The effects of expressive writing before or after punch biopsy on wound healing

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Abstract

Objective: Recent studies have shown that written emotional disclosure (expressive writing) performed in the two weeks prior to wounding improves healing of punch biopsy wounds. In many clinical settings, it would be more practical for patients to perform this intervention after wounding. The aim of this study was to investigate whether expressive writing could speed the healing of punch biopsy wounds if writing was performed after wounds were made.

Methods: One hundred and twenty-two healthy participants aged between 18 and 55 years were randomly allocated to one of four groups in a 2 (intervention) by 2 (timing) design. Participants performed either expressive writing or neutral writing, either before or after receiving a 4mm punch biopsy wound. Wounds were photographed on day 10 (primary endpoint) and day 14 after the biopsy to measure epithelisation. Participants also completed questionnaires on stress and affect two weeks prior to the biopsy, on the day of biopsy and two weeks after biopsy.

Results: There was a significant difference in healing at day 10 between groups, $\chi^2(3, N = 97) = 8.84$, $p = .032$. A significantly greater proportion of participants who performed expressive writing before the biopsy had fully reepithelialised wounds on day 10 compared to participants who performed neutral writing either before or after wounding, with no other significant differences between groups. Amongst people who wrote expressively after wounding, those who finished writing over the first 6 days were significantly more likely to be healed at 14 days than those who finished writing later. There were significant differences in positive and negative affect over the healing period between the pre and post expressive writing groups.

Conclusions: Expressive writing can improve healing if it is performed prior to wounding. Performing expressive writing after wounding may be able to improve healing depending on the timing of writing and wound assessment. Expressive writing causes affect to worsen followed by a subsequent improvement in affect and it is important to consider this in the timing of intervention delivery. Further research with patient groups is required to determine the clinical relevance of these findings.

Keywords: Biopsy, wound healing, expressive writing, timing, affect

1. Introduction

Psychological stress can negatively influence wound healing in both healthy and clinical populations (Walburn, Vedhara, Hankins, Rixon & Weinman, 2009). Stress has been shown to impair the healing of small punch biopsy and blister wounds, as well as slow recovery of skin barrier function after experimental wounds have been created (for example, Altemus et al., 2001; Kiecolt-Glaser, Marucha, Mercado, Malarkey & Glaser, 1995; Kiecolt-Glaser et al., 2005; Marucha, Kiecolt-Glaser & Favagehi, 1998; Muizzuddin, Matsui, Marenus & Maes, 2003). In addition, stress has been observed to impair the healing of surgical and chronic wounds (Broadbent, Petrie, Alley & Booth, 2003; King & Harding, 2001; Maple et al., 2015).

There is initial evidence that psychological interventions can improve wound healing. Written emotional disclosure (also known as expressive writing) involves writing emotionally about past traumatic events. It is thought that writing about stressful or traumatic events and upsetting emotions can help a person process the event, which in turn can decrease stress and rumination (Pennebaker, 1997). Expressive writing has been shown to have beneficial effects on the healing of punch biopsy wounds compared to writing factually about a neutral topic (Weinman, Ebrecht, Scott, Walburn and Dyson, 2008; Koschwanez et al., 2013). Consistent with these studies, a systematic review showed that emotional disclosure has significant effects on immune parameters (Frattaroli, 2006). Researchers have suggested that expressive writing may be useful for patients who have clinical wounds (Weinman et al, 2008).

An important consideration in the translation of this laboratory-based research to clinical populations is the timing of intervention delivery. The previous two studies on emotional disclosure and wound healing both administered the intervention two weeks prior to wounding with instructions to write over the following three consecutive days (Weinman et al., 2008; Koschwanez et al., 2013). However, administering a writing intervention prior to surgery may be impractical in some situations, such as when emergency surgery is performed, when the date of surgery is

scheduled at late notice or surgery is postponed. In the case of chronic wounds, the wound would already have been present for a considerable amount of time. In these situations, it would be more practical for patients to perform expressive writing after the wound has occurred. It is therefore important to investigate whether expressive writing can improve healing when performed after wounding. Previous research indicates that other mind body interventions, such as hypnosis, when performed after surgery can have positive effects on wound healing (Ginandes, Brooks, Sando, Jones & Aker, 2003).

