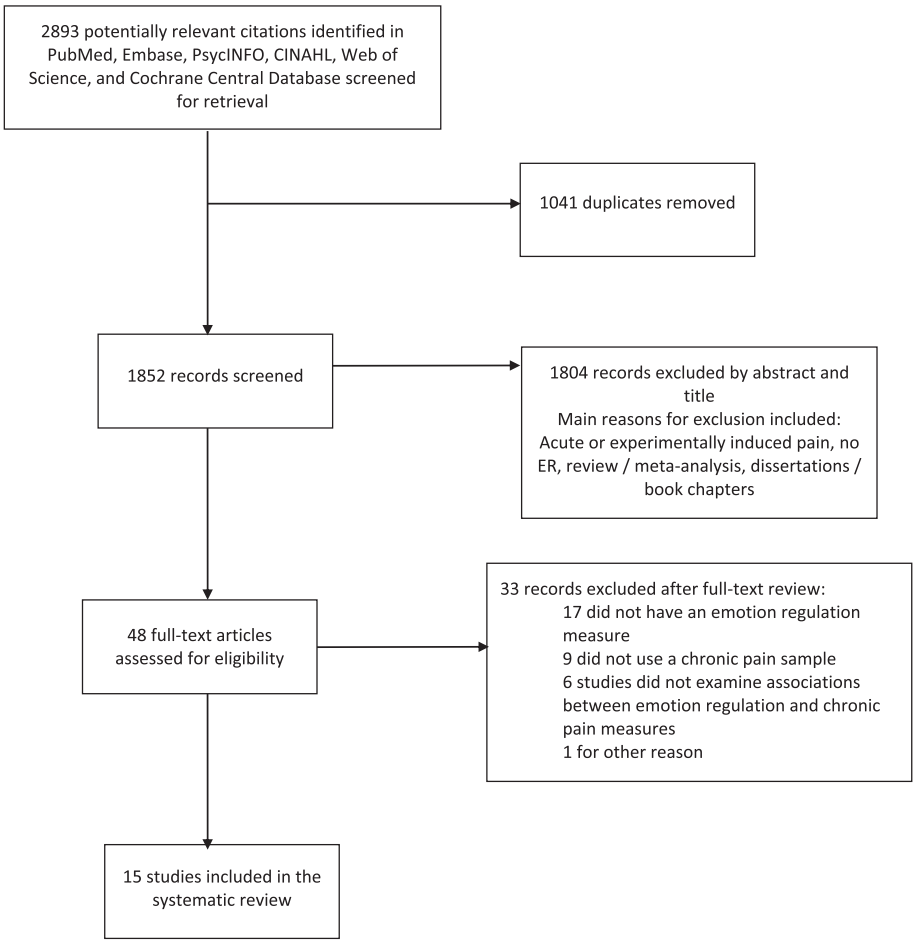

Fig. 3. Flow chart.

as: "No matter how badly I feel, I try to think about pleasant things" [36]. Findings from this group of studies suggest that while there might not be direct associations between antecedent-focused ER and pain, there was a link between antecedent-focused ER and depression, in that thought suppression was positively correlated with more depressive mood and major depressive disorder [22]. Additionally, there was an association between high emotionality and reduced use of adaptive antecedent-focused ER such as cognitive reappraisal [37]. In other words, when patients had more negative emotions, they were less likely to use cognitive reappraisal and thus experienced more pain. Similarly, in the same group of patients, high pain was linked to lower mood [36]. Further, women with chronic pelvic pain reported to suppress their thoughts and emotions more often compared to controls [46]. This study also found that the tendency to suppress unwanted thoughts or emotion was associated to more pain.

Thus, while antecedent-focused ER may not directly influence pain, it is possible that adaptive use of these strategies may reduce pain vulnerability or pain experience indirectly by reducing high emotionality or negative mood, both known vulnerability factors for the development of chronic pain.

