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Investigating the Influence and a Potential Mechanism of Self-Compassion on Experimental Pain: Evidence From a Compassionate Self-Talk Protocol and Heart Rate Variability

Xi Luo,* Jianzhao Liu,* and Xianwei Che[†,‡,§]

*College of Preschool and Primary Education, China West Normal University, Nanchong, China, †Center for Cognition and Brain Disorders, The Affiliated Hospital of Hangzhou Normal University, Hangzhou, China, ‡Zhejiang Key Laboratory for Research in Assessment of Cognitive Impairments, Hangzhou, China, §Monash Alfred Psychiatry Research Centre (MAPrc), The Alfred and Central Clinical School, Monash University, Melbourne, Australia

Abstract: **Previous studies have indicated a positive relationship between self-compassion and psychological and emotional well-being in chronic pain populations. However, evidence on the role and mechanisms of self-compassion in pain perception is largely limited. The current study was designed to investigate the effects and a potential mechanism of self-compassion on experimental pain. Thirty healthy participants underwent a compassionate self-talk protocol, which was followed by cold pain exposure during which high-frequency heart rate variability (HF-HRV) was evaluated. The compassionate self-talk protocol successfully generated compassionate statements among the participants. Our behavioral data showed lower pain ratings in the self-compassion compared to the control condition. Moreover, self-compassion manipulation resulted in higher HF-HRV during pain, which was associated with lower pain ratings. We present interesting findings that a short period of compassionate self-talk may decrease experimental pain as well as mechanistic evidence surrounding bodily control over pain-related arousal indicated by HF-HRV.**

Perspective: ***This study presents the first line of evidence that a short period of compassionate self-talk may be sufficient to reduce experimental pain. We also demonstrate increased bodily control as a potential mechanism underlying this effect.***

Key words: *Self-compassion, pain, heart rate variability.*

Self-compassion is conceptualized as the ability to be kind and caring toward oneself in times of suffering, failure, or perceived inadequacy.[35,36] A number of studies have demonstrated the role of self-compassion in protecting emotional well-being against negative life events.[3,4,30-32,52,57] In the field of pain research, increasing evidence has identified a positive association between self-compassion and emotional well-being in people with chronic pain,[5,15,20,46,56] while the effects of self-compassion on pain perception are mixed.[45] Moreover, some studies have tried to cultivate compassion through therapeutic interventions in chronic pain populations, in which preliminary results have demonstrated the effectiveness in reducing pain and psychological distress.[14,16] These studies together indicate the potential therapeutic role of self-compassion in coping with pain.

However, optimizing compassion-focused strategies in chronic pain is limited by our knowledge of the effects and mechanisms through which self-compassion reduces pain. Current evidence relies primarily on correlational studies, whereby experimental evidence is limited. One study experimentally manipulated self-compassion using vignettes in people with chronic pain, in which a greater ability to show self-compassion was associated with lower negative effect, catastrophizing, and rumination.[44] However, the effects of self-compassion on pain perception need to be further examined in experimental and

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Address reprint requests to Dr. Xianwei Che, Center for Cognition and Brain Disorders, Building 19, 2318 Yuhangtang Road, Hangzhou, 311121, China. E-mail: xianwei.che@monash.edu
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observational studies.[44] Moreover, a recent study indicated the particular importance of understanding the mechanisms by which self-compassion decreases pain experience as a potential avenue for research into self-compassion and chronic pain.[45]

Pain is an unpleasant experience which serves to protect the body. The protective function of pain depends on motor responses in which energy resources are allocated by the autonomic nervous system (ANS).[17,38,53] Painful stimuli usually activate the sympathetic branch while suppress the parasympathetic branch of the ANS.[41,54] Autonomic responses are therefore considered as an integral component of pain and are closely associated with nociception.[33] Self-compassion is believed to be associated with the ability to flexibly adjust physiological and psychological responses to stress.[32,50] A line of evidence has demonstrated a buffering effect of self-compassion on physiological (eg, cortisol, plasma concentrations of interleukin-6) and emotional (eg, anxiety, negative affect) responses to stress.[2,9,10,39] Moreover, self-compassion is associated with increased heart rate variability (HRV) in the context of a stress, in which HRV, especially high-frequency HRV (HF-HRV), is thought to reflect parasympathetic activity.[3,32] As pain is a typical stressor, HF-HRV may provide a means by which self-compassion modulates the autonomic component of pain to reduce pain perception.

The current study was designed to investigate the effects and mechanisms of self-compassion on pain experience. Using a ''compassionate self-talk" protocol,[26,42] participants were asked to cope with experimentally-induced pain with self-kindness, common humanity and acceptance of self. Electrocardiogram (ECG) was recorded to evaluate HF-HRV. We hypothesized that self-compassion would result in decreased self-reported pain and increased HF-HRV. Findings from the experimental and mechanistic perspectives would refine our knowledge of the analgesic properties of self-compassion and potentially provide insights on compassion-focused strategies in chronic pain.