To date only one study has explored whether altering the timing of a psychological intervention has differential effects on wound healing (Robinson, Jarrett & Broadbent, 2015). During this exploratory study participants underwent a tape stripping procedure, designed to damage the skin on the forearm. Participants were randomized to one of three conditions: relaxation for 20 minutes immediately prior to skin damage, relaxation for 20 minutes immediately after skin damage or no relaxation. Participants in the two relaxation conditions had faster skin barrier recovery than the no-relaxation group regardless of whether they did the intervention before or after the tape stripping procedure. This suggests that relaxation can have beneficial effects on healing even if performed after wounding. However, relaxation has immediate effects on physiology (Jacobs, 2001), whereas the beneficial effects of expressive writing may take longer to occur (Pennebaker, 1993). Expressive writing causes a short term increase in distress, negative mood and physical symptoms (Booth, Petrie & Pennebaker, 1997). However, often participants report they feel better and they have physiological improvements in the long term after expressing their problems rather than keeping them bottled up (Murray & Segal, 1994). For example, immediately after expressive writing, patients with rheumatoid arthritis had poorer functioning than a control group, but had significantly better functioning after 3 months. The authors attribute this to the time it takes to process negative events (Kelley, Lumley & Leisen, 1997).

The aim of this study was to compare the effectiveness of an expressive writing intervention performed either pre or post wounding on the healing of punch biopsy wounds. Previous research

found that expressive writing performed prior to wounding significantly improved healing assessed ten to twelve days after the biopsy, and 90% of all wounds were healed by day 14 (Koschwanez et al., 2013). Therefore, the primary endpoint for this study was whether wounds were healed or not at ten days post-biopsy. Wound healing was also assessed at day 14, although it was expected that the majority of wounds would be healed by this time point. It was hypothesized that the expressive writing intervention would improve healing when performed either before or after wounding compared to the control groups performing neutral writing. A secondary aim was to explore how stress and mood differed over the healing period between the groups who performed expressive writing pre or post wounding. It was hypothesised that both intervention groups would experience increased negative affect while writing, and improvements in affect would occur after writing had finished.

2. Methods

2.1. Sample recruitment

Participants were recruited from the local community and university campus through flyers, email and online advertisements. Participants had to be aged between 18 and 55 years and able to give written informed consent. Participants were excluded if they were pregnant, had allergies to local anaesthetic, smoked, had any inflammatory skin diseases, chronic illnesses, immunological-related health problems or were taking medication that affects immune functioning (such as antibiotics or corticosteroids). Ethics approval was obtained from The University of Auckland Human Participants Ethics Committee (UAHPEC). Previous research found the effect of expressive writing on wound healing to be moderate, *Cramer's V* = .35 (Koschwanez et al., 2013). With power set at .80 and a two tailed significance level of $\alpha = .05$, the total sample size required for an ANCOVA analysis with four groups was calculated using G*Power to be 120 (30 participants per group).

2.2. Procedure

Two weeks before the first scheduled appointment, participants were contacted by phone or email and asked to complete a baseline questionnaire online to gather information about

demographics, general health, sleep, stress levels, and affect. Participants were then randomized to one of four groups: expressive writing task pre biopsy, control writing task pre biopsy, expressive writing task post biopsy and control writing task post biopsy. Randomization was performed by a person uninvolved in this project using a random number generator. After the participant completed the baseline questionnaire, the researcher opened a sealed opaque envelope revealing which group the participant was allocated to. Those allocated to write pre biopsy were then given the intervention instructions online and asked to complete the writing task over the next three days prior to their clinical appointment 14 days later. Those allocated to write after the biopsy were simply asked to come back in 14 days for the biopsy appointment.

During this appointment a dermatologist performed a 4mm punch biopsy to the upper inner arm 7cm proximal to the medial epicondial of the humerus (inner upper arm). The area was cleaned with an alcohol solution and the tissue was anaesthetized using 1% lignocaine and 1:200,000 adrenaline. Once the wound stopped bleeding it was photographed using an EOS 100D Canon camera (Canon Ltd., Tokyo, Japan) with a Canon Ultrasonic EF 100-mm f/2.8 Macro USM lens and Canon ringflash. In order to calibrate each photograph, the wound was photographed with a standard-sized adhesive dot (1/4-in. diameter; Avery Dennison, Brea, CA). After photography, the dot was removed, and the wound was sealed with DuoDERM Extra Thin hydrocolloid dressing (ConvaTec, Skillman, NJ) and a water-proof plaster (Cutifilm Plus; Smith & Nephew, London, UK). Hydrocolloid dressings have previously been used in wound healing studies to provide a moist wound healing environment (Kiecolt-Glaser et al., 1995, Korting, Schoellmann & White, 2011). This means that there is faster epithelialisation compared with uncovered wounds and the prevention of eschar formation allows for more accurate assessments of wound reepithelialisation. Participants were instructed to keep the underlying dressing on until the next appointment, when the researcher would clean and redress the wound. After the biopsy all participants were asked to complete a second online questionnaire within 24 hours. Those allocated to the post biopsy writing groups were also asked to complete the online writing task over the next three days.

