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Randomized Clinical Trial of Expressive Writing on Wound Healing Following Bariatric Surgery

Heidi Koschwanez and Hayley Robinson
The University of Auckland

Grant Beban
Auckland City Hospital, Auckland, New Zealand

Andrew MacCormick, Andrew Hill, John Windsor, Roger Booth, Mia Jüllig, and Elizabeth Broadbent
The University of Auckland

Objective: Writing emotionally about upsetting life events (expressive writing) has been shown to speed healing of punch-biopsy wounds compared to writing objectively about daily activities. We aimed to investigate whether a presurgical expressive writing intervention could improve surgical wound healing. ***Method:*** Seventy-six patients undergoing elective laparoscopic bariatric surgery were randomized either to write emotionally about traumatic life events (expressive writing) or to write objectively about how they spent their time (daily activities writing) for 20 min a day for 3 consecutive days beginning 2 weeks prior to surgery. A wound drain was inserted into a laparoscopic port site and wound fluid analyzed for proinflammatory cytokines collected over 24 hr postoperatively. Expanded polytetrafluoroethylene tubes were inserted into separate laparoscopic port sites during surgery and removed after 14 days. Tubes were analyzed for hydroxyproline deposition (the primary outcome), a major component of collagen and marker of healing. Fifty-four patients completed the study. ***Results:*** Patients who wrote about daily activities had significantly more hydroxyproline than did expressive writing patients, $t(34) = -2.43$, $p = .020$, 95% confidence interval [−4.61, −0.41], and higher tumor necrosis factor–alpha, $t(29) = -2.42$, $p = .022$, 95% confidence interval [−0.42, −0.04]. Perceived stress significantly reduced in both groups after surgery. ***Conclusions:*** Expressive writing prior to bariatric surgery was not effective at increasing hydroxyproline at the wound site 14 days after surgery. However, writing about daily activities did predict such an increase. Future research needs to replicate these findings and investigate generalizability to other surgical groups.

Keywords: expressive writing, surgery, bariatric, hydroxyproline, wound healing

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Several studies have shown that psychological stress impairs wound healing (Walburn, Vedhara, Hankins, Rixon, & Weinman, 2009). Many kinds of stressors can impair healing, including exams, caring for a relative with Alzheimer's disease, brief laboratory stressors, and stress and depression prior to surgery. In surgical patients, higher perceived life stress (e.g., feeling life is unpredictable, uncontrollable and overloaded) in the month prior to surgery was associated with lower levels of cytokines in wound fluid over the first 24 hr after undergoing inguinal hernia repair, and slower wound healing in kidney donors (Broadbent, Petrie, Alley, & Booth, 2003; Maple et al., 2015).

Psychological stress may affect wound healing via activation of the sympathetic–adrenal–medullary axis and the hypothalamic–pituitary–adrenal axis (Segerstrom & Miller, 2004). Activation increases the secretion of the adrenal hormones epinephrine, norepinephrine, and cortisol. These hormones bind to white blood cells and affect their distribution and function, including the secretion of proinflammatory cytokines such as interleukin (IL)-1

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Heidi Koschwanez and Hayley Robinson, Department of Psychological Medicine, The University of Auckland; Grant Beban, Department of General Surgery, Auckland City Hospital, Auckland, New Zealand; Andrew MacCormick, Andrew Hill, and John Windsor, Department of Surgery, The University of Auckland; Roger Booth, Department of Molecular Medicine and Pathology, The University of Auckland; Mia Jüllig, Auckland Science Analytical Services, The University of Auckland; Elizabeth Broadbent, Department of Psychological Medicine, The University of Auckland.

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Correspondence concerning this article should be addressed to Elizabeth Broadbent, Faculty of Medical and Health Sciences, Department of Psychological Medicine, The University of Auckland, Private Bag 92019, Auckland Mail Centre, Auckland 1142, New Zealand. E-mail: e.broadbent@auckland.ac.nz

and tumor necrosis factor–alpha (TNF-α). Cytokines regulate the stages of wound repair, including the proliferative phase when granulation tissue (collagen and extracellular matrix) forms (Werner & Grose, 2003).

Psychological interventions to reduce perceived life stress may be able to improve wound healing. A promising psychological intervention is writing emotionally about life events that have occurred (known as expressive writing). Participants write about their most traumatic experiences, delve into their deepest feelings about the events, and disclose emotions not previously shared (Pennebaker, Kiecolt-Glaser, & Glaser, 1988). Writing provides an opportunity to construct a narrative of upsetting events, label and acknowledge emotions, facilitate cognitive processing of the trauma, and potentially illuminate a different understanding of the circumstances (Pennebaker & Chung, 2007). Compared to writing nonemotionally about daily activities (e.g., how you spend your time), writing emotionally about traumatic events has been shown to improve anxiety, distress, and specific immune-related measures (Frattaroli, 2006). Much of this research has been performed with healthy university students but also with nonstudent populations including medical patients. Initial studies suggest that writing expressively about upsetting life events, as compared with writing about how you spend your time, can improve healing of experimentally induced punch biopsy wounds in the inner upper arm of healthy adults (Koschwanez et al., 2013; Weinman, Ebrecht, Scott, Walburn, & Dyson, 2008). Weinman and colleagues (2008) randomized 36 males with a mean age of 22 years to either an experimental group (asked to write about a traumatic and upsetting experience) or to a control group (asked to write about time management—i.e., to write objectively about what they had done the previous day, that day, and their plans for the next week). Participants were asked to write over 3 days beginning 2 weeks before wounding and healing was assessed at 7, 14, and 21 days after the biopsy using high resolution ultrasound. The width of the wound at its base was significantly smaller in the expressive writing group at Days 14 and 21 than in the time management group. Similarly, Koschwanez and colleagues (2013) randomized 49 older adults with a mean age of 79 years to write either about the most traumatic/upsetting experience in their life or about their daily activities for tomorrow, over the next 3 days, beginning 2 weeks before wounding. Healing was assessed by blinded ratings of epithelialization from photographs at Days 7, 11, 14, 17, and 21 postbiopsy. A significantly greater proportion of wounds were rated as healed at Day 11 in the expressive writing group compared to the daily activities writing group. It has been suggested that expressive writing may be indicated for improving healing in patient samples (Weinman et al., 2008).