Methods

Participants

Thirty healthy, pain-free, right-handed adults participated in this study. In order to reduce expectancy effects, participants were told that the aim of the study is to examine heartbeat response to cold water. One participant withdrew as not being able to tolerate the 3-minute cold pain. Data from 29 participants were therefore analyzed (15 males and 14 females, age range: 19 to 27 years, mean = 19.93, SD = 1.60). Exclusion criteria included use of psychoactive medication, or a history or current diagnosis of a psychiatric disorder, as assessed by the Mini International Neuropsychiatric Interview.[48] All study participants provided informed consent and the experiment was approved by the Ethics Committee in the China West Normal University. This study was conducted in accordance with the Declaration of Helsinki.

Experimental Design and Procedure

Participants recruited to this study underwent a single-session, within-subject design protocol. The within-subject variable included 1) self-compassion, and 2) control condition. In total 2 condition orders were created, which was randomized across participants with 15 participants allocated to each order. Gender in each order was also carefully considered in a way that each order included 7 or 8 participants of each gender.

Following consent, participants were asked to generate 4 self-compassion statements (see below Section "*Self-compassion and Control Statements*"). Participants were then setup with the ECG recording system. Next, participants underwent the self-compassion (or control) manipulation using the compassionate statements generated by themselves earlier (or control statements), which was then followed by a 3-minute cold pain exposure (see below Section "*Pain Stimulation*"). Participants were asked to rate pain intensity at 30 second intervals during cold pain.

Self-Compassion and Control Statements

Previous studies have experimentally manipulated self-compassion when faced with life stress using a compassionate self-talk protocol.[26,42] In this protocol participants were instructed to generate compassionate sentences to console a significant other who is dealing with a negative life event.[42] The idea here is that individuals may generate their ''own" or familiar compassionate statements which may in turn promote self-compassion when they faced with a life stressor. This protocol was adapted in the current study to manipulate self-compassion in the experience of pain. The specific instructions were as follows:

> *"I am now going to ask you to imagine that one of your dearest friends is experiencing cold pain. His or her hand is immersed in cold water below zero degree. The painful feelings are very strong and he or she cannot tolerate and therefore feels bad about him/herself. Please write four sentences that you would use to soothe and encourage him/her, and that express compassion, understanding, and unconditional acceptance for your friend. Please limit each sentence to fifteen words."*

A series of 4 control statements were used in this study, which were: "A bird is flying over the roof," "The store is selling fruits," "A TV series is on air," and "The water level is higher after a rain."

Experimental Protocol

Prior to painful stimulation, participants exposed the hands in the air for at least 10 minutes to control baseline temperature. As shown in Fig 1A, participants first relaxed for 3 minutes while watching a fixation cross (PowerPoint, Microsoft Corporation). The presentation computer then displayed 1 self-compassion (or control) statement for 10 seconds, during which participants

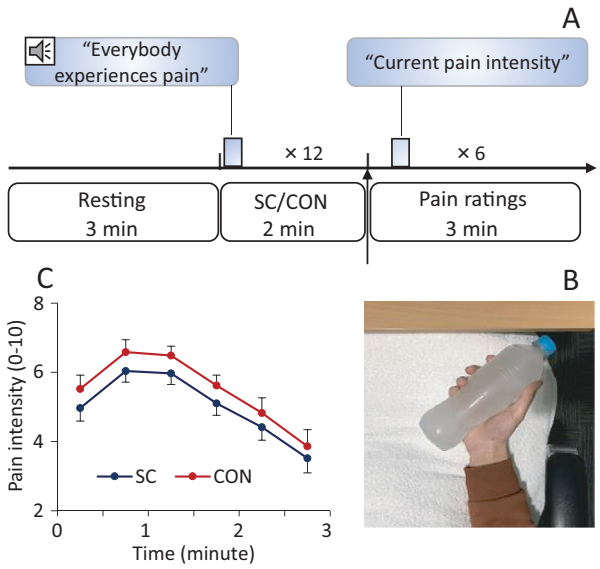

Figure 1. Experimental procedure, pain delivery and ratings. (**A**) Experimental procedure. An example self-compassion statement was presented. (**B**) Pain stimulation. (**C**) Dynamic changes in pain intensity during painful stimulation. Data points indicate group mean pain intensity, error bars represent standard error of the mean (SEM). SC and CON denote self-compassion and control condition respectively.

were asked to read the statement out once. These 2 conditions were performed separately in a single testing session. The self-compassion (or control) manipulation lasted for 2 minutes in which the 4 statements were repeated 3 times with randomized sequence. A reminder then popped out for 10 seconds which asked the participants to hold a bottle filled with iced water using the dominant hand (Fig 1B). A 3-minute cold pain was divided into 6 consecutive 30 second blocks. In a 30 second block, participants viewed a fixation cross for 25 seconds and then rated "pain intensity at the moment" on a scale of 0 to 10 (0 = no pain; 10 = worst pain imaginable) in 5 seconds. Participants wrote the pain ratings on a piece of paper that could not be seen by the experimenter to avoid socially desirable behaviour.[34] In the end of each trial, participants dried the dominant hand with tissues and took break for 10 minutes. In order to control the carry-over effects by last experimental condition, participants were asked to sketch a house image during the 10-minute break. The house image was complex, and the participants were told to sketch as many details as they can. All participants used up the 10-minute break for sketching.