Ten days after the biopsy, all participants were scheduled for a follow-up appointment during which the wound area was gently cleaned with sterile saline and gauze, photographed, and redressed with DuoDERM Extra Thin and a water-proof plaster. Fourteen days after the initial biopsy participants were scheduled to have a final appointment, during which the wound was photographed for the last time. Participants were given a $40 voucher as compensation for their time and were asked to complete a final questionnaire online.

2.3. Expressive writing Intervention

The writing intervention was based on a standardized script used in previous studies (Koshwanez et al., 2013; Pennebaker, 1993; Weinman et al., 2008). Participants in the emotional disclosure groups were asked to write about their "deepest thoughts and feelings about a traumatic, upsetting experience of your entire life." If they did not have a traumatic experience they were instructed to write about a significant life-changing event. Ideally participants were asked to write about something they had not discussed in great detail with anybody else.

Participants in the control groups were asked to write about how they spent their time. For each session they were first asked to write about the past week, then the past 24 hours and finally their plans for the upcoming week. They were specifically instructed to write about the facts, omitting any emotions.

Participants were asked to start writing the next day and to write for 3 consecutive days at home, for 20 minutes a day, without concern for spelling or grammar. Participants were reminded daily by email or text to complete the task each day. They were told that it was alright if they missed a day, but to make sure they wrote the next day instead. Participants used a secure online portal to complete their writing tasks. To ensure anonymity participants used an individual code to log on to the portal and at the end submitted their writing for analysis. Participants were told that their writing would not be read, but analysed by the computer programme (Linguistic Inquiry and Word Count, Pennebaker, Booth & Francis; 2007). This programme automatically categorizes digitized text into multiple psychologically relevant categories (Pennebaker & Francis, 1996). Previous research

has found that expressive writing submitted online is effective (Sheese, Brown & Graziano, 2004). After each writing session, participants were asked to report how much emotion they revealed, ranging from 1 ("not at all") to 5 ("a great deal") (Pennebaker, Colder & Sharp, 1990), as a manipulation check.

2.4. Measures

Participants completed questionnaires at three time points: two weeks prior to the biopsy (baseline), immediately after the biopsy, and 14 days after the biopsy (follow-up). The baseline questionnaire included questions about demographics, health behaviours, sleep, stress and affect. The questionnaires given immediately after the biopsy and at follow-up only included questions on sleep, stress and affect.

2.4.1. Demographic and psychological measures

Participants were asked their age, weight, height, ethnicity and education level. Health behaviour data were collected regarding alcohol consumption, smoking status, exercise regularity, and diet. Alcohol consumption was rated over the past 3 months from 1 (never) to 6 (everyday). On days participants did drink they were asked to rate how many drinks they had ranging from 1 (0 drinks) to 7 (12 or more drinks). Participants were asked to rate how often they did physical activity for 30 minutes over an average week from 1 (never) to 8 (everyday). They were asked to rate their diet over the past week from 1 (very poor) to 5 (very good).

Sleep was assessed using the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman & Kupfer, 1989). The scale consists of 19 questions used to generate seven component scores and an overall global score. The items asked participants to report the time they go to sleep, the time they wake and the amount of sleep they get. They are also asked to rate on a scale from 0 (not at all) to 3 (3 or more times a week) any sleep disturbance over the last month due to commonly experienced problems that disrupt sleep. The scale demonstrated good internal reliability (*Cronbach's* $\alpha = .79$)

The 10 item Perceived Stress Scale (PSS; Cohen & Williamson, 1988) was used to determine how much participants felt their lives were unpredictable, uncontrollable and stressful. Respondents were asked to indicate how often they felt a certain way over the last month on a scale from 0 (never) to 4 (very often). This scale has been found to be reliable and valid previously in student populations (Roberti, Harrington & Storch, 2006). In this study, the scale had good internal reliability (*Cronbach's* α = .85).

Affect was assessed using a modified version of the actual affect subscale of the Affect Valuation Index (AVI; Tsai, Knutson & Fung, 2006). The scale consisted of 25 items designed to measure how much participants were experiencing certain types of affect on a 5-point Likert scale ranging from "not at all" to extremely". In the original wording, participants were asked how they felt over the course of typical week, whereas in this study participants were asked how they felt in the current moment. These modified instructions have been used in previous research and shown to be sensitive to changes in affect over time (Nair, Sagar, Sollers, Consedine & Broadbent, 2015). The scale is comprised of eight factors with three or four items in each factor: high arousal positive affect (HAP; strong, excited, enthusiastic), low arousal positive affect (LAP; calm, relaxed, rested, peaceful), positive affect (PA; happy, content, satisfied), negative affect (NA; sad, lonely, unhappy), high arousal negative affect (HAN; hostile, fearful, nervous), low arousal negative affect (LAN; dull, sleepy, sluggish), low arousal affect (LA; quiet, still, passive) and high arousal affect (HA; aroused, surprised, astonished). This scale has been found to be reliable and valid in different cultures (Tsai, Knutson & Fung, 2006) and in this study had good internal reliability for each subscale (HAP *Cronbach's* α = .80; PA *Cronbach's* α = .81; LAP *Cronbach's* α = .86; LA *Cronbach's* α = 72; LAN *Cronbach's* α = .81; NA *Cronbach's* α = .78; HAN *Cronbach's* α = .71; HA *Cronbach's* α = .82).

