

## Original Article

# Internet-based continuing care is associated with improved quality of life in elderly patients with pressure injuries treated with negative pressure wound therapy: a propensity score-matched mediation study

Qian Ren<sup>1</sup>, Jianfang Sun<sup>2</sup>, Chengcheng Cai<sup>1</sup>, Jingtao Wang<sup>1</sup>, Bingzhao Yang<sup>3</sup>, Qin Zhang<sup>4</sup>

<sup>1</sup>Department of Orthopedics, Lanzhou Second People's Hospital, Lanzhou 730000, Gansu, China; <sup>2</sup>Department of Nursing, Lanzhou Second People's Hospital, Lanzhou 730000, Gansu, China; <sup>3</sup>Department of General Surgery, Lanzhou 730000, Gansu, China; <sup>4</sup>Department of Ophthalmology, Lanzhou Second People's Hospital, Lanzhou 730000, Gansu, China

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**Abstract:** Objective: To investigate the association of negative pressure wound therapy (NPWT) combined with internet-based continuing care with pain, negative emotions, and quality of life in older patients with pressure injuries (PI), and to explore the serial mediation pathway of pain reduction, emotional improvement, and quality-of-life improvement. Methods: This retrospective propensity score-matched cohort study included 403 elderly PI patients receiving NPWT. Patients treated from July 2020 to July 2023 received routine discharge care (control, n = 194), whereas those treated from August 2023 to July 2025 received internet-based continuing care (experimental, n = 209). After 1:1 propensity score matching, 109 matched pairs were analyzed. VAS, SAS, and SDS were assessed at baseline, 4 weeks, and 8 weeks. SF-36 PCS and MCS were assessed at baseline and 8 weeks. Linear mixed-effects models and serial mediation analysis were performed. Results: After matching, baseline balance was substantially improved. The experimental group showed lower follow-up VAS, SAS, and SDS scores and greater improvements in PCS (5.28 vs. 2.22) and MCS (6.06 vs. 3.05) (all P < 0.001). In the PCS model, the chain-mediated pathway "treatment mode → pain improvement → anxiety improvement → PCS improvement" was significant (ind3 = -0.685, 95% CI -1.315 to -0.232). Indirect effects were not significant in the MCS model. Conclusion: NPWT combined with internet-based continuing care was associated with greater reductions in pain, greater improvements in negative emotions, and better quality of life. Pain reduction may improve physical quality of life partly through anxiety alleviation.

**Keywords:** Negative pressure wound therapy, internet-based continuing care, pressure injury, pain, negative emotions, quality of life, serial mediation, propensity score matching

## Introduction

Pressure injury (PI) refers to localized damage to the skin and/or underlying soft tissue, usually occurring over bony prominences, resulting from sustained pressure or pressure combined with shear forces. PI is one of the most common and challenging complications among elderly patients with long-term bed rest, limited mobility, malnutrition, or multiple chronic diseases [1, 2]. With the accelerating aging of the population, the burden of PI among older adults has become increasingly prominent. In elderly

patients, pressure injuries are often characterized by delayed wound healing, repeated infection, persistent exudation, pain, and impaired physical function. Beyond local tissue damage, PI also imposes a substantial psychological and social burden. Persistent wound-related pain may aggravate anxiety and depression, while negative emotions may further reduce treatment adherence, sleep quality, activity level, and confidence in recovery, ultimately leading to deterioration in health-related quality of life [3, 4]. Therefore, the management of PI in elderly patients should not be limited to wound repair

alone, but should also address pain control, emotional support, functional recovery, and quality-of-life improvement.

Negative pressure wound therapy (NPWT) has been widely used in the treatment of acute and chronic wounds in recent years. By applying controlled sub-atmospheric pressure to the wound bed, NPWT can promote granulation tissue formation, reduce wound edema, remove exudate, improve local blood perfusion, and provide a relatively stable wound healing environment. Existing studies have shown that NPWT can accelerate the healing process of pressure injuries and improve wound-related outcomes [5-7]. However, most previous studies have mainly focused on local wound indicators, such as wound area reduction, granulation tissue growth, exudate control, and healing rate. For elderly PI patients, especially those requiring long-term treatment after discharge, wound healing is only one aspect of recovery. Pain intensity, psychological status, self-care ability, and quality of life are also important patient-centered outcomes. In clinical practice, many patients show improvement during hospitalization but encounter challenges after discharge, including insufficient professional guidance, delayed wound assessment, poor adherence to home care, and inadequate psychological support. These problems indicate that NPWT alone may not fully meet the continuous and multidimensional care needs of elderly PI patients.

In recent years, the development of internet-based continuing care has provided a new approach for post-discharge management. Through mobile communication platforms, remote follow-up, online health education, wound image feedback, and real-time nurse-patient communication, internet-based continuing care can extend professional nursing services from the hospital to the home, thereby enhancing the continuity of care. Previous studies have suggested that digital health interventions and telemedicine-based care may improve chronic wound management, enhance patient education, and facilitate timely clinical guidance after discharge [8-10]. Nevertheless, current evidence remains insufficient in several aspects. First, relatively few studies have focused specifically on elderly patients with pressure injuries, who usually have poor mobility, multiple comorbidities, and higher dependence on fam-

ily caregivers. Second, the combined application of NPWT and internet-based continuing care has not been fully evaluated in this population. Third, existing research has mainly assessed clinical effectiveness from the perspective of wound healing or general follow-up outcomes, while limited attention has been paid to whether this integrated care model can simultaneously improve pain intensity, negative emotions, and quality of life.

From a theoretical perspective, pain, emotional status, and quality of life are closely interrelated in patients with pressure injuries. Chronic wound-related pain can increase psychological stress through sleep disturbance, activity restriction, fear of wound deterioration, and feelings of helplessness. Anxiety and depression may in turn amplify pain perception, reduce treatment adherence, and impair functional recovery, thereby further lowering quality of life [11, 12]. However, previous studies have not systematically clarified whether improvement in pain after intervention can be sequentially transmitted to quality-of-life improvement through the alleviation of negative emotions. In other words, the potential pathway of “pain improvement → emotional improvement → quality-of-life improvement” remains unclear. Clarifying this mechanism would help identify key intervention targets at different stages of care and provide a theoretical basis for developing integrated wound management strategies that combine wound treatment, pain management, emotional support, and continuing care.

In light of these research gaps, the present study aimed to investigate the association of NPWT combined with internet-based continuing care with pain intensity, negative emotions, and quality of life in elderly patients with pressure injuries using a propensity score-matched retrospective cohort. In addition, we further explored whether pain improvement and emotional improvement played a serial mediating role in the relationship between treatment mode and quality-of-life improvement. We hypothesized that, compared with NPWT plus routine discharge care, NPWT combined with internet-based continuing care would be associated with greater reductions in pain, anxiety, and depression, as well as greater improvement in quality of life. We also hypothesized that pain improvement would contribute to

quality-of-life improvement partly through the sequential alleviation of negative emotions.

## Materials and methods

### Study design

This was a retrospective comparative cohort study employing propensity score matching (PSM) to balance baseline differences between groups. Patients were not prospectively assigned to different treatment solutions, nor did they randomly choose between two concurrent options. All patients received NPWT according to the same clinical treatment protocol. The difference between groups was the post-discharge nursing care model, which was determined by the routine clinical practice implemented in our hospital during different time periods.

### Sample size calculation

Referring to the existing literature [12] and the principles of sample size estimation for cross-sectional studies [13], assuming a 65% improvement rate, a tolerance error of 10%, and a confidence level of 95% ( $Z = 1.96$ ), the minimum required sample size was calculated to be 88 patients. Accounting for an estimated 40% sample attrition due to PSM and 10% missing data, a final target of at least 176 patients was planned.

### Study population

A total of 403 elderly patients with severe pressure injuries admitted to our hospital between July 2020 and July 2025 were enrolled. According to the chronological implementation of post-discharge care models, patients treated from July 2020 to July 2023 who received NPWT plus routine discharge care were classified as the control group. Since August 2023, internet-based continuing care was introduced as part of the post-discharge management program; therefore, patients treated from August 2023 to July 2025 received NPWT plus internet-based continuing care and were classified as the experimental group. Thus, the grouping was based on the actual nursing care model available during each study period, rather than random allocation or patient preference. Before NPWT and the corresponding post-discharge nursing care were implemented in routine clinical practice, patients and/or their

guardians were informed by the clinical and nursing team about the purpose, procedures, potential benefits, limitations, and precautions of NPWT and post-discharge care. Because this was a retrospective study based on anonymized clinical records and follow-up data, the requirement for individual informed consent was waived by the ethics committee (Figure S1). This study was reviewed and approved by Lanzhou Second People's Hospital Medical Ethics Committee.

The inclusion criteria were as follows: (1) age  $\geq 60$  years; (2) diagnosed with Stage III or IV pressure injury (PI) according to the National Pressure Ulcer Advisory Panel (NPUAP) staging system [14]; (3) receiving negative pressure wound therapy (NPWT); (4) clear consciousness and capable of cooperating with the assessment; and (5) complete baseline and follow-up assessment data at the prespecified time points.

The exclusion criteria were as follows: (1) severe cardiac, hepatic, or renal insufficiency, or end-stage malignancy; (2) psychiatric disorders or cognitive impairment precluding cooperation; (3) active wound bleeding or uncontrolled local infection; (4) wounds unsuitable for NPWT or with major NPWT contraindications, such as malignant wounds, exposed major blood vessels or organs without adequate protective coverage, untreated osteomyelitis, or extensive necrotic tissue not adequately debrided; (5) death during hospitalization or discharge against medical advice; and (6) loss to follow-up after discharge or severely incomplete clinical data.

### Clinical data collection

The following data were collected from the hospital electronic medical record system and follow-up database: (1) Demographic data: age, sex, education level, medical payment method. (2) Anthropometric and vital sign measurements: body mass index (BMI), systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), respiratory rate (RR), body temperature. (3) Wound-related indicators: maximum wound area, wound depth, wound location (sacrum/hip/heel/other), PI stage (Stage III/IV), PI duration, wound bed tissue type (predominantly necrotic/slough/granulation/epithelialization), exudate amount (mild/

moderate/heavy), wound infection status. (4) Laboratory indicators: albumin (ALB), hemoglobin (Hb), C-reactive protein (CRP), white blood cell count (WBC). Fasting venous blood (5 mL) was collected in the early morning on the day after admission and analyzed using an automated biochemical analyzer (AU5800, Beckman Coulter, USA) and an automated hematology analyzer (XN-1000, Sysmex, Japan) following standardized procedures by the hospital clinical laboratory. (5) Behavioral and comorbidity data: smoking history (never/former/current), alcohol history (never/former/current), history of diabetes, history of hypertension.

#### *Intervention protocol*

**Control group:** Patients received NPWT (using the VSD vacuum sealing drainage system, Weihai Shichuang Medical Technology Co., Ltd., China) with negative pressure set at -125 mmHg in continuous suction mode. Dressings were changed every 3-5 days for a total treatment duration of 8 weeks [15]. At discharge, routine discharge instructions were provided, including wound care precautions, positioning advice, nutritional support guidance, and outpatient follow-up arrangements. No proactive follow-up was conducted after discharge.