Pain Stimulation

A recent study has demonstrated that an iced bottle can induce ongoing cold pain.[18] In the current study, participants were asked to hold a .5 L plastic bottle with iced water (−1 °C ± .2 °C) with the dominant hand for 3 minutes (Fig 1B). Participants were told to put the volar surface of the dominant hand on the surface of the bottle, and not to squeeze or avoid it, to minimize the variability of touching. A fresh iced bottle was used in next experimental condition for consistency.

ECG Recording

ECG was recorded using a BITalino (r)evolution Board Kit BT (BITalino, Portugal) (http://bitalino.com/en/). Three Ag/AgCl electrodes were used, with 2 electrodes being attached to the bilateral clavicle area within the rib cage respectively and 1 electrode to the lower edge of left rib cage. Data were recorded with OpenSignals (r)evolution software (v.2017, BITalino, Portugal) in the sampling rate of 1,000 Hz.

Data Analysis

Self-compassion statements post manipulation were coded. Two experimenters (X.L. and J.L.) independently counted the number of each self-compassion dimensions[35,36] from the 4 statements provided by the participants. Discrepancies between the reviewers were solved by consensus.

ECG data during the pain protocol were analyzed as illustrated in Fig 2. The R points were identified from the QRS complex using the Pan-Tompkins algorithm (Fig 2A).[40] Artefacts were visually checked and edited according to published guidelines.[6] The R-R-Intervals were then derived and linearly interpolated to 4 Hz to obtain evenly sampled signals (Fig 2B).[41,51] Interpolated R-R-Interval wave was detrended using a highpass filter with the cutoff frequency of .02 Hz[41] (Fig 2C). Thereafter, HRV was calculated using the time-varying autoregressive (TVAR) model which can capture the dynamics of HRV[8] (Fig 2D). In particular, the TVAR model is able to provide smooth spectral components and accurate estimation of the power spectrum.[7,8] It has been used in the investigation of beat-to-beat spectra during ongoing pain.[41] The model order was set to 12 according to the literature.[7] HF-HRV was expressed as the relative value of high frequency component (.15−.4 Hz) in proportion to the total power minus the very low frequency component (0−.04 Hz).[13] Relative values of HF-HRV emphasize the controlled and balanced behavior of the sympathetic and parasympathetic branch of the ANS.[13] In order to coincide with the dynamics of pain ratings, HF-HRV waves were averaged to 6 bins in the same time range of pain ratings (ie, 6 bins at 30 second intervals).

Statistical Analyses

A series of tests were performed to check the assumptions of using a repeated measures 2-way ANOVA. Specifically, the normality and sphericity were checked using the Shapiro-Wilk test and the Mauchly's Test of Sphericity respectively on pain ratings and HF-HRV data in different combinations of our 2 factors (ie, condition and time). For HF-HRV data, either assumption of normality ($P_s > .05$) or sphericity ($P_s > .05$) was violated. For pain ratings, each combination of the related factors was normally distributed ($P_s > .05$) but the assumption of sphericity was violated ($P_s < .05$). Therefore, adjusted results from the Greenhouse-Geisser test were reported for pain ratings.

Using SPSS (version 23; IBM Corp, Armonk, New York), a repeated measures 2-way ANOVA was performed to examine the effects of condition and time, and their

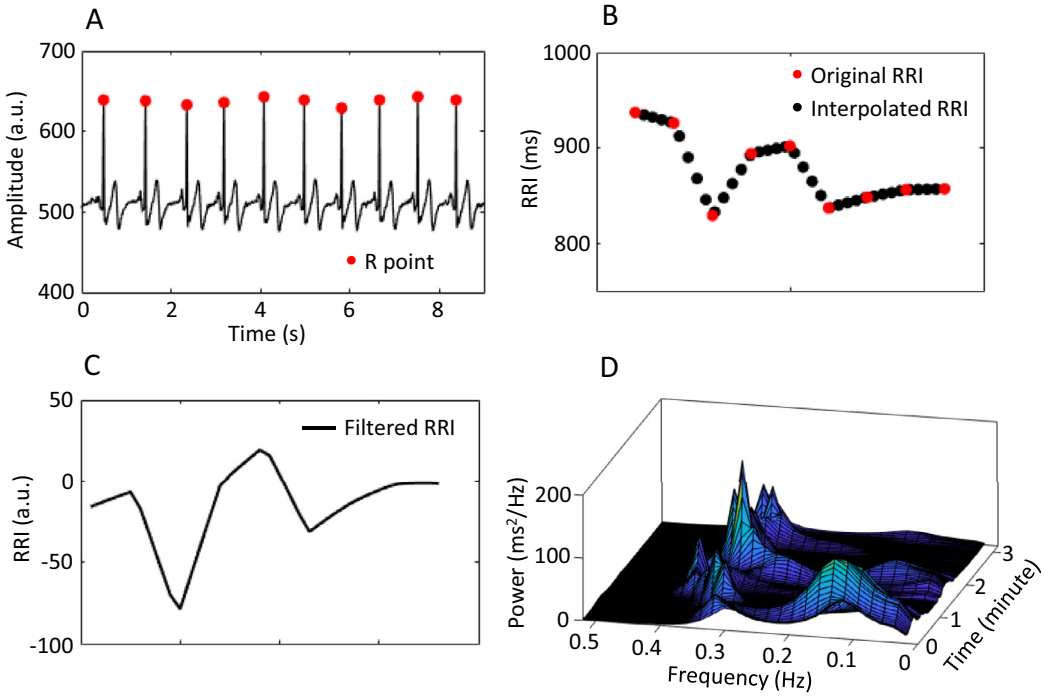

Figure 2. Analysis procedure of HF-HRV. For detail information please refer to the *Methods* section.