3.2. Response-focused emotion regulation

Five studies measured response-focused ER. This included strategies such as response modulation (i.e., influencing physiological, experiential, or behavioral responding) and expression of emotions.

This group of studies sought to determine how pain intensity or pain-related functioning was influenced by behavioral or experiential ER that is typically employed after response tendencies have been initiated. For example, one study investigated whether anger inhibition or expression was related to concurrent pain and pain three hours after anger inhibition or expression [12]. They found that both expression of anger (such as slamming doors or shouting) and inhibition of anger (such as hiding anger or keeping it to oneself) were correlated with pain intensity, in that those participants who strongly expressed or inhibited their anger experienced more pain. Similarly, in patients with more problems controlling their emotional expression, for example, those who had emotional outbursts or sudden and/or frequent mood changes, pain interfered more with their physical activity, mood, relationships, and sleep [8].

With regard to psychological comorbidities, a study that measured participants' self-perceived ability to regulate emotions found that those with low self-perceived ability to do so often also showed depressive symptoms [35]. Interestingly, however, this self-perception was not correlated with pain, but those patients who reported depression symptoms also reported significantly more pain. Similarly, two studies looked at the same sample of patients with rheumatoid arthritis, distinguished different styles of ER and tested if these different styles would relate to dimensions of perceived health such as social and physical functioning and disease activity. They found that none of the ER styles was significantly related to physical functioning or disease activity. However, ER styles were related to social functioning and positive and negative affect [52]. Additionally, they tested if men and women differ with regard to ER styles and perceived health and found that indeed, women had higher scores than men on an ER style that is best described in terms of attending to and intensely experiencing emotions, and valuing emotions in daily life and decision making [53]. For women, the styles of ER found in this study explained 3% of the

Table 2
Demographics and study characteristics.