2.5. Wound Healing Assessment

The primary outcome for the trial was wound reepithelialisation at 10 days post-wounding. Re-epithelialisation was also assessed 14 days post-wounding. The digital wound photographs were de-identified (i.e., participant ID and time-point information removed from the photographs) and

the order randomized by a computerized random number generator, to ensure that the dermatologist (P.J.) remained blind to group allocation and time since wounding. The dermatologist rated each wound as ‘‘healed’’ or ‘‘not healed”, with healed being defined as complete reepithelialisation of the wound surface. The complete set of photographs was assessed in a standardized fashion in the same setting twice sequentially, to ensure consistency. All the photographs were then reassessed on a different occasion to determine inter-rater reliability. The Cohen *k* coefficient was 0.88, indicating high agreement between the two assessments. Where there was a disagreement, the dermatologist reviewed the photograph again to decide on a final rating. Of the 237 photographs assessed, only 8% (*N* = 20) photographs were inconsistently rated as ‘healed’ or ‘not healed’ and needed to be reassessed for a final decision.

Of the 122 participants who completed the study, 10 people did not complete the writing task properly (told the researcher they typed out a children’s book or completed only one or no writing sessions) and were excluded from all analyses (healing, stress, and affect). A further 3 people were excluded from wound analyses due to allergy to the plaster (*N* = 1), or excessive scabbing from bleeding at the wound site obscuring the photograph (*N* =2). On day 10 a further 12 people were not included in the wound healing analysis because they either missed their appointment (*N* =2), or the camera malfunctioned (*N* =3), or the photo had to be taken early due to a public holiday limiting university access (*N* = 7). On day 14, two people did not have their photograph taken due to camera malfunction. There were no significant differences between groups in the number of people excluded for each reason.

2.6. Data analysis

All data were analysed using the Statistics software package ‘IBM SPSS 19.0 for Windows’. Manipulation checks were conducted using a one-way ANOVA between groups with Bonferroni post-hoc tests for self-reported expressed emotion and LIWC analysis of words used. When data was non parametric Kruskal Wallis *H* tests were performed. Post hoc Mann Whitney U tests were conducted to look at differences between groups. For the main outcome variable $\chi 2$ tests were

performed to compare the association between group allocation and wound healing at both 10 and 14 days. A logistic regression was also performed at day 10. Mixed between-within subjects ANOVA were performed to look at changes over time and between the expressive writing groups on stress and affect. Bonferroni post hoc analyses adjusted for multiple comparisons were performed. Point biserial correlations were used to look at affect and healing outcomes. For all analyses, a two-tailed alpha level of .05 was used.

3. Results

3.1. Participant Attrition and Baseline Characteristics

Of the 196 individuals who responded to the study advertisements, 9 individuals did not meet the inclusion criteria and 12 withdrew from the study before completing the first questionnaire. Another 46 people requested the participant information sheet but were unable to be contacted to book the first biopsy appointment. A further two participants withdrew after completing the baseline questionnaire and the writing tasks. Six participants could not or did not want to complete the study. In total 122 participants completed the study, 30 of whom were randomized to the emotional disclosure writing task pre biopsy, 30 were randomized to the control writing task pre biopsy, 30 were randomized to the emotional disclosure task post biopsy and 32 were randomized to the control writing task post biopsy (Figure 1).

Of the 122 participants, 119 (98%) completed at least one writing task and 112 (93%) completed all three writing tasks and submitted them online through a secure portal. Participants assigned to the writing task prior to the biopsy were asked to start writing the next day, 13 days before the biopsy appointment, however there were some issues with compliance. On average, participants assigned to write before wounding commenced writing 8 days before the biopsy (*SD* = 4.64), with no significant difference in timing between the control and intervention groups. Likewise, there were some compliance issues with participants assigned to write after wounding, who were asked to start the next day after wounding. On average, those assigned to write after wounding commenced writing 3 days after the biopsy (*SD* = 2.32), with no significant difference in timing between the intervention and

control groups. The writing task was completed over 5.98 days on average (*SD* = 3.64), with no significant difference between groups in the number of days over which the writing was completed. Eighty-four (69%) of the 112 participants completed the task over the first 6 days or less as instructed (allowing for one day between writing sessions), with the rest taking 7 or more days to complete the task.