**Experimental group:** In addition to the NPWT regimen identical to the control group, patients received internet-based continuing care after discharge: (1) an individualized electronic health record was established, and a dedicated nurse established one-on-one contact with the patient or family member via the WeChat platform; (2) weekly video follow-ups were conducted to assess wound healing progress, pain status, and psychological state, with individualized care plans adjusted based on assessment results; (3) health education content related to PI care, pain management, emotional regulation, and functional exercise was regularly pushed (in text, image, and short-video formats, 3-5 times per week); (4) patients could consult nursing questions at any time via text or voice message, with nurses responding and providing professional guidance within 2 hours; (5) a monthly online patient education lecture was organized covering nutrition management, pain coping strategies, and emotional self-regulation methods.

#### *Measurement instruments*

**Pain intensity:** Assessed using the Visual Analog Scale (VAS) [16] at three time points: T0 (admission), T1 (4 weeks of intervention), and T2 (8 weeks of intervention). The VAS includes a 100 mm horizontal line, where the 0 mm end indicates no pain and the 100 mm end denotes the most severe pain. Patients indicated their perceived pain intensity on the line, and the measured value in millimeters was recorded. In our investigation, the scores are transformed into a 0-10 scale for the result.

**Negative emotions:** Evaluation of anxiety and depression by means of Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS) [17] at time points T0, T1 and T2. Each scale consists of 20 items, with scores on a 4-point scale (1-4). The raw score is subsequently multiplied by 1.25 and rounded to the nearest integer to get the standardized score, which varies from 25 to 100 and shows a higher degree of anxiety or depression.

**Quality of life:** Quality of life was assessed using the 36-Item Short Form Health Survey version 2 (SF-36) [18] at T0 and T2 only. SF-36 was not assessed at T1 because the questionnaire contains multiple dimensions and repeated administration at short intervals would have increased the assessment burden for elderly patients. The SF-36 comprises eight dimensions: Physical Functioning (PF), Role Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VT), Social Functioning (SF), Role Emotional (RE), and Mental Health (MH). The Physical Component Summary (PCS) and Mental Component Summary (MCS) scores were calculated using the Ware 1994 US general population norm-based scoring method and transformed to T-scores (mean = 50, SD = 10). Higher scores indicate better quality of life.

#### *Outcome measures*

**Primary outcomes:** (1) Change in PCS (T2-T0, delta-PCS), reflecting the change in physical quality of life after 8 weeks of intervention; (2) Change in MCS (T2-T0, delta-MCS), reflecting the change in mental quality of life after 8 weeks of intervention.

**Secondary outcomes:** (1) Changes in VAS scores across the three time points (T0, T1, T2);

(2) Changes in SAS and SDS scores across the three time points; (3) Changes in each SF-36 dimension score (T2-T0). Because SF-36 was assessed only at T0 and T2, 4-week PCS, MCS, and SF-36 dimension scores were not available and were not included as outcome measures.

### *Statistical analysis*

All statistical analyses were performed using R 4.5.1 and SPSS 27.0. Normally distributed continuous variables are presented as mean  $\pm$  standard deviation, with between-group comparisons using independent-samples t-tests. Non-normally distributed continuous variables are presented as median (interquartile range), with between-group comparisons using the Mann-Whitney U test. Categorical variables are presented as frequency (percentage), with between-group comparisons using the chi-squared test or Fisher's exact test. A 1:1 propensity score matching (PSM) was performed to reduce baseline imbalance between groups. Propensity scores were estimated using a multivariable logistic regression model, with treatment mode as the dependent variable and 26 baseline covariates as independent variables, including demographic characteristics, vital signs, wound-related indicators, laboratory parameters, behavioral factors, and comorbidities. Nearest-neighbor matching without replacement was conducted with a caliper width of 0.02. Covariate balance before and after matching was assessed using standardized mean differences (SMDs), with  $\text{SMD} < 0.10$  indicating good balance. Balance was further visualized using a Love plot and propensity score density plots. Linear mixed-effects models (LMM) were used to compare VAS, SAS, and SDS scores between groups across the three time points, with group, time point, and their interaction included as fixed effects and patient ID as a random intercept. Between-group comparisons of delta values were performed using independent-samples t-tests. Pearson correlation analysis was used to assess associations among key variables, with results displayed using a GGally matrix plot. Serial mediation analysis was conducted using PROCESS Model 6 [13, 14], with treatment mode as the independent variable (X), deltaVAS (T1-T0) as the first mediator (M1), deltaSAS/deltaSDS (T2-T1) as the second mediator (M2), and deltaPCS/deltaMCS (T2-T0) as

the outcome variable (Y). Path coefficients and 95% bootstrap confidence intervals (5,000 resamples) for indirect effects were estimated using ordinary least squares (OLS) path analysis with matched-pair bootstrap procedures to preserve the PSM matching structure. Sensitivity analyses have been carried out: (1) by re-running the serial mediation model with the inclusion of age, wound area, albumin, CRP, PI stage and wound infection as covariates; (2) using E-values [19] to estimate the possible effect of unobserved confounding on the indirect effects; and (3) by changing the PSM caliper to 0.01 and 0.05 and re-running the serial mediation model to examine the stability. Subgroup analyses have also been performed in different strata according to PI stage (Stage II/III/IV), albumin level (divided into two categories by the median), age (divided into two categories by the median) and wound infection (yes/no). Within each subgroup, PROCESS Model 6 was independently fitted with 2,000 bootstrap resamples, and the consistency of the chain-mediated indirect effect (ind3) across subgroups was examined. Multivariable linear regression was used to identify independent predictors of deltaPCS, with variables significant at  $P < 0.10$  in univariate analysis entered along with core variables (treatment mode, deltaVAS, deltaSAS). The variance inflation factor (VIF) was used to assess collinearity. The assignments and coding of the selected variables used in the statistical analyses are provided in [Table S1](#). All hypothesis tests were two-sided, with  $P < 0.05$  considered statistically significant.

## **Results**

### *Baseline characteristics and PSM balance*

Before matching, 403 elderly patients with PI were enrolled, including 209 patients in the experimental group and 194 patients in the control group. After 1:1 nearest-neighbor PSM with a caliper width of 0.02, 109 matched pairs were generated and included in the final matched analysis. Before matching, several baseline variables were imbalanced between groups, including age, SBP, heart rate, respiratory rate, body temperature, wound depth, and WBC count. After matching, baseline balance was substantially improved, and no statistically significant differences remained between groups. The SMD of the propensity score

decreased from 0.9895 before matching to 0.0052 after matching. Most covariates achieved good balance, while a few variables showed modest residual imbalance and were further considered in sensitivity analyses (**Table 1; Figure 1**).

#### *Pain, emotions, and quality of life comparisons*

**Pain intensity:** LMM analysis revealed a significant group \* time interaction effect ( $F = 14.667$ ,  $P < 0.001$ ). At T0, VAS scores did not differ significantly between groups ( $P = 0.724$ ). The experimental group had significantly lower VAS scores than the control group at both T1 (4.18 vs. 5.10) and T2 (3.02 vs. 4.40, both  $P < 0.001$ ) (**Figure 2**). **Anxiety:** The group \* time interaction was significant ( $F = 3.339$ ,  $P = 0.036$ ). At T0, SAS scores did not differ significantly between groups ( $P = 0.303$ ). The experimental group had significantly lower SAS scores at T1 ( $P = 0.011$ ) and T2 ( $P < 0.001$ ) than the control group (**Figure 3A**). **Depression:** Although the group \* time interaction did not reach statistical significance ( $F = 2.326$ ,  $P = 0.099$ ), between-group comparisons at each time point showed that SDS scores did not differ significantly at T0 ( $P = 0.075$ ), and the experimental group had significantly lower SDS scores at both T1 and T2 compared with the control group (both  $P < 0.001$ ) (**Figure 3B**). **Quality of life:** At T0, PCS and MCS scores did not differ significantly between groups ( $P = 0.264$ ;  $P = 0.333$ ). The experimental group showed significantly greater improvements than the control group in both deltaPCS (5.28 vs. 2.22,  $P < 0.001$ ) and deltaMCS (6.06 vs. 3.05,  $P < 0.001$ ) (**Figure 4A, 4B**). Improvements in all eight SF-36 dimensions were significantly greater in the experimental group than in the control group (PF, BP, VT, SF: all  $P < 0.001$ ; RP:  $P = 0.013$ ; GH:  $P = 0.006$ ; RE:  $P = 0.001$ ; MH:  $P = 0.002$ ) (**Figure 5**).

#### *Correlation analysis*

Pearson correlation analysis showed that treatment mode was significantly negatively correlated with deltaVAS ( $r = -0.233$ ,  $P < 0.001$ ) and significantly positively correlated with deltaPCS ( $r = 0.282$ ,  $P < 0.001$ ) and deltaMCS ( $r = 0.252$ ,  $P < 0.001$ ). deltaVAS showed a moderate positive correlation with deltaSAS ( $r = 0.429$ ,  $P < 0.001$ ), and deltaSAS showed a strong positive correlation with deltaPCS ( $r = 0.537$ ,  $P < 0.001$ ) (**Figure 6**). No significant correlations were observed between deltaVAS and

deltaPCS ( $r = 0.050$ ,  $P = 0.466$ ) or between deltaVAS and deltaSDS ( $r = 0.064$ ,  $P = 0.346$ ).

#### *Serial mediation analysis*

In the PCS model, all path coefficients were statistically significant: a negative effect of treatment mode on deltaVAS ( $a_1 = -0.991$ ,  $P < 0.001$ ), a positive effect of deltaVAS on deltaSAS ( $d_{21} = 2.138$ ,  $P < 0.001$ ), a negative effect of deltaVAS on deltaPCS ( $b_1 = -0.380$ ,  $P = 0.012$ ), a positive effect of deltaSAS on deltaPCS ( $b_2 = 0.324$ ,  $P < 0.001$ ), and a significant direct effect ( $c' = 3.420$ ,  $P < 0.001$ ), indicating partial mediation. Indirect effect 1 (Treatment  $\rightarrow$  deltaVAS  $\rightarrow$  deltaPCS) was significant (ind1 = 0.377, bootstrap 95% CI [0.034, 0.832]); indirect effect 3, the chain-mediated path (Treatment  $\rightarrow$  deltaVAS  $\rightarrow$  deltaSAS  $\rightarrow$  deltaPCS), was significant (ind3 = -0.685, bootstrap 95% CI [-1.315, -0.232]); indirect effect 2 (Treatment  $\rightarrow$  deltaSAS  $\rightarrow$  deltaPCS) was not significant (ind2 = -0.057, 95% CI [-0.955, 0.809]). The total effect was significant ( $c = 3.055$ , 95% CI [1.688, 4.394]) (**Figure 7A**). In the MCS model, none of the indirect effects reached statistical significance (ind1 = 0.109, 95% CI [-0.306, 0.564]; ind3 = 0.002, 95% CI [-0.026, 0.038]), although the total effect remained significant ( $c = 3.018$ , 95% CI [1.523, 4.495]) (**Figure 7B**).