Wound healing is an important outcome in surgical patients. Prior to surgery, patients will have both life stress and stress about the surgery itself. Surgery is a threatening event that usually causes elevated stress and anxiety (Jawaid, Mushtaq, Mukhtar, & Khan, 2007; Mitchell, 2003), and studies suggest that patient anxiety complicates postsurgical recovery (Mavros et al., 2011). Expressive writing may be able to reduce life stress, which has previously been linked to poor healing. There is evidence that expressive writing prior to surgery can shorten hospital stay and improve postsurgical outcome in patients with lower distress levels as well as in patients with higher levels of alexithymia (Solano, Donati, Pecci, Persichetti, & Colaci, 2003; Solano et al., 2007). However, to date, no studies have investigated whether expressive writing can improve wound healing in surgical patients. Because expressive writing is brief, low cost, and easy to administer, it could be easily implemented in clinical practice, if evidence shows it to be effective.

Our primary aim was to investigate whether a presurgical expressive writing intervention could improve wound healing in surgical patients. The choice of bariatric surgery was made because of the long lead-up time prior to surgery, regimented presurgical diets to prepare for surgery (i.e., Optifast meal replacement products), and the multiple clinic visits before and after surgery that facilitated study procedures. In addition, wound healing is relevant in this group because obesity is a risk factor for poor surgical outcomes (Anaya & Dellinger, 2006; Momeni, Heier, Bannasch, & Stark, 2009).

We hypothesized that patients randomly allocated to write emotionally about upsetting life events (expressive writing), would have better healing than patients allocated to write objectively about how they spent their time (daily activities writing). Healing was assessed by the extent of deposition of hydroxyproline (a major component of collagen) in expanded polytetrafluoroethylene (ePTFE) tubes implanted at the surgical wound site. Hydroxyproline deposition served as the primary outcome. Measuring hydroxyproline deposited in ePTFE tubes is one of the best available techniques to assess the later stages of wound healing (Jorgensen, Sorensen, Kallehave, Schulze, & Gottrup, 2001). This method of wound assessment has been used in a number of previous studies (e.g., Broadbent et al., 2012; Goodson & Hunt, 1982; Tønnese, Pedersen, Lavrsen, Tuxøe, & Thomsen, 2012; Windsor, Knight, & Hill, 1988), is safe, and hydroxyproline accumulated in ePTFE tubes has been found to correlate with wound tensile strength (Gottrup, Lorentzen, & Jorgensen, 1999). Secondary outcomes included assessments of proinflammatory cytokine levels and cortisol levels in wound fluid collected over the 24 hr immediately postsurgery to assess the inflammatory response and stress hormones, as well as perceived stress 2 weeks before and 2 weeks after surgery.

Method

Ethical approval was obtained from the Ministry of Health's Health and Disability Ethics Committee. All participating patients gave written informed consent. This study was registered at the Australian New Zealand Clinical Trials Registry (ACTRN 12613000281796; http://www.ANZCTR.org.au/). Data collection commenced in May 2013 and concluded in September 2015.

Sample Characteristics and Setting

Inclusion criteria were bariatric patients over the age of 18, able to communicate and handwrite (or type) in English, and deemed physically and mentally fit to undergo elective laparoscopic sleeve gastrectomy or Roux-en-Y gastric bypass surgery at Auckland City Hospital, Manukau Surgical Centre, or Middlemore Hospital, Auckland, New Zealand, between May 2013 and April 2015. Laparoscopic sleeve gastrectomy involves removing a major portion of the stomach to reduce the stomach from a sac to a narrow tube. In contrast, laparoscopic Roux-en-Y gastric bypass involves constructing a very small pouch from the top part of the stomach,

then connecting this pouch to the small intestine to bypass the majority of the stomach and first portion of the small intestine. Both laparoscopic procedures involve the creation of five small (5 to 12 mm long) incisions, called port sites, to allow camera and surgical instrument access to the organs.

Procedure

Eligible patients were informed about the study at presurgery information sessions at the Manukau Super Clinic and at preadmission surgical clinic appointments at Greenlane Hospital. If patients agreed to participate, written informed consent was obtained.

Approximately 2 weeks prior to surgery (at least 10 days), patients completed a preoperative (baseline) questionnaire, and were randomly assigned to either write factually about how they spent their time (daily activities writing; control) or to write emotionally about important life events (expressive writing; intervention) group. This timeframe was chosen to be similar to the two previous studies on expressive writing and wound healing (Koschwanez et al., 2013; Weinman et al., 2008). Patients were asked to write for 20 min a day, for 3 consecutive days at home, on the assigned topic. These instructions were very similar to the instructions used in the previous studies on expressive writing and wound healing (Koschwanez et al., 2013; Weinman et al., 2008), and other studies on expressive writing (Frattaroli, 2006). Pennebaker recommends writing for at least 3 days (Pennebaker, 2000) and a meta-analysis showed that writing for 3 or more days was associated with better outcomes than writing for less than 3 days (Frattaroli, 2006). Following each writing session, patients completed a postwriting questionnaire. Patients were asked to mail their essays to the researchers for linguistic analysis after they completed the final writing session. Writing was completed approximately a week prior to surgery.

Both groups received standardized peri-operative care. In addition, both groups had a wound drain and two ePTFE (expanded polytetrafluoroethylene) tubes were implanted into separate wound sites before wound closure. On the ward the following day, the wound drain was removed and wound fluid collected for cortisol and proinflammatory cytokine analyses. At 14 days postsurgery, the ePTFE tubes were removed by a nurse blinded to group allocation. The 14-day time point was chosen because granulation tissue fills the wound 1–2 weeks after injury (Werner & Grose, 2003), and patients attended a routine follow-up appointment 14 days after surgery. Patients were also asked to complete the Perceived Stress Scale questionnaire at this appointment.

Trial Design

This was a single-blinded, parallel, between-groups, randomized controlled study. Patients were randomized to groups in a 1:1 ratio using a random sequence generator and group allocation was sealed in consecutively numbered opaque envelopes. Patient recruitment was performed by the study coordinator and research assistant, and group allocation was performed by the principle investigator (who was not involved in study recruitment, data collection, or biological sample and/or analyses). The study coordinator, surgeons and their teams conducting the surgery and postsurgical follow-ups were blinded to group allocation. Patients were discouraged from discussing their essays with the researchers and medical staff involved in the study. The laboratory technicians performing the hydroxyproline and wound fluid analyses, and the researchers performing the thematic/linguistic analyses and statistical tests were also blinded to group allocation.