interaction on pain ratings. Condition (self-compassion, control) and time (6 time points at 30 seconds interval) were specified as the 2 repeated measures factors. Post-hoc pairwise comparisons were conducted to further explore the significant main and interaction effects, with a Bonferroni correction and α-level set to .05. The contrast types were set to ''polynomial" which is suitable for within-subject factors and compares the linear effect, quadratic effect, cubic effect, and so on.[27] See *Supplementary Material* for the syntax.

HF-HRV was examined using a repeated measures 2-way ANOVA. Condition (self-compassion, control) and time (6 time points at 30 seconds interval) were specified as the 2 repeated measures factors. Post hoc comparisons were performed with Bonferroni correction, and the α-level was set to .05. The contrast types were also set to ''polynomial."

A series of correlation analyses were performed to investigate the association between pain changes and HRV changes. Specifically, area under the curve (AUC) of pain and HRV during the 3-minute pain were calculated with the linear trapezoidal rule. The AUC approach was employed as it provides a summary measure of the pain or HRV dynamics across a specific time window. AUC changes in HRV across conditions were than derived and correlated to AUC changes in pain.

Supplementary Analyses

Although we have carefully randomized condition orders across participants and genders, supplementary analyses were further performed to test the effect of condition order. Specifically, analysis of covariance was performed on pain ratings and HF-HRV data separately, with condition order being specified as the covariate (1 = ''self-compassion→control"; 0 = ''control→self-compassion").

Results

Self-Compassion Statements

Among the 4 trials to generate a self-compassion statement, 93.11% of the participants generated 4 self-compassion statements, with the rest (6.89%) generating 3 self-compassion statements. A further analysis showed that these self-compassion statements spread across all the 3 dimensions of self-compassion (mindfulness: 33.30%; self-kindness: 38.60%; common humanity: 28.10%). These findings indicated the effectiveness of the compassionate self-talk protocol. Examples of self-compassion statements were: "I think you are good enough"; "I understand your pain"; "Everybody experiences pain."

Pain Ratings

As shown in the Fig 1C, the ANOVA revealed a significant main effect of condition for pain ratings ($F_{1,28} = 9.59$, $P = .004$, $\eta_p^2 = .26$). Post-hoc pairwise comparison indicated that pain was lower ($P_{Bonf} = .004$) in the self-compassion compared to the control condition. The ANOVA also revealed a main effect of time ($F_{5,140} = 13.23$, $P = .001$, $\eta_p^2 = .32$). Post-hoc pairwise comparisons showed that, across conditions, pain intensity increased from the start to the end of the first minute ($P_{Bonf} = .002$), which then kept decreasing till the end of the trial ($P_{Bonf} = .001$).

Heart Rate Variability

As shown in the Fig 3, the time-frequency maps revealed more HF-HRV in the self-compassion (Fig 3A) relative to the control condition (Fig 3B). The ANOVA