#### *Sensitivity analysis*

In the covariate-adjusted model (adjusted for age, maximum wound area, albumin, CRP, PI stage, and wound infection), the indirect effect estimates for the PCS model were consistent with those from the unadjusted model: adjusted ind1 = 0.426 (95% CI [0.081, 0.879]) and ind3 = -0.683 (95% CI [-1.326, -0.213]) both remained statistically significant (**Figure 8**). In the MCS model, all indirect effects remained non-significant after adjustment. In the PSM caliper substitution analysis, the chain-mediated effect (ind3) was consistently significant across all three caliper values (0.01, 0.02, 0.05; all CIs excluded 0). ind1 marginally crossed 0 at caliper = 0.01 (-0.006, 0.752), but the direction of effect was consistent, and significance was retained at caliper = 0.02 and 0.05, indicating general robustness to matching parameter specification. E-value analysis showed that the point-estimate E-values for ind1 (0.38) and ind3 (0.69) in the PCS model, and the CI-limit E-values (0.03 and 0.23,

# NPWT with internet-based care and mediation effects in elderly PI patients

**Table 1.** Baseline characteristics of the study participants before and after propensity score matching

| Variable                          | Before PSM           |                           |                        |         |        | After PSM            |                           |                        |         |        |
|-----------------------------------|----------------------|---------------------------|------------------------|---------|--------|----------------------|---------------------------|------------------------|---------|--------|
|                                   | Control<br>(n = 194) | Experimental<br>(n = 209) | Statistic              | P value | SMD/V  | Control<br>(n = 109) | Experimental<br>(n = 109) | Statistic              | P value | SMD/V  |
| Age (years)                       | 75.2 ± 7.0           | 73.6 ± 6.1                | t = 2.360              | 0.019   | -0.236 | 74.0 ± 6.7           | 74.2 ± 6.0                | t = -0.320             | 0.749   | 0.043  |
| BMI (kg/m <sup>2</sup> )          | 21.5 ± 2.9           | 21.9 ± 3.1                | t = -1.355             | 0.176   | 0.135  | 21.4 ± 2.7           | 21.8 ± 3.3                | t = -0.841             | 0.401   | 0.114  |
| SBP (mmHg)                        | 135.6 ± 15.0         | 132.8 ± 14.0              | t = 1.973              | 0.049   | -0.197 | 133.9 ± 16.0         | 132.9 ± 13.9              | t = 0.488              | 0.626   | -0.066 |
| DBP (mmHg)                        | 78.1 ± 9.7           | 79.7 ± 9.3                | t = -1.632             | 0.103   | 0.163  | 78.6 ± 10.1          | 78.7 ± 9.4                | t = -0.070             | 0.945   | 0.009  |
| Heart rate (bpm)                  | 79.1 ± 10.4          | 76.2 ± 8.3                | t = 3.096              | 0.002   | -0.311 | 76.4 ± 9.3           | 77.4 ± 8.5                | t = -0.849             | 0.397   | 0.115  |
| Respiratory rate (breaths/min)    | 19.4 ± 2.7           | 18.6 ± 2.7                | t = 2.618              | 0.009   | -0.261 | 19.0 ± 2.8           | 19.1 ± 2.6                | t = -0.277             | 0.782   | 0.037  |
| Temperature (°C)                  | 36.5 ± 0.4           | 36.7 ± 0.4                | t = -4.393             | < 0.001 | 0.439  | 36.6 ± 0.4           | 36.6 ± 0.3                | t = -0.527             | 0.598   | 0.071  |
| Max wound area (cm <sup>2</sup> ) | 18.8 ± 7.9           | 17.6 ± 7.7                | t = 1.472              | 0.142   | -0.147 | 17.0 ± 7.4           | 17.3 ± 7.6                | t = -0.275             | 0.784   | 0.037  |
| Wound depth (cm)                  | 2.2 ± 0.9            | 2.0 ± 0.8                 | t = 2.884              | 0.004   | -0.289 | 2.1 ± 0.9            | 2.0 ± 0.8                 | t = 0.214              | 0.831   | -0.029 |
| PI duration (months)              | 4.6 ± 2.7            | 4.5 ± 2.4                 | t = 0.436              | 0.663   | -0.044 | 4.5 ± 2.5            | 4.7 ± 2.4                 | t = -0.554             | 0.580   | 0.075  |
| Albumin (g/L)                     | 32.6 ± 4.5           | 32.8 ± 4.3                | t = -0.486             | 0.627   | 0.049  | 32.3 ± 4.5           | 32.4 ± 4.1                | t = -0.154             | 0.878   | 0.021  |
| Hemoglobin (g/L)                  | 108.1 ± 15.8         | 109.5 ± 14.9              | t = -0.930             | 0.353   | 0.093  | 108.0 ± 15.4         | 108.1 ± 14.3              | t = -0.041             | 0.967   | 0.006  |
| CRP (mg/L)                        | 27.6 ± 14.5          | 26.3 ± 12.7               | t = 0.922              | 0.357   | -0.092 | 25.2 ± 13.7          | 27.3 ± 13.7               | t = -1.132             | 0.259   | 0.153  |
| WBC (×10 <sup>9</sup> /L)         | 9.1 ± 2.7            | 8.5 ± 2.6                 | t = 2.550              | 0.011   | -0.255 | 8.8 ± 2.7            | 8.7 ± 2.5                 | t = 0.231              | 0.817   | -0.031 |
| Wound location                    |                      |                           | χ <sup>2</sup> = 0.408 | 0.939   | 0.032  |                      |                           | χ <sup>2</sup> = 1.874 | 0.599   | 0.093  |
| Sacrum                            | 95 (49.0%)           | 106 (50.7%)               |                        |         |        | 53 (48.6%)           | 62 (56.9%)                |                        |         |        |
| Hip                               | 41 (21.1%)           | 39 (18.7%)                |                        |         |        | 24 (22.0%)           | 20 (18.3%)                |                        |         |        |
| Heel                              | 31 (16.0%)           | 35 (16.7%)                |                        |         |        | 18 (16.5%)           | 13 (11.9%)                |                        |         |        |
| Other                             | 27 (13.9%)           | 29 (13.9%)                |                        |         |        | 14 (12.8%)           | 14 (12.8%)                |                        |         |        |
| Sex                               |                      |                           | χ <sup>2</sup> = 0.183 | 0.669   | 0.021  |                      |                           | χ <sup>2</sup> = 0.019 | 0.892   | 0.009  |
| Male                              | 85 (43.8%)           | 96 (45.9%)                |                        |         |        | 49 (45.0%)           | 50 (45.9%)                |                        |         |        |
| Female                            | 109 (56.2%)          | 113 (54.1%)               |                        |         |        | 60 (55.0%)           | 59 (54.1%)                |                        |         |        |
| Smoking history                   |                      |                           | χ <sup>2</sup> = 0.456 | 0.796   | 0.034  |                      |                           | χ <sup>2</sup> = 0.267 | 0.875   | 0.035  |
| Never                             | 140 (72.2%)          | 157 (75.1%)               |                        |         |        | 77 (70.6%)           | 80 (73.4%)                |                        |         |        |
| Former                            | 34 (17.5%)           | 33 (15.8%)                |                        |         |        | 23 (21.1%)           | 20 (18.3%)                |                        |         |        |
| Current                           | 20 (10.3%)           | 19 (9.1%)                 |                        |         |        | 9 (8.3%)             | 9 (8.3%)                  |                        |         |        |
| Alcohol history                   |                      |                           | χ <sup>2</sup> = 0.243 | 0.886   | 0.025  |                      |                           | χ <sup>2</sup> = 0.660 | 0.719   | 0.055  |
| Never                             | 162 (83.5%)          | 178 (85.2%)               |                        |         |        | 92 (84.4%)           | 88 (80.7%)                |                        |         |        |
| Former                            | 21 (10.8%)           | 21 (10.0%)                |                        |         |        | 12 (11.0%)           | 16 (14.7%)                |                        |         |        |
| Current                           | 11 (5.7%)            | 10 (4.8%)                 |                        |         |        | 5 (4.6%)             | 5 (4.6%)                  |                        |         |        |

# NPWT with internet-based care and mediation effects in elderly PI patients

|                  |             |             |                  |       |       |             |                  |       |       |
|------------------|-------------|-------------|------------------|-------|-------|-------------|------------------|-------|-------|
| Wound bed tissue |             |             | $\chi^2 = 0.676$ | 0.879 | 0.041 |             | $\chi^2 = 2.156$ | 0.541 | 0.099 |
| Necrotic         | 24 (12.4%)  | 23 (11.0%)  |                  |       |       | 13 (11.9%)  | 15 (13.8%)       |       |       |
| Slough           | 70 (36.1%)  | 70 (33.5%)  |                  |       |       | 37 (33.9%)  | 39 (35.8%)       |       |       |
| Granulation      | 92 (47.4%)  | 106 (50.7%) |                  |       |       | 55 (50.5%)  | 47 (43.1%)       |       |       |
| Epithelial       | 8 (4.1%)    | 10 (4.8%)   |                  |       |       | 4 (3.7%)    | 8 (7.3%)         |       |       |
| Exudate amount   |             |             | $\chi^2 = 0.511$ | 0.775 | 0.036 |             | $\chi^2 = 0.401$ | 0.818 | 0.043 |
| Mild             | 41 (21.1%)  | 50 (23.9%)  |                  |       |       | 29 (26.6%)  | 25 (22.9%)       |       |       |
| Moderate         | 98 (50.5%)  | 104 (49.8%) |                  |       |       | 51 (46.8%)  | 53 (48.6%)       |       |       |
| Heavy            | 55 (28.4%)  | 55 (26.3%)  |                  |       |       | 29 (26.6%)  | 31 (28.4%)       |       |       |
| Education        |             |             | $\chi^2 = 4.961$ | 0.026 | 0.111 |             | $\chi^2 = 0.022$ | 0.881 | 0.010 |
| ≥ High school    | 43 (22.2%)  | 67 (32.1%)  |                  |       |       | 32 (29.4%)  | 31 (28.4%)       |       |       |
| < High school    | 151 (77.8%) | 142 (67.9%) |                  |       |       | 77 (70.6%)  | 78 (71.6%)       |       |       |
| Insurance type   |             |             | $\chi^2 = 0.719$ | 0.396 | 0.042 |             | $\chi^2 = 0.000$ | 1.000 | 0.000 |
| Insured          | 182 (93.8%) | 200 (95.7%) |                  |       |       | 103 (94.5%) | 103 (94.5%)      |       |       |
| Self-pay         | 12 (6.2%)   | 9 (4.3%)    |                  |       |       | 6 (5.5%)    | 6 (5.5%)         |       |       |
| PI stage         |             |             | $\chi^2 = 0.716$ | 0.699 | 0.042 |             | $\chi^2 = 1.581$ | 0.454 | 0.085 |
| Stage II         | 46 (23.7%)  | 56 (26.8%)  |                  |       |       | 28 (25.7%)  | 35 (32.1%)       |       |       |
| Stage III        | 92 (47.4%)  | 99 (47.4%)  |                  |       |       | 47 (43.1%)  | 47 (43.1%)       |       |       |
| Stage IV         | 56 (28.9%)  | 54 (25.8%)  |                  |       |       | 34 (31.2%)  | 27 (24.8%)       |       |       |
| Wound infection  |             |             | $\chi^2 = 0.652$ | 0.419 | 0.040 |             | $\chi^2 = 0.548$ | 0.459 | 0.050 |
| Yes              | 60 (30.9%)  | 57 (27.3%)  |                  |       |       | 35 (32.1%)  | 30 (27.5%)       |       |       |
| No               | 134 (69.1%) | 152 (72.7%) |                  |       |       | 74 (67.9%)  | 79 (72.5%)       |       |       |
| Diabetes         |             |             | $\chi^2 = 0.726$ | 0.394 | 0.042 |             | $\chi^2 = 0.530$ | 0.467 | 0.049 |
| Yes              | 70 (36.1%)  | 67 (32.1%)  |                  |       |       | 37 (33.9%)  | 32 (29.4%)       |       |       |
| No               | 124 (63.9%) | 142 (67.9%) |                  |       |       | 72 (66.1%)  | 77 (70.6%)       |       |       |
| Hypertension     |             |             | $\chi^2 = 0.536$ | 0.464 | 0.036 |             | $\chi^2 = 0.000$ | 1.000 | 0.000 |
| Yes              | 111 (57.2%) | 112 (53.6%) |                  |       |       | 58 (53.2%)  | 58 (53.2%)       |       |       |
| No               | 83 (42.8%)  | 97 (46.4%)  |                  |       |       | 51 (46.8%)  | 51 (46.8%)       |       |       |

Note: Continuous variables are presented as mean ± standard deviation and were compared using independent-samples t-tests. Categorical variables are presented as n (%) and were compared using chi-squared tests or Fisher's exact tests, as appropriate. The corresponding statistical values, *P* values, and balance indices are reported. SMD was used for continuous variables, and Cramér's V was used for categorical variables. PSM, propensity score matching; SMD, standardized mean difference; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; CRP, C-reactive protein; WBC, white blood cell count; PI, pressure injury.