First Author, Publication Year	Study type	Sample size (N) [+]	Age, M (SD)	% Female	Pain diagnosis	Pain measure	Pain duration M (SD), in Years	Emotion regulation measure	Type of ER	Main finding ER - Pain
Agar-Wilson [2]	Cross-sectional	128	52.9 (16.8)	66%	Back pain, multiple pain sites	Oswestry Disability Questionnaire (ODQ)	8.3 (9.0)	Assessing Emotions Scale (AES)	N/A	Efficacy in ER not related to pain-related disability
Baker [8]	Cross-sectional	63	46.8	60%	Back pain, multiple pain sites, fibromyalgia	Brief Pain Inventory (BPI)	9.0	Behavior Rating Inventory of Executive Function, Adult version (BRIEF-A)	R	Clinically elevated emotional control values positively related to worse pain-related functioning
Burns [12]	Observation	105	46.3 (12.1)	49%	Chronic low back pain	Numerical (0–8)	9.0 (7.8)	State-Trait Anger Expression Inventory (STAXI) items	R	Anger expression and inhibition positively correlated with pain intensity
Connelly [16]	Observation	43	13.2 (2.7)	86%	Juvenile Idiopathic Arthritis[°]	Visual Analogue Scale (VAS)	N/A	Children's Emotion Management Scale (CEMS)	A, R	ER self- and parent-report not correlated with pain or functional limitations
Garland [22]	Cross-sectional	115	48.3	68%	Low back pain, fibromyalgia, arthritis, other	Brief Pain Inventory – Short Form (BPI-SF)	N/A At least 90 days	White Bear Suppression Inventory (WBSI)	A	Thought suppression not correlated with pain severity
Geenen [23]	Cross-sectional	403	46.5 (12.3)	100%	Fibromyalgia	Fibromyalgia Impact Questionnaire (FIQ)	10.9 (8.6)	Emotion Regulation Questionnaire (ERQ) Emotion Approach Coping Scales (EACS)	A, R	Cognitive reappraisal not correlated with disease impact, expressive suppression positively correlated with disease impact
Hamilton [37][*]	Longitudinal	81	62.2 (7.3)	100%	Rheumatoid arthritis[°]	Numerical (0 − 100)	N/A	Trait Meta-Mood Scale (TMMS)	A	ER not correlated with pain
Hamilton [36][*]	Longitudinal	81	62.2 (7.3)	100%	Rheumatoid arthritis[°]	Numerical (0–100)	N/A	Trait Meta-Mood Scale (TMMS)	A	ER not correlated with pain
Hamilton [35]	Cross-sectional	35	47.0 (10.5)	100%	Fibromyalgia[°]	McGill Pain Questionnaire – Short Form (MPQ – S)	13.0 (9.2)	The Emotion Amplification and Reduction Scales (TEARS)	R	ER not correlated with sensory dimension of pain experience
Thomas [46]	Cross-sectional	61	31.8 (7.8)	100%	Pelvic pain with and without endometriosis	Visual Analogue Scale (VAS) National Women's Sexual Pain Scale (NWSPS)	7.3 (5.7)	Marlowe-Crowne Social Desirability Scale (MC-SDS) Bending short-form of the Taylor Manifest Anxiety Scale (TMAS Bending SF) State-Trait Anger Expression Inventory (STAXI)	A	Patients with chronic pelvic pain use significantly more thought suppression compared to controls
Tsao et al. [50]	Cross-sectional	69	13.4 (2.0)	55%	Sickle-cell disease	No. Hosp.[1]	N/A	Emotion Regulation Questionnaire for Children and Adolescents (ERQ-CA)	A, R	Cognitive reappraisal and expressive suppression not correlated with pain
Van Middendorp [52][*] Van Middendorp [53][*]	Cross-sectional	335	57.8 (13.3)	73%	Rheumatoid Arthritis[°]	Impact of Rheumatic Diseases on General Health and Lifestyle (IRGL)	12.1 (11.0)	Five Expressivity Facet Scale (FEFS) Self-Assessment Questionnaire Nijmegen (SAQ-N) Ambivalence over Emotional Expressiveness Questionnaire (AEQ)	R	ER style explains 0% of variance of physical functioning and disease activity
Van Middendorp [54]	Cross-sectional	403	46.5 (12.3)	100%	Fibromyalgia[°]	Fibromyalgia Impact Questionnaire (FIQ)	10.9 (8.6)	Emotion Approach Coping Scales (EACS) Emotion Regulation Questionnaire (ERQ) Self-Expression and Control Scale (SECS)	A, R	Cognitive reappraisal and expressive suppression not correlated with pain
Wong [57]	Cross-sectional	224	45.66 (9.87)	55%	Chronic pain[2]	Chronic Pain Grade(CPG)	4.35 (6.05)	Emotion Regulation Questionnaire (ERQ)	A, R	Cognitive reappraisal and expressive suppression not correlated with pain

A: antecedent-focused ER.
R: response-focused ER.
[*] These studies used the same sample.
[1] The number of pain crises in the previous year that did not require hospitalization served as a measure for pain during the study period (comparison between frequent and infrequent hospitalization group).
[+] Number indicates sample size of patients with chronic pain.
[°] These patients had a physician-certified diagnosis of a pain syndrome and are therefore considered to be patients with chronic pain.
[2] Pain sites: head, neck, shoulder, hand, chest, upper back, lower back, pelvis, knee, leg, joint or muscle.

variance of disease activity, which means that a small part of difference between individuals with regard to disease activity is explained by their different styles of ER. This was not true for men, in turn, men reported better physical functioning than women.

Thus, in some cases, response-focused ER was directly correlated with pain and pain-related functioning, while in other cases these strategies related to symptoms of depression, a prevalent psychological comorbidity of chronic pain.

3.3. Antecedent- and response-focused emotion regulation

Five studies measured both antecedent- and response-focused ER. This group of studies sought to determine how antecedent- and response-focused ER strategies differ with regard to their relationship to pain, pain-related disability, and disease impact. For example, one of the few studies that examined a pediatric population asked their participants and participants' parents to complete a baseline ER measure prior to a one-month electronic diary study that assessed emotions and pain thrice daily. The baseline ER measures asked for both antecedent- and response-focused ER to deal with negative emotions, but no correlation with pain intensity was found [16]. However, children that reported more emotional ups and downs in the electronic diary also reported more pain compared to those children with less emotional variability.