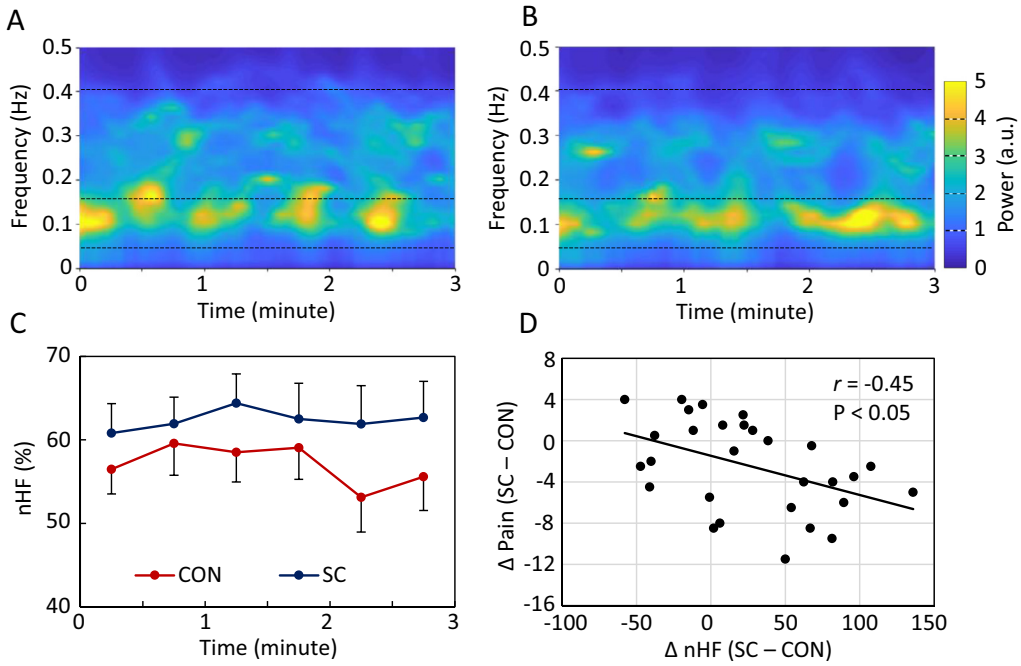

Figure 3. Changes in HF-HRV across the pain induction. **(A)**–**(B)** Show the time-frequency maps of frequency-based HRV in the self-compassion and control condition respectively. Dashed lines indicate the boundaries of very low (0–.04 Hz), low (.04–.15 Hz), and high (.15–.4 Hz) frequency component. **(C)** Self-compassion had higher HF-HRV than the control condition. **(D)** Increased HF-HRV was associated with less pain in the self-compassion relative to the control condition. SC and CON denote self-compassion and control condition respectively. nHF denotes normalized HF-HRV.

revealed a significant main effect of condition for HF-HRV ($F_{1,28} = 8.84$, $P = .006$, $\eta_p^2 = .24$), and the Post-hoc pairwise comparison indicated that HF-HRV was higher ($P_{Bonf} = .006$) in the self-compassion compared to the control condition (Fig 3C). No main effect of time or condition × time interaction effect was observed ($P_s > .05$).

Correlation Analyses

Increased HF-HRV was associated with lower pain in the self-compassion compared to the control condition ($P = .015$; Fig 3D).

Supplementary Results

In the exploration of condition order effect, analysis of covariances revealed no main effect ($P_s > .05$) or any interaction effect ($P_s > .05$) of condition order.

Discussion

Using a compassionate self-talk protocol, this study was designed to investigate the effects and mechanism of self-compassion on pain experience. Our results demonstrated that participants could successfully generate self-compassion statements using the self-talk protocol. Our behavioral data showed lower pain ratings in the self-compassion relative to the control condition. Moreover, self-compassion increased HF-HRV in the experience of pain, which was further associated with lower pain ratings.

Our results indicated that participants could successfully generate compassionate statements that were then used prior to painful administration. Moreover, the compassionate statements spread across the 3 dimensions of self-compassion. A previous study used a self-report measure to evaluate postmanipulation state self-compassion.[42] In this study, we carefully coded the statements provided by the participants, which indicated the efficacy of the protocol in generating compassionate statements. Using compassionate self-talk, one could become aware of the emotional tone of their ''internal dialogue'' in face with pain, and consciously treat his/herself with kindness, acceptance, and a sense of common humanity.[42] This pattern of positive mindset may have an impact on both the subjective pain experience as well as the autonomic component of pain (discussed below).

Our data demonstrated lower pain ratings in the self-compassion compared to the control condition (Fig 1C). Previous studies have used correlational, questionnaire-based designs to reveal the benefits of self-compassion on pain experience.[5,15,20,46,56] Our results further indicated the analgesic properties of self-compassion by experimentally manipulating self-compassion. This is consistent with a recent study which found a positive association between experimentally-induced self-compassion and psychological well-being in chronic pain population.[44] Beyond these findings, our data demonstrated unique changes in pain intensity ratings, whereby the literature has shown consistent relevance in emotional or psychological well-being (eg, pain catastrophizing, rumination).[20,44,46] Overall, our results provide the first line of evidence that a short period of compassionate self-talk may be sufficient to reduce experimental pain.

Self-compassion also resulted in increased HF-HRV compared to the control condition (Fig 3A–C). A line of evidence, including 1 study from our group, has demonstrated the positive association between self-compassion and HRV.[32,50] Moreover, a brief training in self-compassion increased HRV in the experience of social evaluative stressors.[2] Although these studies have used different measures of HRV, ie, the root mean square of successive differences,[32,50] respiratory sinus arrhythmia,[2] and HF-HRV in our data, they are all closely and strongly associated with cardiac vagal tone (ie, parasympathetic tone).[29] Increased HF-HRV in the self-compassion condition may indicate better bodily control over pain-related arousal. This is further supported by the correlation between increased HF-HRV and lower pain ratings in the self-compassion relative to the control condition (Fig 3D). Our data therefore present evidence that self-compassion may reduce pain experience by modulating the autonomic component of pain.

However, our findings did not rule out the possibility that self-compassion reduces pain through other mechanisms (discussed below), which is then associated with increased HF-HRV. It is difficult to fully isolate the autonomic and the perceptual component of pain, future studies using more delicate designs would be able to provide valuable information on the causal relationship between self-compassion, HF-HRV, and pain.