Participant ranged in age from 18 to 41 years (mean = 23.91, *SD* = 6.14). The majority of the sample were female (*N* = 94, 71.8%). Almost half the participants identified themselves as being European (*N* = 73, 55.7%). The rest of the sample identified as being Asian (*N*= 47, 35.9%), Māori or Pacific Island (*N* = 12, 9.2%). Table 1 shows the demographic data and the baseline psychological measures for each group. There were no significant differences between groups on these measures, apart from diet. However, diet was not significantly correlated with healing on Day 10 or Day 14 ($p > .05$)

3.2. Manipulation check

A manipulation check was conducted to see whether the average amount of emotion revealed during writing sessions differed between groups. The results are reported in Table 2. In comparison to the two expressive writing groups, the two groups who wrote about a neutral topic reported that they expressed significantly less emotion in their writing, and LIWC analysis showed that they used significantly fewer affective, cognitive, and insightful words, and fewer personal pronouns. There were no significant differences between the two expressive writing groups in the types of words used. There was no significant difference between groups in the frequency of the words 'biopsy' and 'wound', although participants in the control after group had slightly higher means. This may be because they were asked to write about what they did during the past week and their plans for the upcoming week, which included the receiving the biopsy and attending appointments to get their biopsy dressing changed.

3.3. Primary outcome: Wound reepithelialisation

There was a significant difference in wound healing at day 10 post-biopsy between writing groups, $\chi^2(3, N = 97) = 8.84$, $p = .032$. In comparison to the other three groups, participants in the expressive writing before group had a greater proportion of fully reepithelialised wounds: 52% (12/23) of the group healed compared to 15% (4/26) in the control before group, 23% (6/26) in the control after group and 27% (6/22) in the expressive writing after group; Figure 2). This yielded a medium effect size (*Cramer's V* = 0.30). Column proportion comparisons adjusted for Bonferroni showed that the rate of healing in the expressive writing before group differed significantly from those in both control groups ($p < .05$). Examination of standardised residuals indicated that the high proportion of participants healed in the expressive writing before group (standardised residual = 2.08) contributed to the significant result. The odds of a participant with a healed wound on day 10 were 6.00 times higher if they performed expressive writing before wounding compared to the control writing before wounding group, and 3.64 times higher compared to the control writing after wounding group. A logistic regression showed similar results. The overall model was significant $\chi^2(3, N = 97) = 8.55$, $p = .036$, Nagelkereke's $R^2 = .12$. Participants who wrote expressively before wounding were significantly more likely to be healed than participants who wrote about a neutral topic before wounding ($\beta = 1.79$, $p = .009$), and compared to those who wrote about a neutral topic after wounding ($\beta = 1.29$, $p = .039$). Participants who wrote expressively after wounding showed no significant difference in healing compared to those who wrote expressively before wounding ($\beta = -1.07$, $p = .093$), or compared to those who wrote about the neutral topic either before ($\beta = 0.72$, $p = .318$) or after wounding ($\beta = 0.22$, $p = .738$).

By Day 14, 80% to 90% of participants in each group achieved full wound reepithelialisation and there were no significant differences between groups, $\chi^2(3, N = 107) = .62$, $p = .892$.

3.4. The effects of writing before or after wounding on stress and affect

3.4.1. Stress

We were interested in whether the difference in the timing of the expressive writing intervention differentially affected participants' stress and affect over the wound healing period. There were no significant differences in perceived stress between the expressive writing groups at any time point, so this was not considered further. Similarly, there were there no significant changes in stress over time in the two control groups.

3.4.2. Affect

Of the eight subscales assessing affect, there were significant differences between the two expressive writing groups in four domains. First, there was a main effect of time on high arousal affect, $F(2, 82) = 3.72$, $p = .028$, *partial* $\eta^2 = .08$, whereby high arousal affect increased during the healing period (from immediately after biopsy to the 14 day follow-up) in both expressive writing groups.