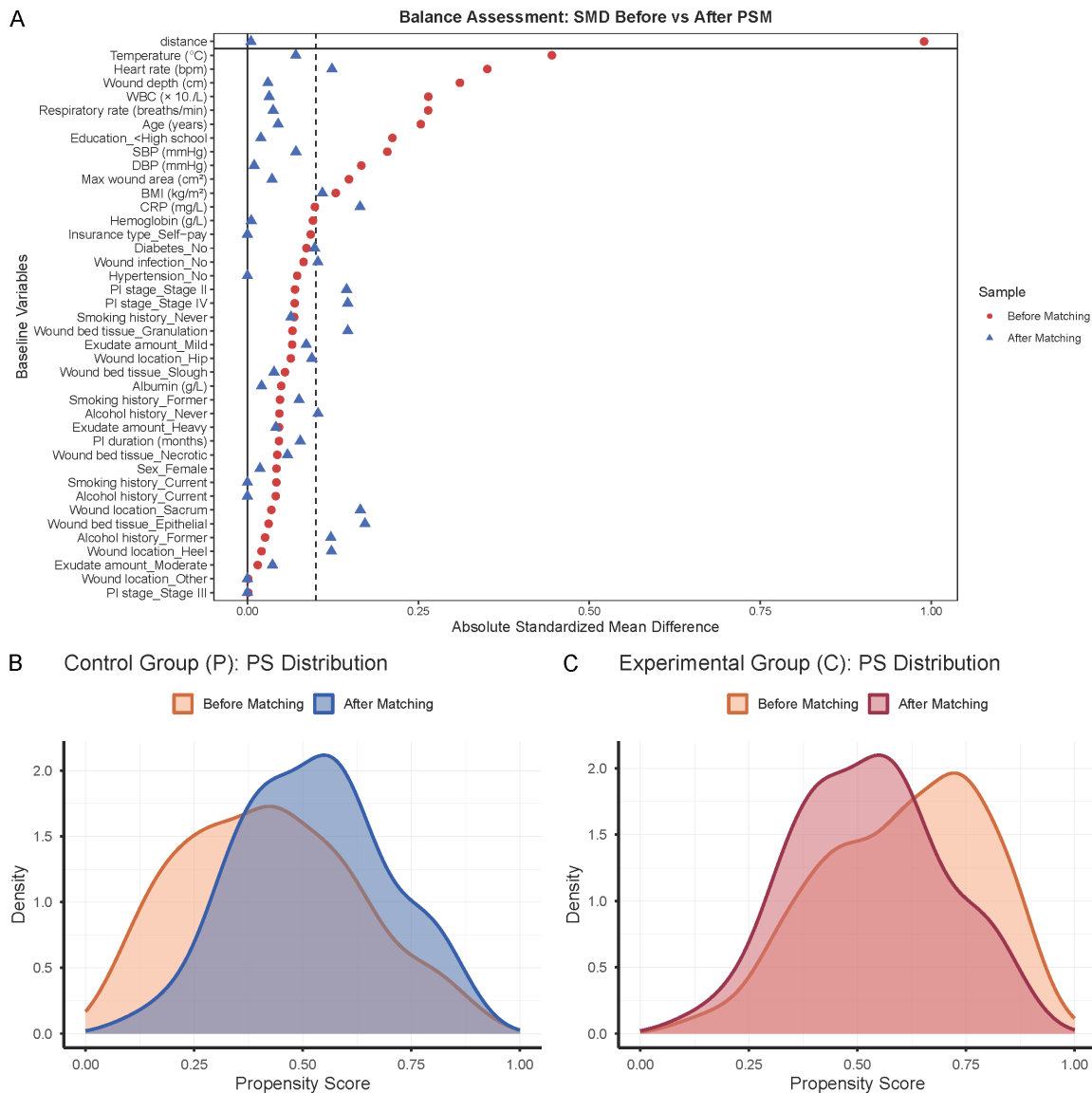


**Figure 1.** Covariate balance before and after propensity score matching. A. Love plot showing absolute standardized mean differences before and after matching. B, C. Propensity score distributions in the control and experimental groups before and after matching. The dashed line indicates SMD = 0.10. Note: PSM, propensity score matching; SMD, standardized mean difference; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; CRP, C-reactive protein; WBC, white blood cell count; PI, pressure injury; ALB, albumin; Hb, hemoglobin.

respectively), were all substantially below the conventional threshold of 2.0, indicating that no unmeasured confounder of plausible strength could fully explain the observed indirect effects. All E-values in the MCS model were  $\leq 0.31$ , yielding the same conclusion.

#### Subgroup analysis

Across all four stratification variables, the direction of the chain-mediated effect (ind3) was consistently negative, in agreement with the

main analysis, suggesting a robust direction of effect (**Figure 9A**). ind3 remained statistically significant in the following subgroups: Stage III PI (-0.946, 95% CI [-2.128, -0.240]), low albumin (-0.349, [-1.006, -0.019]), high albumin (-1.232, [-2.149, -0.367]), younger age (-0.604, [-1.400, -0.056]), older age (-0.720, [-1.633, -0.108]), wound infection present (-1.054, [-2.244, -0.140]), and wound infection absent (-0.580, [-1.266, -0.111]). ind3 CIs crossed 0 in Stage II PI (-0.623, [-1.663, 0.279]) and Stage IV PI (-0.334, [-1.314, 0.160]), but the direction

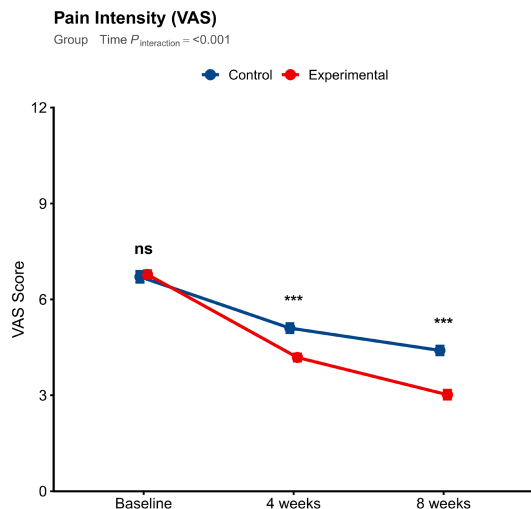


**Figure 2.** Changes in pain intensity after propensity score matching. VAS scores were compared between the control and experimental groups at T0, T1, and T2. Data are presented as mean  $\pm$  SEM. Note: VAS, Visual Analog Scale; SEM, standard error of the mean; PSM, propensity score matching; LMM, linear mixed-effects model; NPWT, negative pressure wound therapy; T0, baseline; T1, 4 weeks; T2, 8 weeks. \*\*\* $P < 0.001$ ; ns, not significant.

remained consistent; this may be attributable to the smaller sample sizes in these subgroups ( $n = 63$  and  $61$ , respectively). Indirect effects 1 (ind1) and 2 (ind2) were non-significant in most subgroups (**Figure 9B**). Total effects were generally significant across subgroups, with the exception of the low-albumin subgroup ( $1.463$ ,  $[-0.438, 3.432]$ ). Overall, the chain-mediated effect was directionally consistent and of comparable magnitude across clinical subgroups, with no evidence of substantial effect modification.

#### Multivariable regression analysis

To identify independent predictors of deltaPCS (T2-T0, 8-week physical quality of life improvement), univariate linear regression was first conducted across 33 candidate variables. Only treatment mode ( $\beta = 3.055$ , 95% CI  $[1.668, 4.443]$ ,  $P < 0.001$ ) and deltaSAS (T2-T1, anxiety improvement) ( $\beta = 0.274$ , 95% CI  $[0.218, 0.330]$ ,  $P < 0.001$ ) were significantly associated with deltaPCS. The remaining baseline variables, including age ( $P = 0.172$ ), BMI ( $P = 0.231$ ), wound area ( $P = 0.134$ ), wound depth ( $P = 0.750$ ), PI duration ( $P = 0.216$ ), albumin ( $P = 0.358$ ), hemoglobin ( $P = 0.796$ ), CRP ( $P = 0.733$ ), WBC ( $P = 0.760$ ), PI stage (all stages  $P > 0.05$ ), wound infection ( $P = 0.434$ ), diabetes

( $P = 0.920$ ), and hypertension ( $P = 0.642$ ), were not statistically significant (**Figure 10A**). deltaVAS (T1-T0, pain improvement) was also non-significant in univariate analysis ( $\beta = -0.035$ ,  $P = 0.809$ ), suggesting that its direct effect on deltaPCS is limited and likely operates through the chain-mediated pathway (via deltaSAS), consistent with the mediation analysis results.

Before entering the variables significant at  $P < 0.10$  in univariate analysis (treatment mode, deltaSAS, wound area, albumin) and the core variable (deltaVAS) into the multivariable model, collinearity diagnostics were performed. VIF analysis showed that all candidate variables had VIF values between 1.07 and 1.32, with the maximum VIF of only 1.32, well below the commonly used threshold of 5, indicating no problematic collinearity (**Figure 10B**).

In the final multivariable linear regression model, four variables were retained as independent predictors of deltaPCS: (1) treatment mode (experimental vs. control,  $\beta = 3.358$ , 95% CI  $[2.231, 4.485]$ ,  $P < 0.001$ ), indicating that, all else being equal, patients receiving NPWT combined with internet-based continuing care had an average PCS improvement 3.36 points greater than controls after 8 weeks; (2) deltaSAS ( $\beta = 0.327$ , 95% CI  $[0.270, 0.384]$ ,  $P < 0.001$ ), meaning that each 1-point reduction in anxiety between 4 and 8 weeks was associated with an additional 0.33-point increase in deltaPCS; (3) deltaVAS ( $\beta = -0.424$ , 95% CI  $[-0.717, -0.130]$ ,  $P = 0.005$ ), i.e., each 1-point reduction in pain between 0 and 4 weeks was associated with an additional 0.42-point increase in deltaPCS; and (4) wound area ( $\beta = 0.095$ , 95% CI  $[0.021, 0.169]$ ,  $P = 0.012$ ), with each 1  $\text{cm}^2$  increase in initial wound area associated with a 0.10-point greater deltaPCS, potentially reflecting greater room for improvement in patients with larger wounds (**Figure 10C**). Notably, albumin was no longer significant after adjustment ( $P = 0.492$ ) and was excluded from the final model. The overall model was highly significant ( $F = 41.82$ ,  $P < 0.001$ ), with an adjusted  $R^2$  of 0.429, explaining 42.9% of the total variance in deltaPCS.