Intervention

Writing instructions for both groups were similar to those outlined in previous writing studies (e.g., Mackenzie, Wiprzycka, Hasher, & Goldstein, 2007; Pennebaker & Chung, 2007), including those used in the previous two writing and wound healing studies (Koschwanez et al., 2013; Weinman et al., 2008). Patients in the expressive writing group were asked to write emotionally about the most traumatic/upsetting experience in their life, delving into their deepest thoughts, feelings, and emotions about the event, ideally not previously shared with others. In contrast, patients in the daily activities writing group (control) were asked to write objectively about their day-to-day activities, without mentioning emotions, opinions, or beliefs: on Day 1, they were asked to write about what they did last week; on Day 2, what they did the last 24 hr; and on Day 3, to write about their plans for the upcoming week. (These were similar to Weinman et al.'s [2008] control group instructions to write about what they had done the previous day on Day 1, to write about what they had done that day on Day 2, and to write about what they planned to do the next week on Day 3.) Due to the timing of the intervention, "plans for the upcoming week" in the daily activities writing instructions corresponded with the week prior to surgery for many patients. Both groups were instructed to write uninterrupted for 20 min per session, without concern for spelling or grammar (see online supplemental material for full instructions).

Wound Drain and ePTFE Tube Implantation

All patients underwent standard elective laparoscopic sleeve gastrectomy or Roux-en-Y gastric bypass surgery under general anesthesia. Prior to wound closure, two 65-mm ePTFE tubes (high-porosity PTFE tubing, International Polymer Engineering, Tempe, AZ) with an internal diameter of 1.2 mm, a 0.6-mm wall thickness, and 90- to 120-μm internodal distance were inserted in the subcutaneous adipose tissue of two 5-mm (most lateral) port sites (one tube per site). The ends of the ePTFE tubes were sutured to the skin to avoid accidental removal. During healing, connective tissue infiltrates the porous ePTFE and when the tubes are removed the hydroxyproline content inside the tube can be measured. Separate to the ePTFE tubes, a wound drain (5111006, Van Straten Medical, Medinorm GmbH, Nieuwegein, the Netherlands) was inserted into the subcutaneous tissue of the 12-mm port site to allow for fluid collection (to measure proinflammatory cytokine and cortisol levels) from the wound site. Standard sterile dressings (Smith and Nephew Opsite Post-Op, London, UK) were applied.

All patients were seen approximately 24 hr postsurgery by the study coordinator or nurse for wound drain removal and fluid collection. Wound fluid was sent immediately to the lab for processing. Patients were seen again at 14 days postsurgery by the study coordinator and nurse for ePTFE tube removal. Explanted tubes were sent immediately to the lab for −80°C storage until hydroxyproline analysis was performed.

Measures

Wound fluid analysis. Wound fluid was transferred to 1.6-mL Eppendorf containers, centrifuged at 6,800 g for 15 min at ambient temperature, and the plasma was recovered and stored frozen at −80°C. When all samples had been collected, they were assayed for IL-1β, TNF-α, IL-6, and cortisol. Proinflammatory cytokines were measured using Milliplex MAP Kits (Cat# HCYTOMAG-60K; EMD Millipore Corporation), as per manufacturer's instructions, using a Luminex 100 instrument (Luminex Corporation). Cytokine samples were assayed undiluted and at 1:10 dilution, with each sample assayed in duplicate. Intra- and interassay coefficients of variation were 2.3% and 6.7% for IL-1β, 2.0 and 18.3% for IL-6, and 2.6% and 13.0% for TNF-α. Wound fluid cortisol was measured using the Cortisol Saliva enzyme-linked immunosorbent assay kit (Cat# RE52611; IBL International) as per manufacturer's instructions. Wound fluid was diluted to 1:10, 1:25, or 1:40. Measurements were read on an uQuant Plate Reader (BioTek) and analyzed on KC4 software (BioTek). Standards were plotted to a four-parameter curve fit and upper and lower limits chosen from the range of the linear section. Sample measures that fell within range were read from the standard curve for level of cortisol and corrected for dilution factor.

Hydroxyproline assessment. All buffers required for the assay were prepared according to established methods (Chiariello et al., 1986). The ePTFE tubes were trimmed to a length of 3 cm and submerged in 950 μl of 6-M HCl in a 10-ml screw-cap Pyrex glass tube (Corning Incorporated). The embedded proteins were broken down into composite amino acids by hydrolysis at 105°C for 17 hr in a CONTHERM Series 5 oven. The samples were then dried for 20 hr (Savant SC250EXP SpeedVac Concentrator attached to a Savant RVT5105 Refrigerated Vapor Trap and a soda lime trap). Once dry, 950 μl of ultrapure water was added and pH adjusted to 6 with 12–40 μ ofl 5-M NaOH. All tubes were then supplemented with 950 μl of isopropyl alcohol (Merck) mixed and centrifuged for 5 min at 2,000 g. Duplicate samples of 120 μl were transferred to 2-ml microcentrifuge tubes and supplemented with 280 μl of acetate-citrate buffer and 100 μl of oxidant solution. After incubation at room temperature for 5 min, 1.3 ml of Erlich's reagent was added and the tubes incubated for a further 30 min in a 60°C water bath. Absorbance at 558 nm was measured in 96-well plates using a spectrophotometer (EnSpire 2300 Multilabel Reader, Perkin Elmer) and concentrations (μg hydroxyproline/cm ePTFE tube) were determined against a concentration curve of hydroxyproline (Sigma) in a concentration range from 1.6 to 100 μg/ml. For each patient, the average of a total of four measurements (duplicate measurements from two implants) was computed.

Questionnaires.

Demographic and current health questionnaires. Age, gender, weight, height, ethnicity, relationship status, current medical conditions, medications, and smoking status were assessed at baseline.

Health-related behaviors. Alcohol consumption, sleep quantity and quality, multivitamin use, and exercise per week were assessed at baseline. Questions included, "During the past 3 months, how often have you drunk alcohol, on average?" "During your average week, how many times do you engage in 30 min or more of physical activity (e.g., going for a walk, going to the gym)?" and "During the past month, how many hours of actual sleep did you get at night?" Tick boxes were provided with each question, outlining a range of quantities to choose from (e.g., two times a week).

Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983; Cohen & Williamson, 1988). A 10-item scale that assesses perceived stress with scores ranging from 0 to 40; higher scores indicate greater perceived stress. Perceived stress over the past month was assessed at baseline and perceived stress since surgery was assessed at 14 days postsurgery.

Postwriting question (adapted from Pennebaker, Colder, & Sharp, 1990). A one-item scale assessed the effectiveness of the study manipulation (e.g., whether the writing instructions were followed) by asking how much the patient revealed their emotions in their writing (i.e., the "emotionality" of the essay) after each writing session. (Both expressive writing and daily activities writing groups completed this questionnaire.) Emotionality scores ranged from 0 to 4, and scores were averaged over the three writing sessions; higher emotionality scores indicated greater emotional expression. Patients were also asked to record the length of each writing session (e.g., 21 min).

Content analysis of writing. The content of the essays was examined to assess whether patients were writing about trauma and/or activities specifically related to the surgery itself. For each essay, two researchers, blinded to group allocation, independently counted the number of activities/plans listed to prepare for surgery (e.g., cook meals to freeze for family, pack overnight bag for hospital), and also categorized (i.e., yes/no) each essay as expressing anxiety/distress/fear about their surgery or not (e.g., "I'm scared about the surgery next week"). Any disagreement was resolved by consensus with the two researchers.

Statistical analysis. Data were analyzed as intention to treat (ITT) and performed intervention (PI). Intention to treat analyses included all consenting patients, according to the writing group they were randomly assigned, regardless of whether they performed the writing intervention or not. Performed intervention analyses included those patients who remained in the study and completed a minimum of one essay. Variables were examined for normality and skewness. Where appropriate, nonnormal distributions were log transformed (i.e., cytokine concentrations, cortisol concentration) or analyzed using nonparametric tests. Hydroxyproline content, proinflammatory cytokine and cortisol levels, and thematic analysis categories were compared between the two groups using independent *t* tests and Mann–Whitney *U* tests for continuous variables and Pearson chi-square analyses for categorical variables. Perceived stress scores were analyzed using a mixed between-within subjects analysis of variance. Spearman correlation examined the association between hydroxyproline deposition and the number of presurgical plans listed in patient essays.

To examine the validity of the experimental manipulation, emotionality ratings of the writing sessions were compared using Mann–Whitney *U* tests. For all analyses, a two-tailed alpha level of $<.05$ was used. Statistical and power analyses were performed using SPSS Version 20 and G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007), respectively.

Power analysis. A previous psychological intervention study reported a mean difference of 8.80-μg hydroxyproline/cm of ePTFE tube explanted from laparoscopic wounds 7 days postsurgery, with an effect size of Cohen's $d = .66$ (Broadbent et al., 2012). To achieve a similar effect size for between-groups differences in hydroxyproline deposition (μg hydroxyproline/cm ePTFE tube), 38 patients per group would be required, using 80% power and a significance of .05. To allow the detection of a slightly smaller effect size ($d = .60$), we originally aimed to recruit 45 patients per group. However, the study ended when the maximum time period for recruitment finished, when we had managed to recruit 76 participants but not 90.

Results

Recruitment

A patient flow diagram is included in Figure 1. Two hundred two patients on the waiting list for bariatric surgery were invited to participate, of whom 123 declined and three did not meet the inclusion criteria. Seventy-six patients provided written informed consent and were randomized to either expressive writing or daily activities writing groups (38 per group). Prior to baseline measures, four patients withdrew, and 11 were excluded due to surgery-scheduling conflicts, leaving 30 pa-