The literature also suggests some adaptive coping strategies to link or mediate the influence of self-compassion on pain experience. In the literature of stress and health, emotion regulation and cognitive reconstructing were demonstrated to mediate the benefits of self-compassion on mental health.[1,21,24,28,49] Moreover, a short course of self-compassion intervention was able to increase healthy self-regulation (eg, healthy impulse-control, reductions in self-judgment) and emotional well-being.[22] However, to our knowledge, no study has identified the mediating impact of adaptive coping in the influence of self-compassion on pain experience. Moreover, a larger body of research has identified the influence of distraction on pain reduction.[11,43,47] It is possible that the self-compassion statements were more distracting than the control statements in the current investigation that modulated the effects of self-compassion on pain ratings and HF-HRV. In addition, there is no evidence surrounding the neural (eg, blood oxygenation level dependent, BOLD) or endocrine (eg, oxytocin) activities that may mediate the impact of self-compassion on pain. Findings in these avenues may refine our knowledge of the benefits of self-compassion in chronic pain populations.

Findings in the current study may have implications for pain coping. Our results indicate that a short period of compassionate self-talk is sufficient to reduce pain. This finding suggests that one could change the mindset in a more compassionate fashion toward him/herself in the experience of pain procedures, eg, a dental procedure. Moreover, it provides empirical evidence for the development of compassionate interventions in the management of chronic pain.[14,16] Using HRV, we also demonstrate that bodily control over arousal is potentially one of the mechanisms underpinning the analgesic influence of self-compassion. Future compassionate interventions could incorporate elements to manage bodily arousal in chronic pain populations. Beyond pain coping, our results also indicate the relevance and significance of self-compassion in the management of life stress, eg, examination stress, public speaking anxiety.

There are some strengths in the research methods. We used an ongoing pain protocol that allowed to evaluate the dynamic modulation of pain by self-compassion. Our results indicated that the analgesic properties of self-compassion tended to be independent of the phases of pain. Similarly, HF-HRV was calculated using the TVAR model which can capture the dynamics of HRV compared to the traditional fast Fourier transform models.[8,41] We also used a distraction task to avoid carry-over effects between experimental conditions. There are also some limitations in the study. We presented findings in healthy participants, which may have limitations in translating our findings to chronic pain populations in which psychological functioning has undergone significant changes.[25,55] Although we presented reduced pain ratings that may be considered as a large effect size ($\eta_p^2 = .26$),[19] the reported effect size reflects the sample used. A different sample could produce a different effect size estimate. We also used a convenient, relatively small sample that consists of young adults, results of which needed to be further validated in a larger sample with a wider age range. It is noted that bottled iced water was used to induce ongoing pain in the current investigation, compared to previous studies which used a tank filled with cold water.[12,23] One limitation of bottled iced water is the condensation on the surface of the bottle. But we have tried to carefully control this by using a fresh bottle before each condition and precisely controlling the timing to bring out the bottle from the freezer. Therefore, it is not expected to induce different pain across conditions in a systematic fashion in our data. A recent study has also demonstrated the effectiveness of bottle iced water in inducing pain.[18] In addition, general positive emotions may have influenced the effects of self-compassion on pain ratings and HF-HRV. Although we have controlled the length and use of plain language in the self-compassion and control statements, it is expected that compassionate statements may induce positive emotions compared to the control statements. Future studies may wish to include a general positive condition to examine the specificity of our findings and the possibility that positive emotion may mediate or modulate the influence of self-compassion on pain perception and autonomic component. We have also presented results in an Asian culture, and future studies may wish to replicate these findings in western cultures as there may be cultural differences in self-compassion.[37]

To conclude, a short period of compassionate self-talk may be sufficient to reduce experimentally-induced pain. We also present evidence of a potential mechanism underlying the analgesic effect of self-compassion, which is increased HF-HRV that indicates bodily control

over pain-related arousal. Findings in the study support the potential role of self-compassion in the management of pain.

References

1. Allen AB, Leary MR: Self–compassion, stress, and coping. Soc Personal Psychol Compass 4:107-118, 2010

2. Arch JJ, Brown KW, Dean DJ, Landy LN, Brown KD, Laudenslager ML: Self-compassion training modulates alpha-amylase, heart rate variability, and subjective responses to social evaluative threat in women. Psychoneuroendocrinology 42:49-58, 2014

3. Arch JJ, Landy LN, Schneider RL, Koban L, Andrews-Hanna JR: Self-compassion induction enhances recovery from social stressors: comparing adults with social anxiety disorder and healthy controls. Anxiety Stress Coping 31:594-609, 2018

4. Barlow MR, Turow REG, Gerhart J: Trauma appraisals, emotion regulation difficulties, and self-compassion predict posttraumatic stress symptoms following childhood abuse. Child Abuse Negl 65:37-47, 2017

5. Barnes A, Adam ME, Eke AO, Ferguson LJ: Exploring the emotional experiences of young women with chronic pain: the potential role of self-compassion. J Health Psychol, 2018. https://doi.org/10.1177/1359105318816509

6. Berntson GG, Thomas Bigger J, Eckberg DL, Grossman P, Kaufmann PG, Malik M, Nagaraja HN, Porges SW, Saul JP, Stone PH: Heart rate variability: origins, methods, and interpretive caveats. Psychophysiology 34:623-648, 1997