#### Discussion

In this propensity score-matched retrospective cohort study, we investigated the association of NPWT combined with internet-based con-

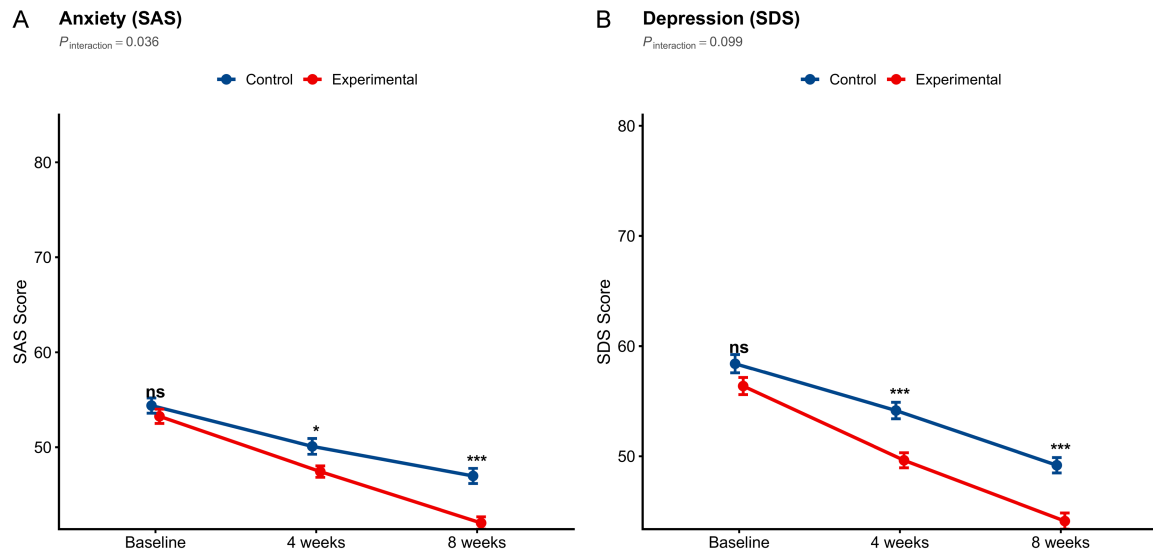


**Figure 3.** Changes in negative emotions after propensity score matching. (A) SAS scores and (B) SDS scores were compared between groups at T0, T1, and T2. Data are presented as mean  $\pm$  SEM. Note: SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale; SEM, standard error of the mean; PSM, propensity score matching; LMM, linear mixed-effects model; NPWT, negative pressure wound therapy; T0, baseline; T1, 4 weeks; T2, 8 weeks. \*P < 0.05; \*\*\*P < 0.001; ns, not significant.

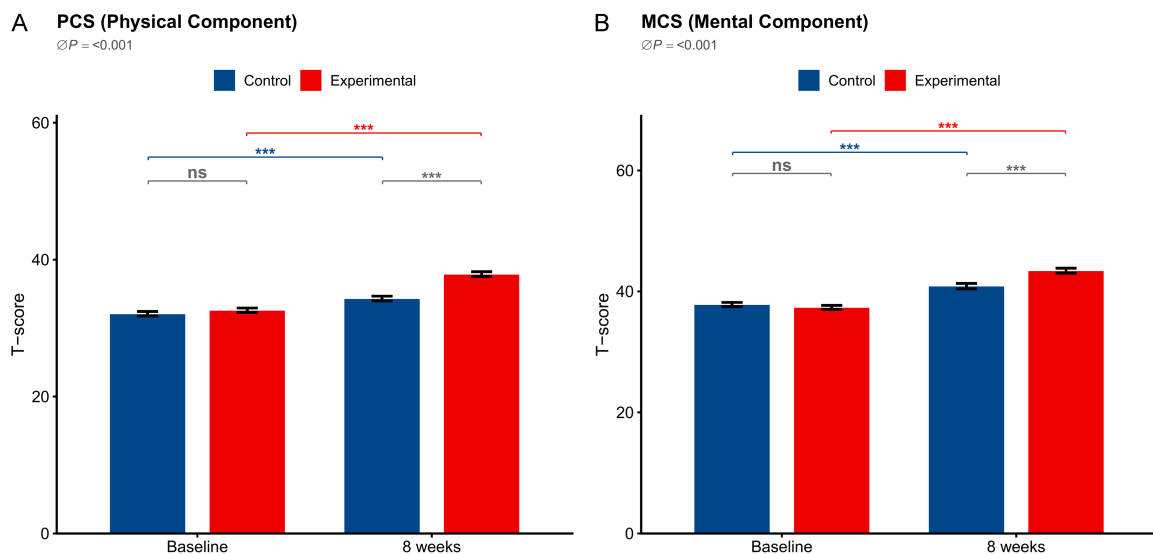


**Figure 4.** Changes in quality-of-life summary scores after propensity score matching. (A) PCS and (B) MCS scores were compared between groups at T0 and T2. Data are presented as mean  $\pm$  SEM. Note: PCS, Physical Component Summary; MCS, Mental Component Summary; SF-36, 36-Item Short Form Health Survey; SEM, standard error of the mean; PSM, propensity score matching; NPWT, negative pressure wound therapy; T0, baseline; T2, 8 weeks. \*\*\*P < 0.001; ns, not significant.

tinuing care with pain intensity, negative emotions, and quality of life in elderly patients with severe PI. In addition, a serial mediation model was used to explore the potential pathway linking pain improvement, emotional improvement, and quality-of-life improvement. The main findings were as follows. First, compared with the

control group, the experimental group showed greater reductions in pain intensity, anxiety, and depression, as well as greater improvements in PCS, MCS, and SF-36 dimension scores. Second, the serial mediation analysis suggested that pain reduction was associated with improvement in physical quality of life part-

## NPWT with internet-based care and mediation effects in elderly PI patients

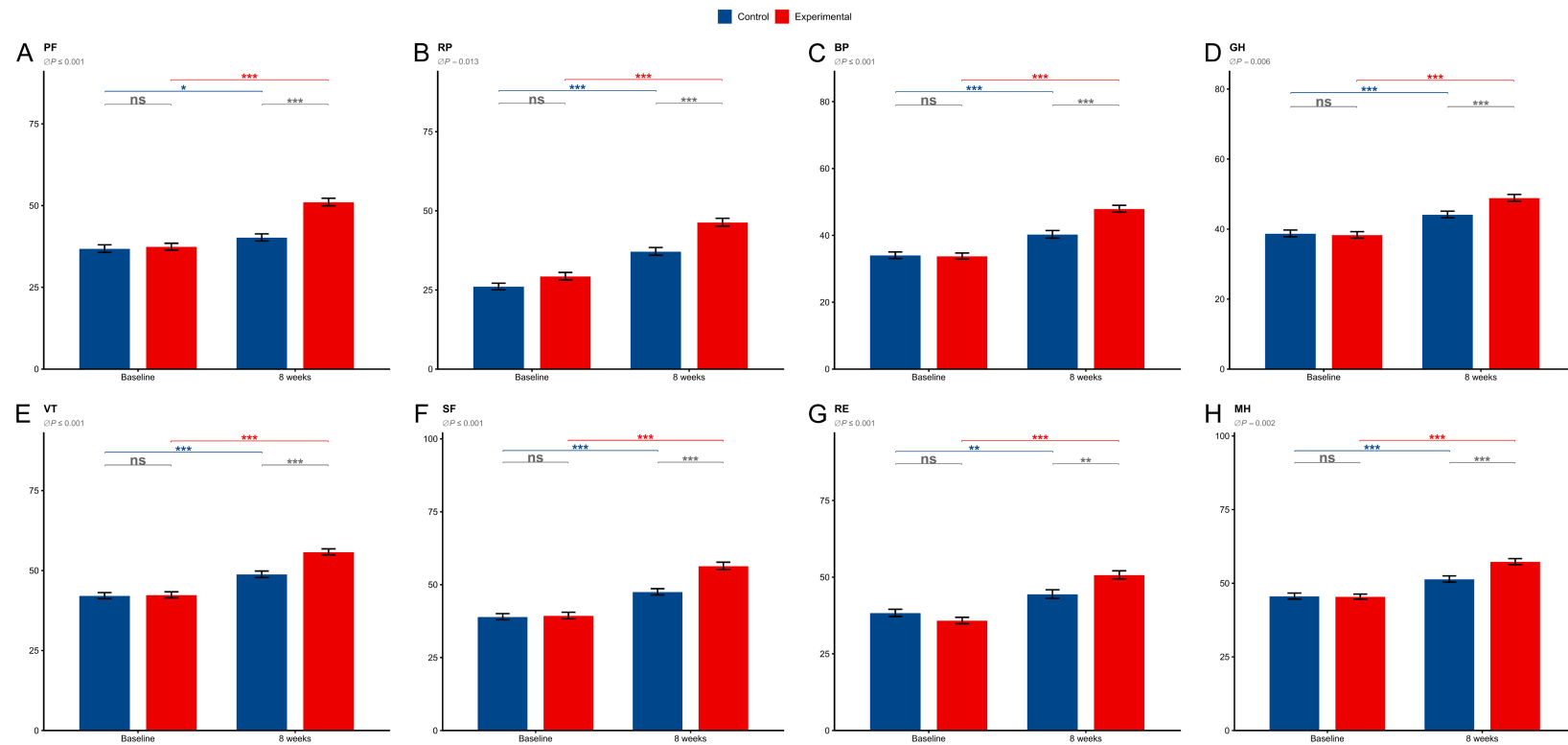


**Figure 5.** Changes in SF-36 scores after propensity score matching. Eight SF-36 dimensions were compared between groups at T0 and T2. Data are presented as mean  $\pm$  SEM. Note: SF-36, 36-Item Short Form Health Survey; PF, Physical Functioning; RP, Role Physical; BP, Bodily Pain; GH, General Health; VT, Vitality; SF, Social Functioning; RE, Role Emotional; MH, Mental Health; SEM, standard error of the mean; PSM, propensity score matching; NPWT, negative pressure wound therapy; T0, baseline; T2, 8 weeks. \* $P < 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ ; ns, not significant.