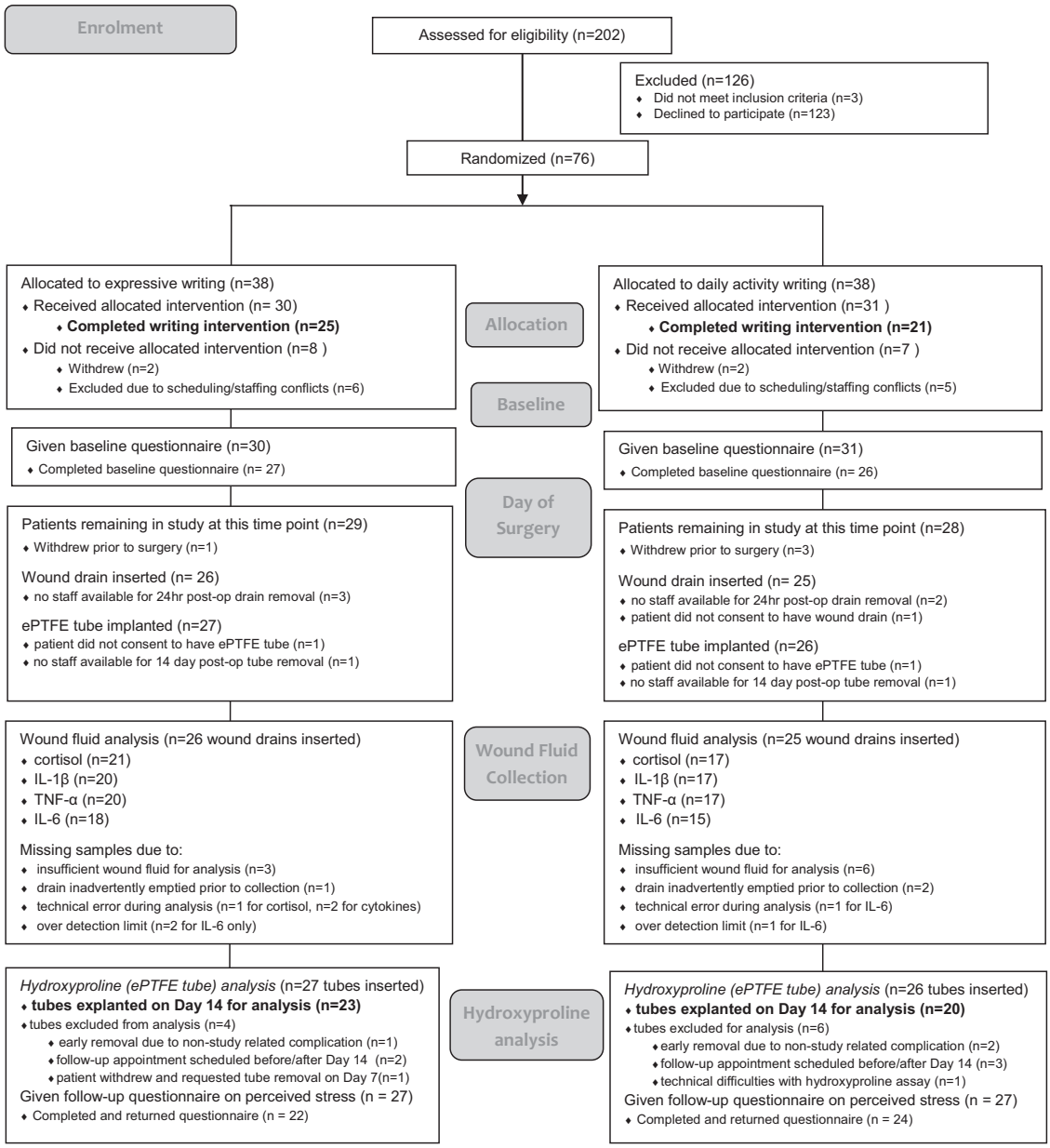

Figure 1. CONSORT flow diagram. ePTFE = expanded polytetrafluoroethylene; IL = interleukin; TNF-α = tumor necrosis factor–alpha.

tients in the expressive writing group and 31 patients in daily activities writing group. Table 1 provides baseline characteristics of the two writing groups; there were no significant differences in these variables.

Compliance With Writing Intervention and Manipulation Check

Of the 61 patients who received the writing instructions, 25 of the 30 expressive writing patients and 21 of the 31 daily activities writing patients performed the writing intervention, $\chi^2(1, N = 61) = 1.99$, $p = .157$. There were 23 expressive writing patients who completed three essays, one patient who completed two essays, and one patient who completed one essay. Though 25 expressive writing patients wrote essays, two patients did not submit their essays, deeming them too personal, and one patient wrote their essays in a foreign language. Therefore, the essays from 22 expressive writing patients were available for analysis. There were 19 daily activities writing patients who completed three essays, and two patients who completed two essays.

Based on the data collected from the Postwriting Questionnaire, there were no significant between-groups differences for the total number of minutes spent writing, the number of days between starting writing and having surgery, or the number of days needed to complete the three writing tasks. Overall, patients wrote a total of 67 min (range 20–180 min) across the three writing sessions, commenced writing 10 days prior to surgery (range 2–33 days, with one outlier in the daily activities writing group of 207 days due to surgery rescheduling), and performed the writing intervention consecutively over 3 days (range 1–6 days).

As expected, there were significant differences in self-reported emotionality of the essays on all 3 days of writing: Day 1 ($U = 42.00$, $z = -4.79$, $p < .001$), Day 2 ($U = 50.00$, $z = -4.52$, $p < .001$), and Day 3 ($U = 52.50$, $z = -3.90$, $p < .001$). Expressive writing patients had higher emotionality scores: Day 1 (*median* = 3, range 1–4, $n = 24$), Day 2 (*median* = 3, range 1–4, $n = 23$), Day 3 (*median* = 3, range 0–4, $n = 22$) than daily activities writing patients: Day 1 (*median* = 1, range 0–3, $n = 20$), Day 2 (*median* = 0.5, range 0–4, $n = 20$), Day 3 (*median* = 1, range 0–3, $n = 17$). This suggests patients were following the instructions.

Table 1
Demographics and Medical Characteristics for Expressive Writing and Daily Activities Writing Groups

Demographics	Expressive writing ($n = 30$)	Daily activities writing ($n = 31$)
Age in years, *M* (*SD*)	46.0 (9.1)	45.4 (10.6)
Gender, *n* (%)		
Female	24 (80%)	21 (68%)
Male	6 (20%)	10 (32%)
Weight (kg) at start of study, *M* (*SD*)	118.1 (22.6)	125.0 (20.6)
District Health Board, *n* (%)		
Auckland	23 (77%)	26 (84%)
Counties Manukau	7 (23%)	5 (16%)
Ethnicity, *n* (%)		
European descent	11 (37%)	9 (29%)
Māori	6 (20%)	6 (19%)
Other	8 (27%)	9 (29%)
Missing	5 (17%)	7 (23%)
Smoking status, *n* (%)		
Nonsmoker	24 (80%)	22 (71%)
Smoker	3 (10%)	5 (16%)
Missing	3 (10%)	4 (13%)
Exercise, *n* (%)		
<150 min per week	20 (67%)	12 (39%)
≥150 min per week	6 (20%)	13 (42%)
Sleep per night (hr), median (range)	6.5 (3.5–9.0)	6.3 (5.0–8.0)
Comorbidities, *n* (%)		
Hypercholesterolemia and/or hypertension	20 (67%)	21 (68%)
Type II diabetes	9 (30%)	14 (45%)
Sleep apnea	13 (43%)	13 (42%)
Use of NSAIDs and/or steroids, *n* (%)		
Not using	18 (60%)	13 (42%)
Currently using	5 (17%)	9 (29%)
Missing	7 (23%)	9 (29%)
Day of surgery characteristics, *n*	29	28
Table weight in kg, *M* (*SD*)	118.9 (26.9)	124.7 (18.9)
Type of surgery, *n* (%)		
Sleeve	21 (72%)	17 (61%)
Bypass	8 (23%)	11 (39%)

Note. NSAID = nonsteroidal anti-inflammatory drug.

Effects of the Intervention on Hydroxyproline Deposition

There were no infections related to the port sites used for the ePTFE. The hydroxyproline data were normally distributed and there were no outliers. As shown in Figure 1, 53 patients had ePTFE tubes inserted at time of surgery; however, hydroxyproline yield was assessed in 43 patients due to several reasons: withdrawal from the study ($n = 1$), technical difficulties with the assay ($n = 1$), ePTFE tube removal before or after Day 14 due to scheduling conflicts ($n = 5$), and early removal due to nonstudy related surgical complications ($n = 3$).