Three studies that all measured both cognitive reappraisal and expressive suppression did not find significant correlations of pain with either one of the ER strategies [51,54,57]. However, findings of these studies suggest that while cognitive reappraisal and expressive suppression do not directly influence pain, expressive suppression seems to have a negative impact on patients' experience of their pain. For example, one study found that participants who used more suppression of their emotional expression also reported significantly more symptoms of anxiety and depression [54]. In the same study, a significant positive correlation between negative emotions, such as feeling upset or scared, and pain was reported. Another study found that patients who employed more expressive suppression also had more catastrophic thoughts around pain such as “When I'm in pain, I worry all the time about whether the pain will end” (item from the Pain Catastrophizing Scale PCS; [45]). These catastrophic thoughts were significantly positively correlated with pain intensity and pain-related disability [57]. Additionally, children with sickle cell disease who used expressive suppression were more likely to be hospitalized due to pain crises compared to those who employed less expressive suppression [51]. In line with these findings, patients who reported often expressing their feelings freely also reported less consequences of their pain such as number days of work missed, physical impairment, and morning tiredness [23].

Thus, most studies that measured both antecedent- and response-focused ER found no direct relationship of either strategy to pain, but found response-focused ER to be correlated with catastrophizing thoughts around pain, likelihood of being hospitalized during pain crises, and the impact the disease has in patients' everyday life.

One study measured ER that could not be classified as either antecedent- or response-focused. Questions such as “When I experience a positive emotion, I know how to make it last” or “I have control over my emotions” were asked to determine participants' efficacy in ER [2]. Participants who rated themselves as being effective in regulating their emotions also reported less negative affect and better quality of life. ER efficacy was not correlated with pain-related disability, but positively with self-efficacy in managing pain [2].

In sum, the studies included in this review rarely found direct associations between emotion regulation and pain intensity or pain-related disability. Rather, the relationship between ER (antecedent or response-focused) and pain seemed to be mediated by psychological factors such as emotionality, anxiety, or negative mood. The studies that more closely explored response-focused ER seemed to provide the best evidence for a strong relationship between maladaptive ER, psychological symptoms, and pain.

4. Discussion

This systematic review examined the relationship between antecedent- and response-focused ER and chronic pain. We found that ER is a relatively new construct in the chronic pain literature and the direct and indirect influences of ER and pain are not yet clearly defined. Most studies in this review found indirect associations between ER and pain, via other psychological factors. However, there were several studies that found direct associations between maladaptive response-focused ER and chronic pain, pain-related disability, and depressive symptoms. This is in line with previous research that differentiated between adaptive and maladaptive ER based on their relationship with psychological symptoms and found antecedent-focused strategies (such as cognitive reappraisal) to be more adaptive compared to response-focused strategies (such as expressive suppression; [4]). However, the differentiation between adaptive and maladaptive ER is more precise when it incorporates the idea of ER flexibility, i.e. the ability of an individual to implement an ER strategy that matches the contextual demands [5]. Maladaptive ER can thus be thought of as a limited range of strategies inappropriately matched to changing social and contextual demands. Suffering from chronic pain may present as a constant stressor that increases the amount of negative affect one experiences (due to missing days at work or school or not being able to actively participate in social activities; Vos et al. [58]) and thus it might become increasingly difficult to employ adaptive ER.