Second, there was a main effect of time ($F(2, 82) = 7.12$, $p = .001$, *partial* $\eta^2 = .15$) and a significant interaction effect between groups over time on low arousal negative affect ($F(2, 82) = 4.81$, $p = .011$, *partial* $\eta^2 = .11$). Bonferroni post hoc analyses found that people who performed expressive writing prior to wounding experienced a significant increase in low arousal negative affect during the writing period (baseline to time of biopsy, $p = .002$); and a decrease in low arousal negative affect during their healing period (immediately after the biopsy to the 14 day follow-up) ($p < .001$). People who performed expressive writing after the biopsy appeared to have an increase in low arousal negative affect before the biopsy and the writing task but this was not statistically significant. Similar to the expressive writing before group, they also experienced an increase in low arousal negative affect over the period they wrote (from time of biopsy to follow-up, which coincided with their healing period; Figure 3a). At follow-up, those who completed the expressive writing prior to wounding reported less low arousal negative affect (*mean* = 6.36, *SD* = 2.74) than those who completed the writing post wounding, although this was not statistically significant (*mean* = 7.71, *SD* = 2.15, $p = .080$).

Third, there was a main effect of time (F(1.62, 66.25) = 5.38, p = .011, *partial* η^2= .12), and a significant interaction effect between groups over time in positive affect (F(1.62, 66.25) = 8.01, p = .002, *partial* η^2= .16). The group who performed expressive writing before wounding experienced a decrease in positive affect over the writing period (baseline to biopsy, p = .082), followed by an increase in positive affect during their healing period (from biopsy to follow-up; Figure 3b). Those who performed expressive writing after wounding experienced a significant decrease in positive affect while writing which coincided with their healing period (from biopsy to follow-up, p < .001). The results showed that participants who wrote expressively after the biopsy had a significantly larger decrease in positive affect after the writing task (*mean* = -2.19, *SD* = 2.44), compared to the decrease in positive affect in the expressive writing before group (*mean* = -.77, *SD* = 1.48; t(41) = 2.32, p = .026, r = .33). Those who performed expressive writing prior to wounding had significantly higher positive affect at follow-up (*mean* = 9.36, *SD* = 3.59) than those who wrote expressively post wounding (*mean* = 6.71, *SD* = 2.80, p = .029).

Fourth, there was a significant interaction effect between the two expressive writing groups over time in high arousal positive affect, F(2, 82) = 3.75, p = .028, partial η^2= .08. Figure 3c shows a trend for high arousal positive affect to decrease while writing in the group who wrote before wounding (baseline to biopsy) and to increase during the healing period (from biopsy to follow-up; Figure 3c). The group who performed expressive writing post wounding also experienced a trend for a decrease in high arousal positive affect while writing which coincided with their healing period (from biopsy to follow-up; p = .129). At the follow-up point, high arousal positive affect was significantly higher in the group who wrote prior to wounding (*mean* = 8.68, *SD* = 3.05) than the group who wrote post wounding (*mean* = 6.71, *SD* = 2.32, p = .022).

In contrast, there were no significant changes in any affect scales over time for the control groups with one exception. High arousal positive affect increased from the time of biopsy to the follow-up point amongst those who wrote about daily activities after the biopsy (p = .004).

3.4.1.3 Associations between emotional expression and changes in affect

To check whether affect ratings were a good proxy for intervention response, correlations were performed between the self-reported amount of emotion expressed during the writing task and affect ratings at Day 14. In the expressive writing before group, more emotion expressed on average over the three tasks was correlated with more high arousal positive affect at the 14 day follow-up (r_s = .44, p = .042). In the expressive writing after group, more emotion expressed was correlated with less high arousal positive affect at the 14 day follow-up (r_s = -.57, p = .005). This suggests that affect did change as a result of emotional expression. It illustrates that soon after completing the writing task, positive affect decreased, but by 14 days after the writing task, sufficient time had passed for it to have a beneficial effect and positive affect increased.

3.5. Post hoc analyses

On average, the participants assigned to complete expressive writing after the biopsy started writing 3 days after the biopsy. However 12 participants started the writing immediately after the biopsy and had completed the writing intervention by day 6. As a post-hoc analysis, we investigated whether people who complied with the instructions to write over the first three to six days had better healing than those who took longer to write. There were no significant differences in healing between groups at day 10 (p = .667). However, on day 14, 100% (12/12) of the participants who completed the expressive writing task over the first six days were rated as healed, compared to only 67% (8/13) of the participants who took longer to complete the task (χ^2(1, N = 25) = 5.77, p = .039, *Cramer's V* = .48. The odds of a participant with a healed wound on day 14 were 13.24 times higher if they had completed the writing over the first six days.

We then examined whether expressive writing soon after wounding improved healing at days 10 and 14 compared to the control groups and the expressive writing before group, including only the 12 participants who finished their writing within six days of receiving the biopsy. However, this did not change the significance of the results presented in section 3.3.