## NPWT with internet-based care and mediation effects in elderly PI patients

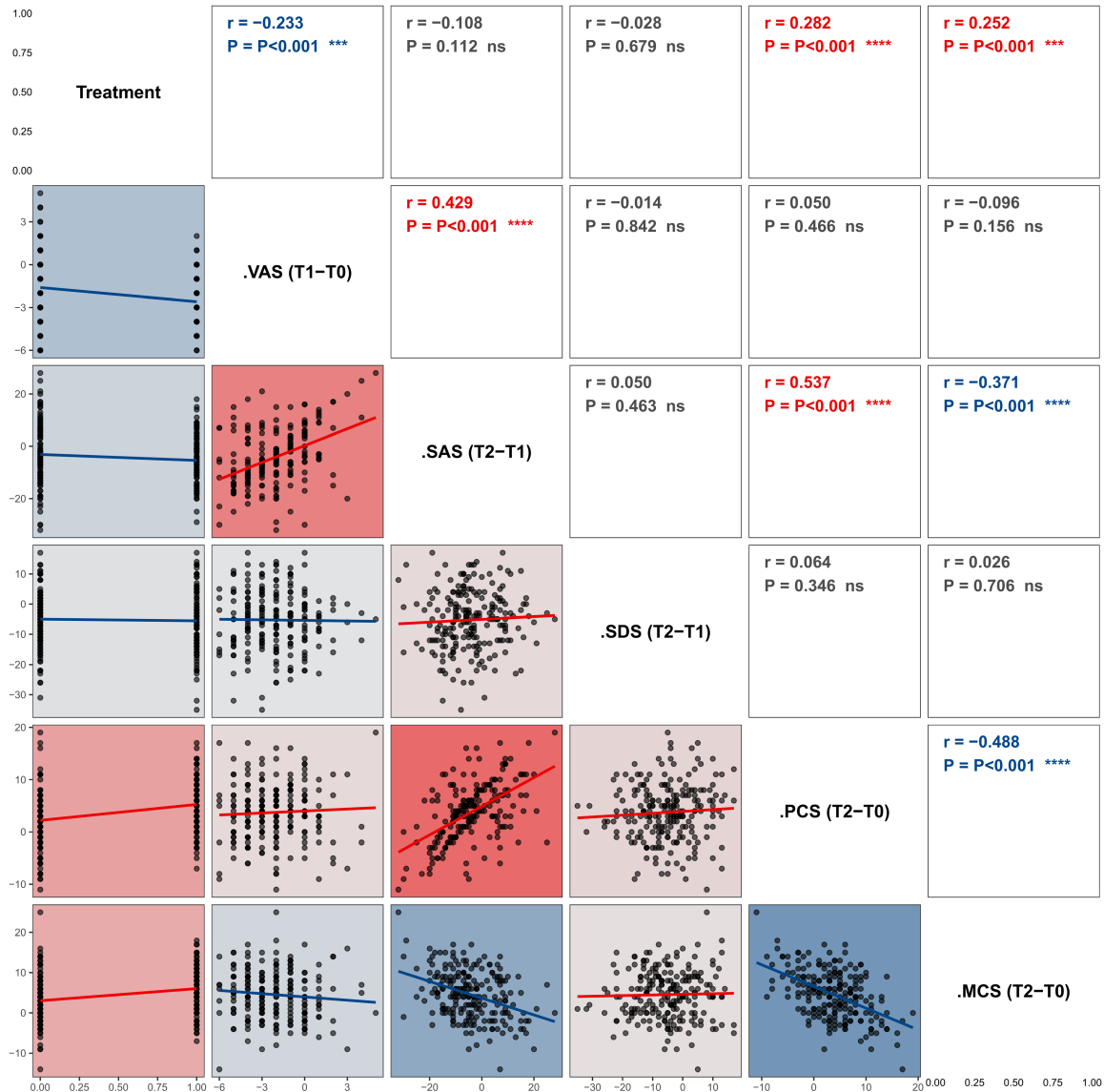


**Figure 6.** Correlation matrix of key study variables. Pearson correlation coefficients were used to assess associations among treatment mode, changes in pain, negative emotions, and quality-of-life scores. Note: VAS, Visual Analog Scale; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale; PCS, Physical Component Summary; MCS, Mental Component Summary; QoL, quality of life. \* $P < 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ .

ly through the alleviation of anxiety, supporting a partial mediation pathway. Third, sensitivity analysis and subgroup analysis showed that the direction and magnitude of the mediated effect were generally stable across clinically relevant subgroups, including PI stage, albumin level, age group, and wound infection status, without obvious evidence of substantial effect modification. These findings indicate that the combined model of NPWT and internet-based continuing care may provide benefits beyond local wound repair by improving patient-centered outcomes. Related work by Kapp et al.

[19] also supports the clinical rationale of nurse-led remote wound consultation and highlights the potential value of remote nursing support in pressure injury management.

In the present study, the mean  $\Delta$ PCS in the experimental group was 3.06 points higher than that in the control group ( $P < 0.001$ ), suggesting not only statistical significance but also potential clinical relevance. Gronkvist et al. [20] estimated that the minimal clinically important difference of the SF-36 PCS ranged from 2.62 to 4.69 points in patients with chronic pain. The

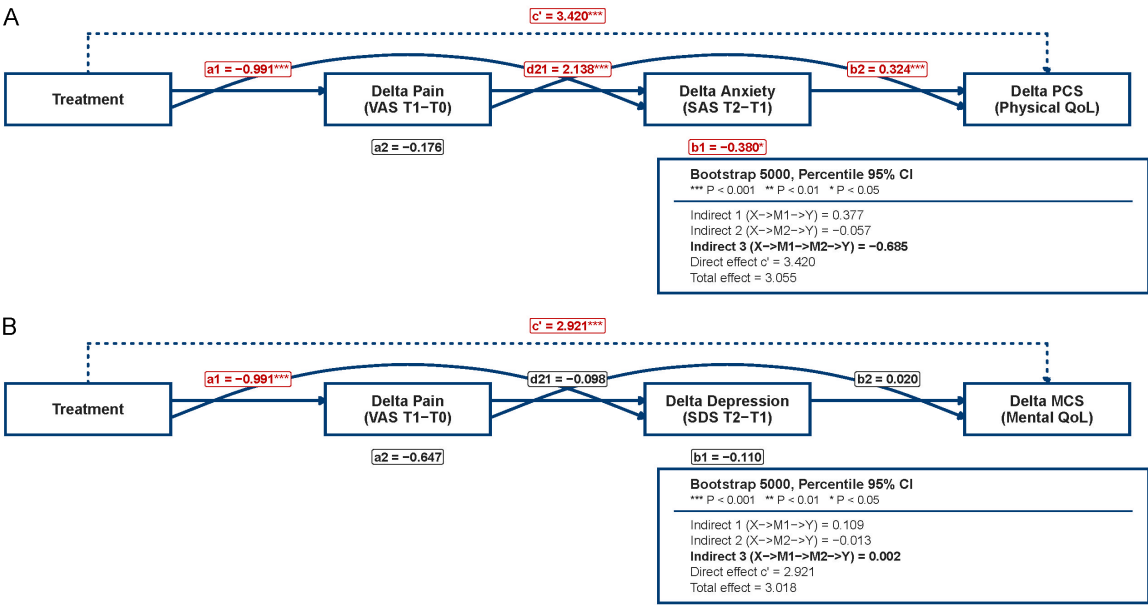


**Figure 7.** Serial mediation models for quality-of-life improvement. (A) PCS model and (B) MCS model. Solid lines indicate statistically significant paths, and dashed lines indicate non-significant paths. Path coefficients are unstandardized regression coefficients. Note: VAS, Visual Analog Scale; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale; PCS, Physical Component Summary; MCS, Mental Component Summary; NPWT, negative pressure wound therapy; T0, baseline; T1, 4 weeks; T2, 8 weeks. \* $P < 0.05$ ; \*\*\* $P < 0.001$ ; \*\*\*\* $P < 0.0001$ ; ns, not significant.

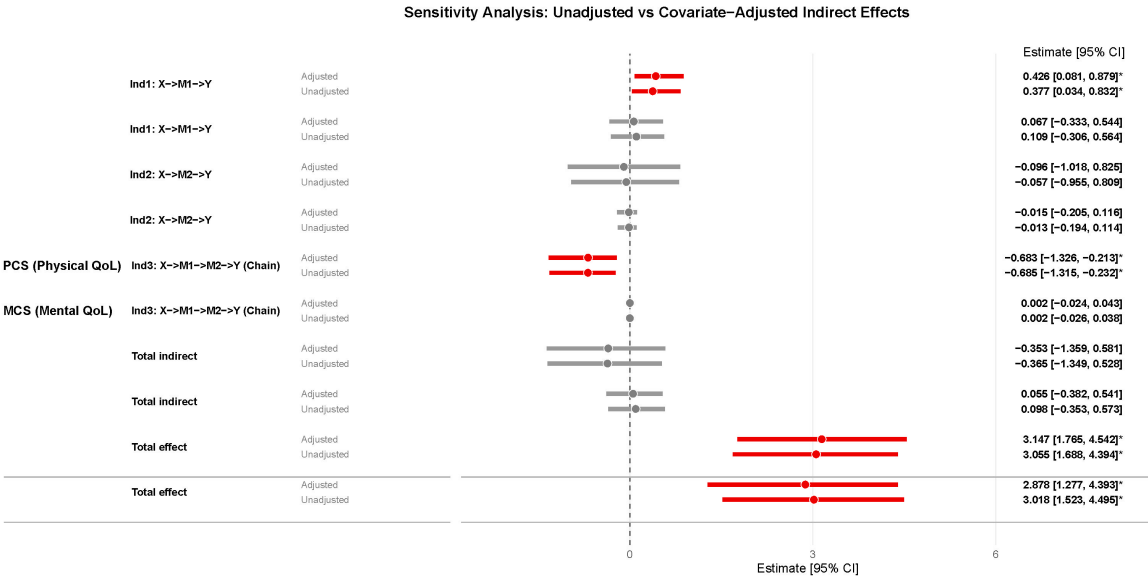


**Figure 8.** Sensitivity analysis of the serial mediation models. Indirect effects were compared between the unadjusted and covariate-adjusted models. Point estimates and 95% bootstrap confidence intervals are shown. Note: VAS, Visual Analog Scale; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale; PCS, Physical Component Summary; MCS, Mental Component Summary; CI, confidence interval; CRP, C-reactive protein; PI, pressure injury. Red points indicate significant effects; grey points indicate non-significant effects.

observed between-group difference in our study was within this range, indicating that the improvement in physical quality of life may be perceptible to patients. Previous studies have

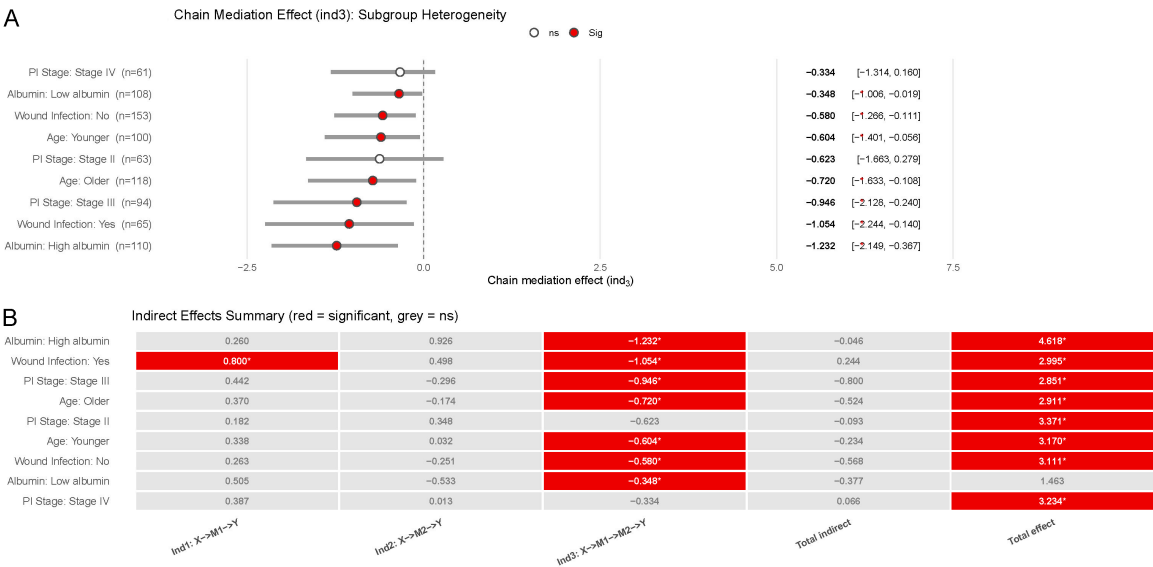


**Figure 9.** Subgroup analysis of the serial mediation effect. A. Forest plot of the chain-mediated indirect effect across clinical subgroups. B. Heatmap summary of indirect and total effects across subgroups. Note: VAS, Visual Analog Scale; SAS, Self-Rating Anxiety Scale; PCS, Physical Component Summary; PI, pressure injury; CI, confidence interval. Red cells or filled circles indicate significant effects; grey cells or empty circles indicate non-significant effects. \* indicates  $P < 0.05$  or 95% CI excluding 0.

shown that negative pressure wound therapy can promote wound healing by improving the wound microenvironment, facilitating granulation tissue formation, removing exudate, reducing edema, and decreasing the risk of infection. However, wound-centered treatment alone may not be sufficient to improve overall quality of life, because elderly patients with PI often experience persistent pain, restricted mobility, sleep disturbance, emotional distress, and impaired social participation. In this context, internet-based continuing care may complement NPWT by extending professional nursing guidance from the hospital to the home through remote follow-up, wound image feedback, real-time communication, and individualized health education. This may partly explain why the experimental group achieved better improvements in pain, emotions, and quality of life.