Even in cases where ER is not directly associated with pain intensity or disability, it plays an important role in patients' overall well-being and functioning, as it can be associated with symptoms of depression, anxiety, stress [8,35,54], or quality of life [2]. All these factors might then further worsen pain or limit functioning in this population. It is therefore suggested to include ER in current models of chronic pain, such as the one proposed by von Baeyer and Champion ([55]; see Fig. 1). Based on Mayer and Bushnell's work [39], von Baeyer and Champion differentiate between primary risk factors for chronic pain, such as central sensitization, or autonomic nervous system activity, and secondary risk factors, such as catastrophizing, and symptom-related worries. While early gene-environment interactions may shape primary risk factors, secondary risk factors may be more responsive to the cultural, social, and medical environment and are thus commonly targets of chronic pain interventions. The results of our systematic review suggest that ER may be an important secondary risk factor that cuts across different chronic pain syndromes.

Further, as a secondary risk factor, ER is a good target for training modules within the treatment of chronic pain, as adaptive use of ER strategies can be trained (e.g. [17,20,27]). Preliminary studies that included ER in current treatment options for chronic pain report positive results, both in adolescents (e.g. [6]) and adults (e.g. [27]). In a study of two case examples of patients with chronic pain and comorbid anxiety or depression, the training of ER lead to improvements in at least some of the domains of interest (pain, functional limitations, anxiety, ER, and others more; [6]). In a study that extended cognitive behavioral therapy (CBT) with ER training and compared it to CBT alone, CBT with ER training showed greater effect sizes for almost all treatment objectives [27]. Hence, adding ER to current theoretical frameworks of chronic pain may help to further clarify why some people are more vulnerable to chronic pain than others and how this knowledge can be implemented in new interventions.

Several limitations have to be considered when interpreting the results of this review. We only found a small number of studies that examined ER and chronic pain, and one major obstacle in conducting this systematic review was that even in this small sample of literature the term ER was used very heterogeneously. Besides the Process Model of ER [30], there is significant variability in regards to how the term ER

is operationalized. Some working definitions include (or do not clearly exclude) alexithymia, coping style, emotional awareness, and emotional intelligence. The variability in conceptualization of this term is also evident in the wide range of measures developed to systematically assess ER [18,56]. The studies included in this review used a range of different questionnaires. However, in an attempt to clarify the subject, only studies that explicitly measured ER were included. Similar challenges present themselves in the field of chronic pain. First, there are a variety of pain sites and syndromes assessed within this review. Second, study participants suffered from chronic pain conditions for time periods that ranged between several months and more than a decade. Living with chronic pain for such an extended period of time might lead to more accentuated problems in the areas of social life, job, and functioning in general [41]. Further, although we included all age groups, only two of the 15 studies looked at pediatric populations. Given that ER involves higher order cognitive processing, we certainly cannot assume that our findings would generalize more broadly to pediatric samples. Moreover, no statement can be made regarding age-specific relationships between ER and chronic pain. Other significant limitations include the bias of female only studies (6/15) in this review and the cross-sectional design of most of the studies.

The results of this review are also limited in part by the standard questionnaire format of all measures used for studies within this review. In general, as ER is a phenomenon that includes cognitive, behavioral, and physiological aspects, it is advisable to measure it using several methods, such as psychophysiological and observational methods and questionnaires [28,33,47]. Future studies should employ newer ambulatory assessment methods, such as ecological momentary assessment [44]. Electronic diaries are one example for electronic momentary assessment [18]. Fernandez and colleagues [21] proposed to include ER as a new Research Domain Criteria (RDoC) domain. This would support future research in the field of ER and chronic pain, as it would allow to further understand not just the cognitive and behavioral, but also the neural, genetic, and physiological systems that underlie the ER - chronic pain relationship.

To our knowledge, this is the first review to systematically examine the role of both antecedent- and response-focused ER in chronic pain. Our results suggest that ER may be an important and understudied risk factor that can have direct or indirect influences on pain, pain-related disability, and psychological comorbidities in patients with chronic pain. Further investigation is needed to more directly explore the role of ER in chronic pain and importantly to ascertain if training in adaptive ER strategies could provide direct symptom relief or even potentially serve as a protective factor, reducing pain vulnerability in patients who may have other identified risk factors for the development of chronic pain.

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Conflicts of interest

The authors have no competing interests to report.

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