There was a significant negative correlation between taking longer to complete the writing task and high low arousal negative affect at day 14 (r_s = -.42, p = .039) within the expressive writing

after group. Higher levels of low arousal negative affect at day 14 were also correlated with slower healing on day 14 in this group (r_{pb} = -.54, p = .005).

4. Discussion

This study showed that expressive writing pre-biopsy was associated with a greater proportion of healed wounds by day 10 compared to control writing pre or post biopsy. In contrast, the proportion of healed wounds by day 10 did not differ significantly between the expressive writing post-biopsy group and the two control writing groups. Thus, expressive writing is clearly more efficacious than control writing when performed pre biopsy. However, we also observed that wound healing between the two expressive writing groups (i.e., those completing writing pre and post biopsy) did not differ significantly. Post hoc analyses indicated there may be differential effects of expressive writing after wounding on healing, depending on the timing of the writing and wound assessment. People who finished the expressive writing task in the first 6 days after the wound had better healing at 14 days than those who took longer to do the expressive writing task after wounding.

Differences in affect between the two expressive writing groups over the healing period may explain why those who performed expressive writing before wounding had better healing. The participants who completed expressive writing before wounding experienced decreases in positive affect and high arousal positive affect, and an increase in low arousal negative affect over the writing period. However, during the healing period, their low arousal negative affect, positive affect and high arousal positive affect scores all rebounded. On the other hand, the participants who completed expressive writing after wounding also experienced decreases in positive affect and high arousal positive affect as well as an increase in low arousal negative affect over the writing period. However this occurred over the same period as healing. In other words, during the healing period, participants who performed expressive writing prior to wounding experienced improvements in positive and negative affect, whereas those who performed expressive writing after wounding experienced deteriorations in positive affect and increases in negative affect, which may have

influenced healing. Previous research has linked optimism to better healing (which could be likened to positive affective states), and linked depression with worse healing (which could be likened to negative affective states; Cole-King & Harding, 2001; Ebrecht et al., 2004).

The control groups demonstrated stable affect across the study period, with the exception of the post-biopsy control writing group, who had a significant increase in high arousal positive affect over the time they completed the writing task. In contrast, the post-biopsy expressive writing group had a greater decrease in positive affect after completing the writing task than the pre-biopsy expressive writing group. It is possible that writing after the biopsy had a stronger effect on positive affect than writing beforehand due to the compound effect of having a wound at the same time. Future research is needed to assess whether this is due to added burden or something else.

The effects of expressive writing do not appear to operate via changes in perceived stress. Similar to this study, previous studies have also found that expressive writing does not reduce perceived stress, but still had an effect on wound healing (Koschwanez et al., 2013, Weinman et al., 2008). An alternative explanation is that the perceived stress scale used in all three of these studies is not sensitive enough to detect subtle changes in stress or the scale may not assess aspects of stress relevant to expressive writing.

The results suggest that improvements in healing only occur sometime after expressive writing has finished and improvements in affect have begun. Expressing more emotion during the writing task before wounding was associated with greater high arousal positive affect at 14 days after wounding, suggesting that expressive writing can lead to beneficial effects in affect over time (15-28 days). In contrast, expressing more emotion during the writing task after wounding, was associated with lower high arousal positive affect at day 14 after wounding (0-13 days after writing). Most of the participants did not follow the instructions to write on the assigned days and they tended to write over a spread of days either before or after wounding, which makes the findings in affect more difficult to interpret in relation to writing and healing. However, it appears that expressing emotions initially reduces positive affect and later increases it. Positive affect may aid

healing, as is suggested in other work on trait positive affect (Robles, Brooks & Pressman, 2009). Further evidence supporting the statement that benefits in healing occur only after some time following writing comes from the results of the post-hoc analysis. This showed that participants who finished the expressive writing task in the first six days post-wounding showed better healing on day 14 compared to those who took longer to finish. By completing the writing earlier, participants had more to time for their affect to improve after the writing task and on day 14 benefits in healing were seen. Although it has been found that writing over a longer time period is associated with bigger effect sizes for other outcomes (Smyth, 1998), due to the short time period over which healing occurred, completing the intervention sooner had better outcomes for participants in this study. It could be argued that expressive writing both before and after the wound may have some benefits but it is all in the timing. The beneficial effects of expressive writing on healing seem to emerge after about 8 -11 days.

Changes to affect may be important during wound repair. Wound healing is composed of several phases, and research shows that psychological stress affects several components of healing via enhanced glucocorticoid and catecholamine production (Gouin & Kiecolt-Glaser, 2011). The data presented in Figure 3 suggest that, on average, there were positive changes in affect in the expressive writing before group between the time of biopsy to 14 days, which occurred concurrently with the healing process. For those who wrote after wounding, there were no positive changes to affect on average during this healing period. However, the affect data is not sufficiently detailed to be able to match specific changes in affect to specific healing phases more closely.