There were no differences in hydroxyproline yield between patients who had laparoscopic Roux-en-Y gastric bypass ($M = 6.12$ μg/cm; $SD = 3.47$ μg/cm; $n = 19$) and patients who had laparoscopic sleeve gastrectomy ($M = 6.41$ μg/cm, $SD = 3.36$ μg/cm, $n = 24$), $t(41) = .29$, $p = .775$, 95% confidence interval (CI) [−1.81, 2.41]. There were no differences in hydroxyproline yield between male ($M = 5.65$ μg/cm, $SD = 3.50$ μg/cm, $n = 14$) and female ($M = 6.58$ μg/cm, $SD = 3.30$ μg/cm, $n = 29$) patients, $t(41) = .85$, $p = .399$, 95% CI [−1.29, 3.16].

For the ITT analysis, expressive writing patients ($M = 5.65$ μg/cm, $SD = 2.90$, $n = 23$) did not significantly differ from daily activities writing patients ($M = 6.99$ μg/cm, $SD = 3.79$, $n = 20$) in hydroxyproline deposited in ePTFE tubes explanted on Day 14, $t(41) = -1.31$, $p = .198$, 95% CI [−3.40, 0.73]. However, when including only those patients in the analysis who wrote at least one essay (PI), there was significantly more hydroxyproline deposited at the wound site in daily activities writing patients ($M = 7.53$ μg/cm, $SD = 3.76$, $n = 16$) than in expressive writing patients ($M = 5.02$ μg/cm, $SD = 2.41$, $n = 20$), $t(34) = -2.43$, $p = .020$, 95% CI [−4.61, −0.41] (see Figure 2). This represents a large effect size of Cohen's $d = 0.84$, with an achieved power of 0.68.

Effects on 24-Hr Postsurgery Wound Fluid Proinflammatory Cytokine and Cortisol Levels

Daily activities writing patients had significantly higher TNF-α concentrations in wound fluid than did expressive writing patients, both when analyzing the data as ITT, $t(35) = -3.02$, $p = .005$, 95% CI [−0.42, −0.08] or as PI, $t(29) = -2.42$, $p = .022$, 95% CI [−0.42, −0.04]. There were no significant between-groups differences for wound fluid cortisol levels, or IL-6 and IL-1beta cytokine levels collected over 24 hr postsurgery (see Table 2).

Effects of the Intervention on Perceived Stress

A mixed between-within subjects analysis of variance was conducted to assess the effects of the two writing conditions on patients' perceived stress scores between baseline (approximately 2 weeks prior to surgery) and 14 days postsurgery. There was no significant interaction between writing group and time, for ITT: Wilks' $\lambda = .998$, $F(1, 42) = .09$, $\eta_p^2 = .002$, and for PI: Wilks' $\lambda = .989$, $F(1, 39) = .45$, $p = .508$, $\eta_p^2 = .01$. There was a significant main effect for time, with both writing conditions showing a reduction in perceived stress from baseline to 14 days postsurgery, for ITT: Wilks' $\lambda = .75$, $F(1, 42) = 13.75$, $p = .001$, $\eta_p^2 = .25$; and for PI: Wilks' $\lambda = .79$, $F(1, 39) = 10.48$, $p = .002$, $\eta_p^2 = .21$. The between groups effect was not significant, for ITT: $F(1, 42) = 2.13$, $p = .152$, $\eta_p^2 = .05$; and for PI: $F(1, 39) = 1.68$, $p = .203$, $\eta_p^2 = .04$. This suggests that patients in both writing conditions experienced similar reductions in perceived stress following surgery, regardless of presurgical writing condition (see Table 3).

Associations Between Writing Content and Hydroxyproline

A total of 118 essays (60 essays from the expressive writing group, 58 essays from the daily activities writing group) were analyzed for instances of presurgical planning and expressions of anxiety/fear about surgery. As expected, significantly more patients in the expressive writing group (13 of 22) expressed anxiety about their upcoming surgery than did patients in the daily activities writing group (three of 20), $\chi^2(1, N = 42) = 8.64$, $p = .003$. Three of these 13 expressive writing patients wrote exclusively about their anxieties about surgery; the remaining 10 wrote about at least one additional life trauma. Of the nine expressive writing patients who did not write about surgery-related anxiety, three

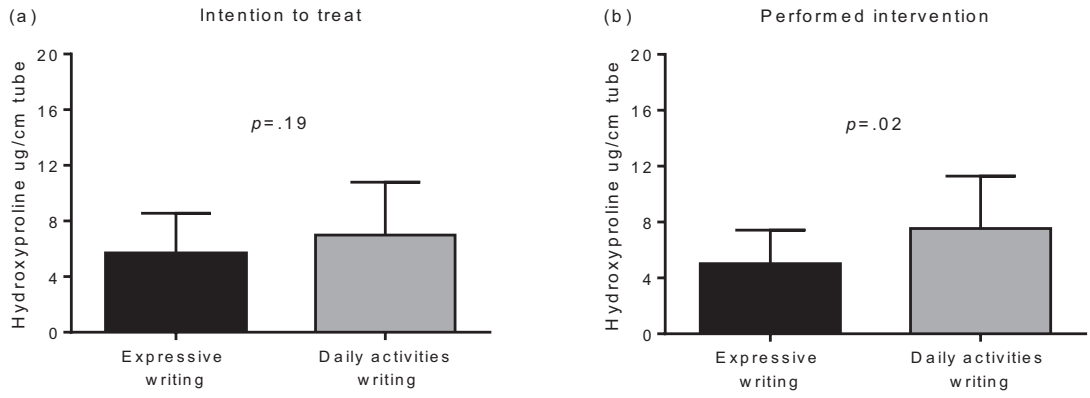

Figure 2. Between-groups comparison of hydroxyproline at the wound site 14 days postsurgery, analyzing groups as (a) intention to treat (ITT) and (b) performed intervention (PI). In patients who performed the writing intervention, daily activities writing patients had more hydroxyproline (μg per cm ePTFE tube) than expressive writing patients. Bars represent means, and lines represent standard deviation.