7. Bianchi AM, Mainardi L, Petrucci E, Signorini MG, Mainardi M, Cerutti S: Time-variant power spectrum analysis for the detection of transient episodes in HRV signal. IEEE Trans Biomed Eng 40:136-144, 1993

8. Bianchi AM, Mainardi LT, Cerutti S: Time-frequency analysis of biomedical signals. Trans Inst Meas Control 22:215-230, 2000

9. Bluth K, Roberson PN, Gaylord SA, Faurot KR, Grewen KM, Arzon S, Girdler SS: Does self-compassion protect adolescents from stress? J Child Fam Stud 25:1098-1109, 2016

10. Breines JG, Thoma MV, Gianferante D, Hanlin L, Chen X, Rohleder N: Self-compassion as a predictor of interleukin-6 response to acute psychosocial stress. Brain Behav Immun 37:109-114, 2014

11. Brooks JC, Nurmikko TJ, Bimson WE, Singh KD, Roberts N: fMRI of thermal pain: Effects of stimulus laterality and attention. NeuroImage 15:293-301, 2002

12. Brown JL, Sheffield D, Leary MR, Robinson ME: Social support and experimental pain. Psychosom Med 65:276-283, 2003

13. Cardiology: Heart rate variability: Standards of measurement, physiological interpretation, and clinical use. Circulation 93:1043-1065, 1996

14. Carson JW, Keefe FJ, Lynch TR, Carson KM, Goli V, Fras AM, Thorp SR: Loving-kindness meditation for chronic low back pain: results from a pilot trial. J Holist Nurs 23:287-304, 2005

Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jpain.2019.11.006.

15. Carvalho SA, Gillanders D, Palmeira L, Pinto–Gouveia J, Castilho P: Mindfulness, selfcompassion, and depressive symptoms in chronic pain: the role of pain acceptance. J Clin Psychol 74:2094-2106, 2018

16. Chapin HL, Darnall BD, Seppala EM, Doty JR, Hah JM, Mackey SC: Pilot study of a compassion meditation intervention in chronic pain. J Compass Health Care 1:e4, 2014

17. Che X, Cash R, Fitzgerald P, Fitzgibbon BM: The social regulation of pain: autonomic and neurophysiological changes associated with perceived threat. J Pain 19:496-505, 2017

18. Che X, Cash R, Chung S, Bailey N, Fitzgerald PB, Fitzgibbon BM: The dorsomedial prefrontal cortex as a flexible hub mediating behavioral as well as local and distributed neural effects of social support context on pain: a theta burst stimulation and TMS-EEG study. NeuroImage, 2019. https://doi.org/10.1016/j.neuroimage.2019.116053

19. Cohen J: Statistical Power Analysis for the Behavioral Sciences. Hilsdale, Lawrence Earlbaum Associates, 1988

20. Costa J, Pinto–Gouveia J: Experiential avoidance and self–compassion in chronic pain. J Appl Soc Psychol 43:1578-1591, 2013

21. Diedrich A, Burger J, Kirchner M, Berking M: Adaptive emotion regulation mediates the relationship between self–compassion and depression in individuals with unipolar depression. Psychol Psychother-T 90:247-263, 2016

22. Dundas I, Binder PE, Hansen TG, Stige SH: Does a short self–compassion intervention for students increase healthy self–regulation? A randomized control trial. Scand J Psychol 58:443-450, 2017

23. Edwards R, Eccleston C, Keogh E: Observer influences on pain: An experimental series examining same-sex and opposite-sex friends, strangers, and romantic partners. Pain 158:846-855, 2017

24. Finlay-Jones AL, Rees CS, Kane RT: Self-compassion, emotion regulation and stress among Australian psychologists: testing an emotion regulation model of self-compassion using structural equation modeling. PLoS One 10: e0133481, 2015

25. Gatchel RJ, Peng YB, Peters ML, Fuchs PN, Turk DC: The biopsychosocial approach to chronic pain: Scientific advances and future directions. Psychol Bull 133:581-624, 2007

26. Gilbert P: Compassion Focused Therapy: Distinctive Features. London, Routledge, 2010

27. IBM Knowledge Center. 2013. Available at: https://www.ibm.com/support/knowledgecenter/SSLVMB_23.0.0/spss/advanced/syn_glm_repeated_measures_contrasts_wsfactor.html

28. Inwood E, Ferrari M: Mechanisms of change in the relationship between self–compassion, emotion regulation, and mental health: a systematic review. Appl Psychol Health Well Being 10:215-235, 2018

29. Koenig J, Jarczok MN, Ellis RJ, Hillecke T, Thayer JF: Heart rate variability and experimentally induced pain in healthy adults: A systematic review. Eur J Pain 18:301-314, 2014

30. Kyeong LW: Self-compassion as a moderator of the relationship between academic burn-out and psychological health in Korean cyber university students. Pers Individ Dif 54:899-902, 2013

31. Leary MR, Tate EB, Adams CE, Batts Allen A, Hancock J: Self-compassion and reactions to unpleasant self-relevant events: The implications of treating oneself kindly. J Pers Soc Psychol 92:887-904, 2007