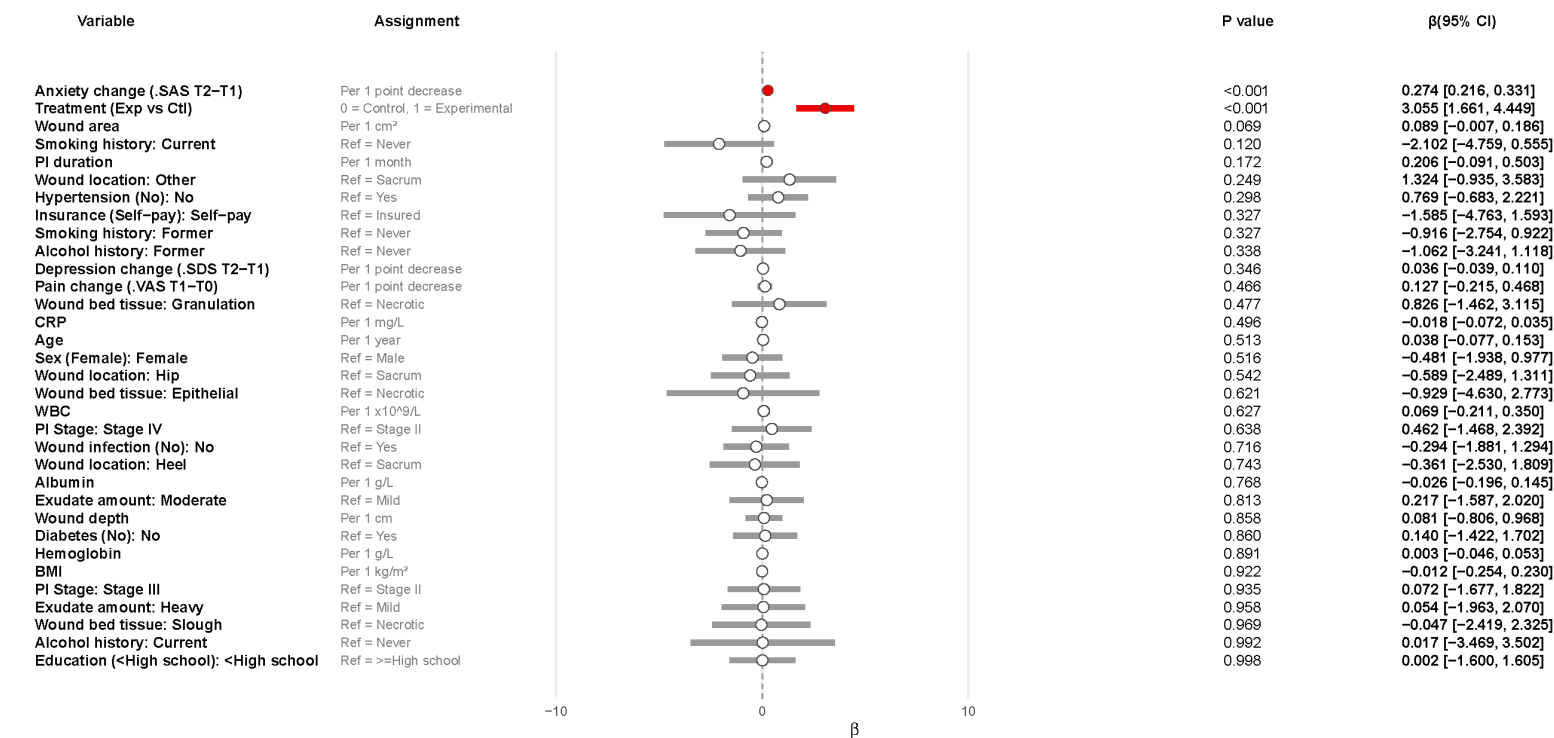
The main theoretical contribution of this study is the exploration of a serial mediation pathway. In the PCS model, treatment mode was associated with pain reduction from baseline to 4 weeks, which was further associated with anxiety reduction from 4 to 8 weeks, and finally with improvement in physical quality of life from baseline to 8 weeks. The chain-mediated effect was statistically significant ( $\text{ind3} = -0.685$ , bootstrap 95% confidence interval:

-1.315 to -0.232). Because changes in VAS and SAS were calculated as follow-up scores minus previous scores, negative values indicated reductions in pain and anxiety. Therefore, the negative indirect effect should be interpreted as a beneficial pathway in which greater pain reduction was associated with greater anxiety reduction and subsequent PCS improvement. Clinically, this finding suggests that early pain control may not only directly improve patient comfort but may also contribute to later functional recovery by reducing anxiety and interrupting the pain-anxiety cycle. From a potential biological and behavioral perspective, persistent pain may aggravate anxiety through activation of the hypothalamic-pituitary-adrenal axis, enhancement of central sensitization, and disturbance of monoamine neurotransmitter regulation, whereas anxiety may further amplify pain perception, reduce treatment adherence, worsen sleep quality, and delay functional recovery [21]. The present findings provide quantitative evidence supporting this clinically plausible pathway, although the observational nature of the study means that this pathway should be interpreted as associative rather than definitively causal.

In contrast, the serial mediation effect was not significant in the MCS model, suggesting that improvement in mental quality of life may not

NPWT with internet-based care and mediation effects in elderly PI patients

A Univariate Analysis: delta-PCS (Physical QoL)



B Multicollinearity Diagnosis (VIF)



NPWT with internet-based care and mediation effects in elderly PI patients

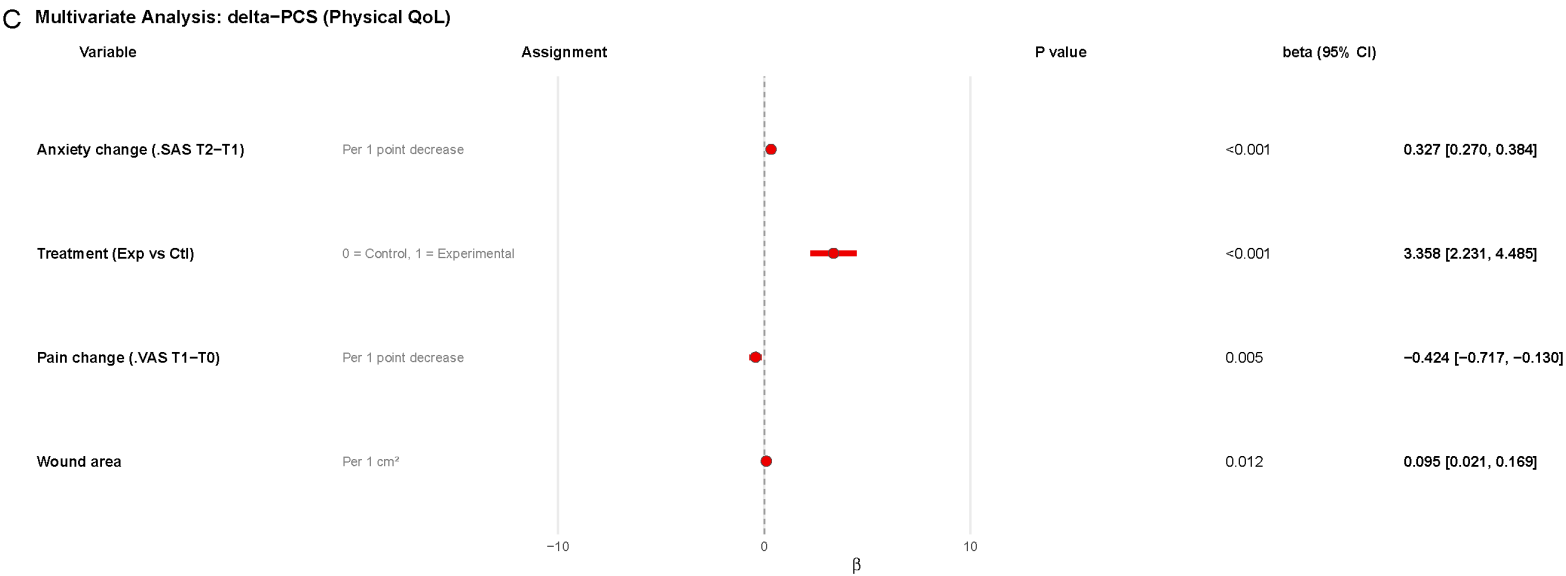


**Figure 10.** Regression analysis of predictors of  $\Delta$ PCS. A. Univariate regression analysis. B. Variance inflation factor analysis. C. Final multivariable regression model. Point estimates and 95% confidence intervals are shown. Note:  $\Delta$ PCS, change in Physical Component Summary score from T0 to T2; VAS, Visual Analog Scale; SAS, Self-Rating Anxiety Scale; PCS, Physical Component Summary; VIF, variance inflation factor; CI, confidence interval; BMI, body mass index; CRP, C-reactive protein; WBC, white blood cell count; PI, pressure injury. Red points indicate statistically significant predictors.

be primarily driven through the pain-emotion pathway examined in this study. Instead, the improvement in MCS appeared to be mainly associated with the direct effect of the care model ( $c' = 2.921$ ,  $P < 0.001$ ). One possible explanation is that MCS reflects broader psychological and social dimensions, including mental health, role emotional function, and social functioning. These dimensions may be more directly influenced by non-pain factors, such as perceived social support, quality of nurse-patient communication, self-efficacy, confidence in home wound care, and reduced uncertainty after discharge. These factors are core components of internet-based continuing care, including personalized online communication, regular emotional support, targeted health education, and timely feedback from nursing staff [22, 23]. In addition,  $\Delta$ MCS and  $\Delta$ PCS were significantly negatively correlated ( $r = -0.488$ ,  $P < 0.001$ ), suggesting that physical and mental components of quality of life may follow different trajectories and time windows during recovery. Therefore, future studies should further clarify whether mental quality-of-life improvement is more closely related to social support, self-efficacy, sleep quality, or perceived continuity of care.