Table 2
Between-Group Comparison of Wound Fluid Cortisol and Proinflammatory Cytokine Concentrations

Wound fluid analysis[a]	Expressive writing, *M*	Daily activities writing, *M*	95% CI of the difference	*p*	*d*
Cortisol in wound fluid (ng/mL)[b]					
ITT	172.90	169.82	[.53, 1.93]	.955	.02
PI	170.69	164.93	[.46, 2.31]	.931	.03
Proinflammatory cytokines in wound fluid[b]					
IL-1β (pg/mL)					
ITT	7.38	11.79	[.20, 1.94]	.406	.28
PI	7.00	8.64	[.23, 2.83]	.733	.13
IL-6 (pg/mL)					
ITT	37,310	50,320	[.38, 1.46]	.374	.31
PI	33,760	56,690	[.26, 1.55]	.190	.55
TNF-α (pg/mL)					
ITT	18.20	32.49	[.38, .83]	.005	1.00
PI	18.06	30.68	[.37, .92]	.022	.92

Note. CI = confidence interval; ITT = intention to treat; PI = performed intervention; IL = interleukin; TNF = tumor necrosis factor. Results from intention to treat and performed intervention analyses presented.
[a] Fluid collected over 24 hr postsurgery. [b] Data presented as geometric means with endpoints of the confidence interval back-transformed.

wrote about life traumas that had contributed to their weight gain and need for weight-loss surgery, while six wrote exclusively about past traumas, with no mention of surgery. In an analysis of the 33 patients who returned their essays and had their ePTFE tubes explanted on Day 14 postsurgery ($n = 17$ expressive writing patients and $n = 16$ daily activities writing patients), hydroxyproline deposition did not statistically differ between those patients who expressed anxiety about surgery ($n = 10$ from expressive writing; $n = 3$ from daily activities writing; $M = 5.19$ μg/cm, $SD = 2.95$ μg/cm) and those who did not ($n = 7$ from expressive writing; $n = 13$ from daily activities writing; $M = 6.93$ μg/cm, $SD = 3.57$ μg/cm), $t(31) = 1.46$, $p = .154$, 95% CI [−0.69, 4.17], $d = 0.53$. The difference remained nonsignificant when only patients in the expressive writing group were included, $t(15) = 0.71$, $p = .487$, 95% CI [−1.83, 3.67], $d = 0.30$ (anxiety $M = 4.65$, $SD = 2.22$; no anxiety $M = 5.57$, $SD = 3.12$).

As expected, essays from the daily activities writing patients outlined significantly more plans and activities related to their surgery (*median* = 6.5 plans, range 3–22) than did those in the expressive writing group (*median* = 0.5 plans, range 0–4), $U = 6.50$, $z = -5.44$, $p < .001$. The Spearman's rho correlation between the number of plans and amount of hydroxyproline in the 33 patients who both submitted their essays and had hydroxyproline results was .30, $p = .092$.

Table 3
Perceived Stress Scores From the Expressive Writing and Daily Activities Writing Groups From Baseline to Day 14 Postsurgery

	Expressive writing			Daily activities writing		
Time period	*n*	*M*	*SD*	*n*	*M*	*SD*
ITT						
Baseline	21	19.05	5.89	23	16.13	6.00
Day 14 postsurgery	21	14.71	7.91	23	12.43	7.61
PI						
Baseline	21	19.05	5.89	20	15.85	6.08
Day 14 postsurgery	21	14.71	7.91	20	13.00	8.00

Note. ITT = intention to treat; PI = performed intervention.

Discussion

Contrary to our hypothesis, patients who performed daily activities writing prior to bariatric surgery had a better inflammatory response and higher collagen content in the wound compared with those who performed expressive writing about upsetting events. This is opposite to the results of previous expressive writing studies performed with healthy participants who had experimentally induced punch biopsy wounds (Koschwanez et al., 2013; Weinman et al., 2008). We believe the primary reason for this discrepancy is that the surgical patients were about to face a major life stressor (surgery) whereas the healthy participants in previous studies were facing general life stress alone.

Patients in both groups experienced a significant reduction in perceived stress from before to after surgery, but there were no differences between the writing groups. The two previous studies on expressive writing and wound healing found no differences between groups in perceived stress either, despite finding expressive writing improved wound healing (Koschwanez et al., 2013; Weinman et al., 2008). The effects of expressive writing on wound healing therefore do not appear to operate via reduced stress. Several theories have been proposed for how expressive writing improves health outcomes, including disinhibition theory (the expression of inhibited thoughts leads to stress reduction). In a meta-analysis, inhibition theory and stress reduction received very little support while exposure theory (repeated exposure to thoughts and feelings about an event eventually leads to their extinction) received the most support (Frattaroli, 2006). In this study, surgery was still in the future, so the cessation of thoughts about it would have been extremely unlikely.

Though expressive writing patients were not instructed to write specifically about their surgery, many of the expressive writing patients wrote at least one essay on this upcoming event. These

emotive surgery-focused essays often discussed patient fears and concerns about the procedure and about whether or not they would be able to manage the postsurgical lifestyle changes. In contrast, daily activities writing patients included activities and plans for their upcoming surgery which is not surprising given the timing of the intervention often coincided with the week prior to surgery. All daily activities essays included activities and plans pertaining to the upcoming surgery, ranging from very basic (i.e., having an Optifast shake) to extensive plans (e.g., listing items to bring to the hospital, outlining tasks to complete at work prior to taking sick leave). The act of planning for surgery may have helped patients prepare for surgery. How these results fit within the current literature, clinical implications and future work are discussed below.

Although emotionally expressive writing has been shown to improve physical, psychological, and overall function outcomes in healthy and clinical populations, wide variability has been observed (Frattaroli, 2006). Previous studies investigating the effects of expressive writing on postsurgical recovery have found mixed results. Compared with nonwriting controls, male patients awaiting bladder papilloma resection surgery (Solano et al., 2003) and transurethral prostate resection (Solano et al., 2007) who wrote expressively about their upcoming surgeries and hospital experiences had shorter hospital stays, less distress, and fewer postoperative symptoms. However, these effects were only apparent in a subset of patients: patients high in alexithymia and patients with low surgical risk/low distress, respectively. Expressive writing has not been recommended as a presurgical stress management intervention for women with breast cancer undergoing active treatment (de Moor et al., 2008). In this study, patients were asked to write expressively about their cancer experience and impending surgery (intervention) or to write descriptively about different health behaviors (control). No significant differences between writing groups were found for overall distress, perceived stress, sleep disturbance, or pain following the intervention. These null findings were partially attributed to implementing the writing intervention in the middle of a chronic stressor.