32. Luo X, Qiao L, Che X: Self-compassion modulates heart rate variability and negative affect to experimentally induced stress. Mindfulness 9:1522-1528, 2018

33. Melzack R, Casey KL: Sensory, motivational and central control determinants of pain: A new conceptual model, in Kenshalo D, (ed): The Skin Senses, Springfield, C C Thomas, 1968, pp 423-443

34. Modić Stanke K, Ivanec D: Social context of pain perception: The role of other people's presence and physical distance. Review Psychol 17:69-74, 2010

35. Neff K: The development and validation of a scale to measure self-compassion. Self Identity 2:223-250, 2003

36. Neff K: Self-compassion: an alternative conceptualization of a healthy attitude toward oneself. Self Identity 2:85-101, 2003

37. Neff KD, Pisitsungkagarn K, Hsieh Y-P: Self-compassion and self-construal in the United States, Thailand, and Taiwan. J Cross Cult Psychol 39:267-285, 2008

38. Nickel MM, May ES, Tiemann L, Postorino M, Dinh ST, Ploner M: Autonomic responses to tonic pain are more closely related to stimulus intensity than to pain intensity. Pain 158:2129-2136, 2017

39. Pace TW, Negi LT, Adame DD, Cole SP, Sivilli TI, Brown TD, Issa MJ, Raison CL: Effect of compassion meditation on neuroendocrine, innate immune and behavioral responses to psychosocial stress. Psychoneuroendocrinology 34:87-98, 2009

40. Pan J, Tompkins WJ: A real-time QRS detection algorithm. IEEE Trans Biomed Eng 32:230-236, 1985

41. Peng R-C, Yan W-R, Zhou X-L, Zhang N-L, Lin W-H, Zhang Y-T: Time-frequency analysis of heart rate variability during the cold pressor test using a time-varying autoregressive model. Physiol Meas 36:441-452, 2015

42. Petrocchi N, Ottaviani C, Couyoumdjian A: Compassion at the mirror: exposure to a mirror increases the efficacy of a self-compassion manipulation in enhancing soothing positive affect and heart rate variability. J Posit Psychol 12:525-536, 2017

43. Petrovic P, Petersson KM, Ghatan P, Stone-Elander S, Ingvar M: Pain-related cerebral activation is altered by a distracting cognitive task. Pain 85:19-30, 2000

44. Purdie F, Morley S: Self-compassion, pain, and breaking a social contract. Pain 156:2354-2363, 2015

45. Purdie F, Morley S: Compassion and chronic pain. Pain 157:2625-2627, 2016

46. Santerre-Baillargeon M, Rosen NO, Steben M, Pâquet M, Macabena Perez R, Bergeron S: Does self-compassion benefit couples coping with vulvodynia? Associations with psychological, sexual, and relationship adjustment. Clin J Pain 34:629-637, 2018

47. Seminowicz D, Mikulis D, Davis K: Cognitive modulation of pain-related brain responses depends on behavioral strategy. Pain 112:48-58, 2004

48. Sheehan D, Lecrubier Y: MINI SCREEN 5.0.0/English version/DSM-IV July/1/06. Florida, University of South Florida-TAMPA, 2001

49. Sirois FM, Molnar DS, Hirsch JK: Self-compassion, stress, and coping in the context of chronic illness. Self Identity 14:334-347, 2015

50. Svendsen JL, Osnes B, Binder P-E, Dundas I, Visted E, Nordby H, Schanche E, Sørensen L: Trait self-compassion reflects emotional flexibility through an association with high vagally mediated heart rate variability. Mindfulness 7:1103-1113, 2016

51. Terkelsen AJ, Mølgaard H, Hansen J, Andersen OK, Jensen TS: Acute pain increases heart rate: differential mechanisms during rest and mental stress. Auton Neurosci 121:101-109, 2005

52. Terry ML, Leary MR, Mehta S: Self-compassion as a buffer against homesickness, depression, and dissatisfaction in the transition to college. Self Identity 12:278-290, 2013

53. Tiemann L, Hohn VD, Dinh ST, May ES, Nickel MM, Gross J, Ploner M: Distinct patterns of brain activity mediate perceptual and motor and autonomic responses to noxious stimuli. Nature Commun 9:e4487, 2018

54. Treister R, Kliger M, Zuckerman G, Aryeh IG, Eisenberg E: Differentiating between heat pain intensities: The combined effect of multiple autonomic parameters. Pain 153:1807-1814, 2012

55. Turk DC, Okifuji A: Psychological factors in chronic pain: evolution and revolution. J Consult Clin Psychol 70:678-690, 2002

56. Wren AA, Somers TJ, Wright MA, Goetz MC, Leary MR, Fras AM, Huh BK, Rogers LL, Keefe FJ: Self-compassion in patients with persistent musculoskeletal pain: Relationship of self-compassion to adjustment to persistent pain. J Pain Symptom Manag 43:759-770, 2012

57. Zhang Y, Luo X, Che X, Duan W: Protective effect of self-compassion to emotional response among students with chronic academic stress. Front Psychol 7: e1802, 2016