It is interesting to compare the results of this study to the earlier study on the effects of timing of relaxation on wound healing (Robinson et al., 2015). Relaxation had beneficial effects on skin barrier recovery both when performed immediately before or immediately after skin damage compared to a no-relaxation control group. The mechanism involved may have been the reduction of physiological arousal and stress hormones, although these were not measured. In contrast to this study, relaxation was performed within 20 minutes of skin damage, and the wound was more

superficial so healed more quickly. The mechanisms involved in expressive writing are likely to be different in some ways due the initial distressing effects of expressive writing. However, by the time this initial distress has dissipated, the resultant effects on stress hormones and inflammatory responses may be similar. This is an area for future research.

The temporary increases in negative affect that were observed in this study during the writing intervention have been reported in previous research (Booth, Petrie & Pennebaker, 1997). These changes in affect may be linked to sympathetic activity and release of stress hormones (Miller & Cohen, 2001). When the distress subsides, there may be a temporary boost in mood and immune parameters. Supporting this hypothesis, research has found that immediately after expressive writing, participants have lower circulating lymphocytes and basophils in the blood, but one month later these differences disappeared (Petrie et al., 1995). While there is insufficient research at this stage to understand the exact timeframe of changes to affect and immune function after expressive writing, this wound healing study suggests that 10 days may be sufficient time for positive effects on mood and inflammatory processes to occur.

In this study, those who wrote expressively prior to wounding showed changes to both negative affect and positive affect, and both of these aspects may be important to immune function and wound healing. Previous research has shown that negative mood is associated with lower natural killer cell counts assessed across two days at the same (unspecified) time of day (Valdimarsdottir & Bovbjerg, 1997). Furthermore, greater positive mood was associated with higher natural killer cell counts but only in those people who also experienced negative affect. In other words, the experience of positive affect may buffer the effects of negative affect on immune parameters.

Positive health outcomes may be related to decreasing autonomic arousal that occurs as participants engage in emotional processing over time (McGuire, Greenberg & Gevirtz, 2005). By processing events through writing, intrusions associated with the event are less frequent and may decrease the strain on physiological resources required to contend with distressing thoughts

(Pennebaker, 1993). The analysis of the words participants used suggests that participants in the expressive writing groups used more cognitive, insightful and affective words compared to participants in the control groups. This suggests (even though the essays were not examined for narrative construction) that participants in the expressive writing groups were able to cognitively process distressing events and previous research suggests that this process can result in physiological improvements (Low, Stanton & Danoff-Burg, 2006).

A further important observation concerns the fact that the majority of wounds had healed by day 14. This, of course, suggests that the effects of the intervention are limited to the speed of healing, rather than whether or not wounds will heal. We are, however, limited in this study by the nature of the wounds (i.e., small experimental wounds that we would expect to resolve completely). Further examination of this issue would require a focus on chronic wounds where intervention effects on both speed of healing and complete wound resolution could be examined.

This study had a number of limitations. First because the sample was comprised of healthy volunteers, it is difficult to apply these finding to clinical settings. Further research needs to replicate these findings in clinical populations, such as people with chronic wounds or people undergoing surgery. The longer time period needed for chronic wounds to heal may mean that expressive writing could improve healing even though it is performed after the wound has occurred. Another limitation is that this study did not measure stress hormones, such as cortisol, during the writing tasks. This might be useful for understanding the underlying biological processes involved in the effects of expressive writing on healing and to help determine optimal timing of intervention delivery. The measurement of circulating or in situ immune cells or cytokines would add further physiological evidence for these effects. In order to understand the effects of writing on affect and healing better, future research should measure affect more frequently. Due to the limited assessment points, it may not be appropriate to attribute changes in affect to wound healing efficacy, and more research is needed in this area. However, other research measuring affect after performing expressive writing have shown similar changes (Booth, Petrie & Pennebaker, 1997).

Lastly, a mediation model testing whether affect mediated the effects of writing on healing was not tested due to multiple time points and groups, and mediational modelling is an area for future research.

5. Conclusions

This research supports the literature showing that expressive writing during the two week period prior to a punch biopsy improves wound healing in comparison to neutral writing. Expressive writing after wounding may also improve healing, but the effects appear dependent on the timing of the writing and the healing assessment point. This research highlights the complexities of implementing an expressive writing intervention and the importance of timing for wound healing. The results suggest that expressive writing causes initial distress followed by improvements in affect which may affect healing. However, further research is needed to assess the effects of expressive writing on wound healing and affect using more time points, and to investigate effects in clinical populations, before stronger conclusions can be made.

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