Expressive writing about upcoming major high-risk surgery may not be helpful, especially for highly anxious individuals. Bariatric patients are a group who have typically been obese for a number of years and for whom bariatric surgery is a major life event. Patients do have positive expectations about life after bariatric surgery, as reflected in the literature (Homer, Tod, Thompson, Allmark, & Goyder, 2016) as well as in the patient essays. However, it was not surprising that many patients in the expressive writing group considered their upcoming surgery a traumatic event and a source of considerable anxiety, not only from the surgical procedure itself, but also from the significant dietary and lifestyle changes postsurgery. A similar observation was made in an expressive writing intervention with surgical patients awaiting transurethral prostate resection: patients disclosed feelings of uncertainty and fear toward the operation in their essays (Solano et al., 2007).

Writing objectively about day-to-day activities often serves as a control topic in expressive writing interventions (Frattaroli, 2006); however, it may be beneficial for people facing current stressors. Illustrative of this, primary caregivers of older adults who wrote objectively about how they spent their time experienced improvements in physical and mental health outcomes, including anxiety, while those who wrote expressively about caregiver stress and burden did not (Mackenzie et al., 2007). Providing stressed and busy caregivers time to better plan their activities may have offered a form of problem-focused coping. A similar mechanism may underpin the results of the current study: providing patients an opportunity to spend time planning their activities leading up to surgery may help them feel better prepared. Evidence suggests that expressive writing is most effective following a traumatic event, not during it (Pennebaker & Chung, 2007) which helps explain why expressive writing may not have produced the anticipated results in both these studies. The inclusion of third group who do not write at all could help to provide a neutral comparison to emotional expression and daily activities writing groups in future research.

A strength of this study was the use physiological markers of early inflammation as well as later healing. Daily activities writing resulted in both increased TNF-α and hydroxyproline which provides greater confidence in our findings. In addition, increased TNF-α suggests the proinflammatory response may be a mechanism by which writing affects wound healing. This is supported by previous research that reported less presurgical stress was associated with higher proinflammatory cytokines and matrix metalloproteinase-9 (Broadbent et al., 2003). Significant between-groups differences for the interleukin cytokines were not observed; however, this may be due to the small sample size coupled with high variability in biological samples. In particular, several of the IL-6 samples exceeded detection limits, further reducing the sample size.

The optimal timing of an expressive writing intervention to aid wound healing remains unclear. The reason we designed the study to have the intervention performed 2 weeks prior to surgery was that this timing was used in both previous studies showing that expressive writing could improve wound healing in healthy participants (Koschwanez et al., 2013; Weinman et al., 2008). Most patients in the current study completed the intervention 1 week prior to surgery and results suggest expressive writing did not produce the anticipated improvements in wound healing. Expressive writing may be better suited for the postoperative period, after the stress of surgery is over. A recent study with healthy participants found relaxation performed after skin damage was just as effective at improving healing as relaxation performed prior to skin damage compared with a no-relaxation control group (Robinson, Jarrett, & Broadbent, 2015).

Previous work suggests cortisol can be reduced by pre- and postsurgical practice of relaxation with guided imagery (Holden-Lund, 1988). To investigate whether expressive writing could lower cortisol levels, wound fluid was collected over the 24-hr postsurgery period to allow site-specific cortisol measurement over the full circadian cycle. However, cortisol levels did not differ between expressive writing and daily activities writing groups. High variability in cortisol levels, coupled with a small sample size, may have contributed to null findings. These stress hormone results align with the findings that there were no significant between group differences in perceived stress as a result of the intervention.

Some limitations of the study must be acknowledged. Due to participant withdrawal, scheduling issues, time and funding constraints, the final sample size was less than our target. With 54 completers, there was 29% attrition based on the enrolled sample ($n = 76$) and 40% based on the original target size ($n = 90$).

Nevertheless, the sample size for hydroxyproline (ITT, $n = 43$; PI, $n = 36$) was similar to two previous studies on writing and wound healing in healthy samples ($n = 40$ and $n = 36$, respectively; Koschwanez et al., 2013; Weinman et al., 2008) and this study serves as an important pilot for a larger trial.

Wound healing consists of three broad, overlapping phases: inflammation, proliferation, and maturation. The wound drains and PTFE tube wound models assessed aspects of the inflammatory and proliferative phases by measuring proinflammatory cytokine production and collagen deposition, respectively. These models do not permit evaluation of reepithelization, a key component in wound closure. Though our results suggest the presurgical writing intervention affected some features of wound healing, it cannot be assumed that this intervention affected all aspects of tissue repair. It is therefore unclear how this translates to a practical difference in clinical outcomes.

Surgery-specific anxiety was not measured in the current study. Administering a simple visual analogue scale to measure preoperative anxiety (Kindler, Harms, Amsler, Ihde-Scholl, & Scheidegger, 2000) at baseline and again prior to surgery might have improved our understanding of whether expressive writing increased presurgical anxiety, or daily activities writing decreased it. Additionally, this intervention was only conducted in bariatric patients undergoing weight-loss surgery, limiting the generalizability of these results to other types of surgery. For instance, bariatric patients have the expectation of significant improvements in their lives and may approach their upcoming surgery differently from those with cancer for whom it is not known whether cure is possible and where significant uncertainly will remain after their operation.

In conclusion, writing emotionally about traumatic life events prior to surgery did not increase hydroxyproline at the wound site 2 weeks after surgery in a bariatric surgery sample. Therefore, expressive writing cannot be recommended as a way to improve healing for this group. Future research needs to investigate whether these results can be replicated in a larger sample of bariatric surgery patients, as well as other surgical groups. Research could also investigate whether altering the timing of the expressive writing intervention in relation to surgery changes the results. An unexpected finding was that writing factually about daily activities resulted in an increased inflammatory response and more hydroxyproline at the wound site. Planning is a problem-focused activity that involves thinking about how to deal with a stressor (Carver, Scheier, & Weintraub, 1989). Often, people write down plans, or make lists of things to do. This is considered a productive coping strategy to deal directly with controllable aspects of a stressful situation. Moreover, list making is included as a strategy in stress management interventions, which have been shown to improve immune status in patient populations (Antoni, 2003). Future research could investigate the merit of a presurgical planning intervention in reducing presurgical anxiety and improving wound healing.

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