From a clinical perspective, internet-based continuing care has several practical advantages, including low cost, high accessibility, real-time interaction, and suitability for patients with limited mobility. These features are particularly important for elderly patients with PI, who often require long-term wound observation, dressing guidance, repositioning support, nutritional advice, and caregiver participation after discharge. Huang et al. [24] reported that nurse-led remote wound care in super-aged individuals in Taiwan could improve access to wound care services and support chronic wound management. Similarly, in the present study, internet-based continuing care enabled the nursing team to monitor wound changes, provide individualized guidance, identify potential complications earlier, and adjust care plans dynamically. In addition, the subjective experience of patients should not be overlooked. Qualitative evidence has shown that PI can substantially affect psychological well-being, social functioning, dignity, and daily life [25]. Sen [26] reported that the annual cost of chronic wound prevention and treatment in the US Medicare population was considerable,

ranging from 28.1 to 96.8 billion US dollars. Considering the growing number of elderly patients with PI and the uneven distribution of medical resources in China, the combined model evaluated in the present study may be valuable for improving continuity of care and reducing the long-term burden of wound management.

Several potential mechanisms may explain the observed benefits. First, internet-based continuing care extends professional nursing support from the hospital to the home, allowing timely wound assessment, dressing guidance, and correction of improper care behaviors after discharge. This may help reduce wound-related discomfort and prevent deterioration, thereby contributing to pain relief. Second, continuous nurse-patient communication may reduce uncertainty, fear, and helplessness among elderly patients, which may help alleviate anxiety and depression. Third, regular follow-up and health education may improve adherence to NPWT-related precautions, nutritional support, repositioning, wound observation, and self-care behaviors. Fourth, caregiver education through online platforms may improve the quality of home-based wound care and reduce delays in responding to wound-related problems. These mechanisms may jointly promote functional recovery and quality-of-life improvement. The serial mediation analysis further supports this explanation by suggesting that pain improvement may be associated with subsequent emotional improvement, which in turn may contribute to better physical quality of life.

This study has several intrinsic limitations and caveats. First, this was a single-center retrospective cohort study, and the generalizability of the findings to other institutions or populations may be limited. Second, patients were grouped according to the chronological implementation of different post-discharge nursing care models rather than by random allocation. Although propensity score matching and covariate adjustment were used to reduce baseline imbalance, residual confounding from unmeasured variables cannot be completely ruled out. Third, quality of life was assessed using the SF-36 only at baseline and 8 weeks after intervention; therefore, 4-week PCS, MCS, and SF-36 dimension scores were not available. Fourth, VAS, SAS, SDS, and SF-36 are self-

reported or questionnaire-based measures, which may be affected by patient understanding, recall, and response bias, especially in elderly patients. Fifth, the mediation analysis was exploratory and based on observational data; therefore, the identified pathways should not be interpreted as definitive causal mechanisms. Sixth, although the temporal arrangement of the mediators, namely pain change from 0 to 4 weeks and emotional change from 4 to 8 weeks, helped to construct a clinically plausible sequence, the interaction between pain and emotional status may be bidirectional and partially overlapping. Finally, the follow-up period was relatively short, and future prospective multicenter studies with longer follow-up are needed to verify the long-term effects of NPWT combined with internet-based continuing care.

In summary, this study suggests that NPWT combined with internet-based continuing care is associated with greater improvements in pain alleviation, negative emotions, and quality of life among elderly patients with severe PI compared with NPWT plus routine discharge care. The serial mediation analysis further suggests a potential pathway in which early pain reduction is associated with later anxiety alleviation and subsequent improvement in physical quality of life. These findings support an integrated care strategy that combines wound treatment, early pain management, continuous emotional support, and home-based nursing guidance. Future prospective multicenter studies with randomized designs, longer follow-up periods, and additional mediating variables, such as sleep quality, social support, caregiver involvement, and self-efficacy, are needed to further validate and refine this care model.

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### Disclosure of conflict of interest

None.

**Address correspondence to:** Qin Zhang, Department of Ophthalmology, Lanzhou Second People's Hospital, No. 388 Jingyuan Road, Chengguan

District, Lanzhou 730000, Gansu, China. E-mail: zhangqin202606@163.com

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## NPWT with internet-based care and mediation effects in elderly PI patients

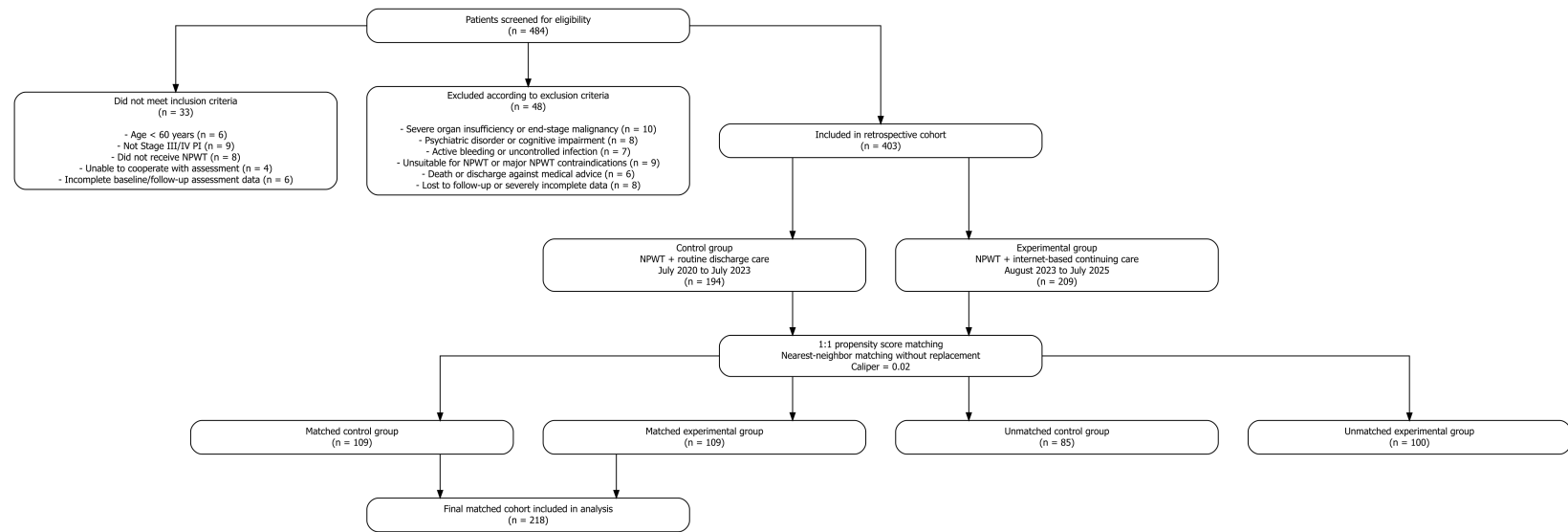


**Figure S1.** Flow diagram of patient screening, eligibility assessment, grouping, and propensity score matching. A total of 484 patients were screened for eligibility. After excluding 33 patients who did not meet the inclusion criteria and 48 patients who met the exclusion criteria, 403 patients were included in the retrospective cohort. Before propensity score matching, 194 patients were assigned to the control group and 209 to the experimental group. After 1:1 propensity score matching, 109 matched pairs were included in the final analysis. Note: PI, pressure injury; NPWT, negative pressure wound therapy; PSM, propensity score matching.

## NPWT with internet-based care and mediation effects in elderly PI patients

**Table S1.** Variable assignments and coding used in the statistical analyses

| Variable           | Type             | Assignment/coding                                                                              | Used in analysis           |
|--------------------|------------------|------------------------------------------------------------------------------------------------|----------------------------|
| Treatment mode     | Binary           | 0 = Control group; 1 = Experimental group                                                      | PSM, mediation, regression |
| Control group      | Group definition | NPWT plus routine discharge care                                                               | Grouping                   |
| Experimental group | Group definition | NPWT plus internet-based continuing care                                                       | Grouping                   |
| Age                | Continuous       | Years                                                                                          | PSM, regression, subgroup  |
| BMI                | Continuous       | kg/m <sup>2</sup>                                                                              | PSM, regression            |
| SBP                | Continuous       | mmHg                                                                                           | PSM                        |
| DBP                | Continuous       | mmHg                                                                                           | PSM                        |
| Heart rate         | Continuous       | beats/min                                                                                      | PSM                        |
| Respiratory rate   | Continuous       | breaths/min                                                                                    | PSM                        |
| Temperature        | Continuous       | °C                                                                                             | PSM                        |
| Maximum wound area | Continuous       | cm <sup>2</sup>                                                                                | PSM, regression            |
| Wound depth        | Continuous       | cm                                                                                             | PSM, regression            |
| PI duration        | Continuous       | Months                                                                                         | PSM, regression            |
| Albumin            | Continuous       | g/L                                                                                            | PSM, regression, subgroup  |
| Hemoglobin         | Continuous       | g/L                                                                                            | PSM, regression            |
| CRP                | Continuous       | mg/L                                                                                           | PSM, regression            |
| WBC                | Continuous       | ×10 <sup>9</sup> /L                                                                            | PSM, regression            |
| Wound location     | Categorical      | 1 = Sacrum; 2 = Hip; 3 = Heel; 4 = Other                                                       | PSM, regression            |
| Sex                | Binary           | 1 = Male; 2 = Female                                                                           | PSM, regression            |
| Smoking history    | Categorical      | 1 = Never; 2 = Former; 3 = Current                                                             | PSM, regression            |
| Alcohol history    | Categorical      | 1 = Never; 2 = Former; 3 = Current                                                             | PSM, regression            |
| Wound bed tissue   | Categorical      | 1 = Necrotic; 2 = Slough; 3 = Granulation; 4 = Epithelial                                      | PSM, regression            |
| Exudate amount     | Categorical      | 1 = Mild; 2 = Moderate; 3 = Heavy                                                              | PSM, regression            |
| Education level    | Binary           | 1 = ≥ High school; 2 = < High school                                                           | PSM, regression            |
| Insurance type     | Binary           | 1 = Insured; 2 = Self-pay                                                                      | PSM, regression            |
| PI stage           | Categorical      | 1 = Stage II; 2 = Stage III; 3 = Stage IV                                                      | PSM, subgroup, regression  |
| Wound infection    | Binary           | 1 = Yes; 2 = No                                                                                | PSM, subgroup, regression  |
| Diabetes           | Binary           | 1 = Yes; 2 = No                                                                                | PSM, regression            |
| Hypertension       | Binary           | 1 = Yes; 2 = No                                                                                | PSM, regression            |
| VAS                | Continuous       | 0-10 points; higher scores indicate more severe pain                                           | Outcome assessment         |
| SAS                | Continuous       | Standardized score; higher scores indicate more severe anxiety                                 | Outcome assessment         |
| SDS                | Continuous       | Standardized score; higher scores indicate more severe depression                              | Outcome assessment         |
| PCS                | Continuous       | SF-36 physical component summary score; higher scores indicate better physical quality of life | Outcome assessment         |
| MCS                | Continuous       | SF-36 mental component summary score; higher scores indicate better mental quality of life     | Outcome assessment         |
| ΔVAS T1-T0         | Continuous       | VAS at T1 minus VAS at T0; negative values indicate pain reduction                             | Mediation, regression      |

## NPWT with internet-based care and mediation effects in elderly PI patients

|                      |            |                                                                                             |                       |
|----------------------|------------|---------------------------------------------------------------------------------------------|-----------------------|
| $\Delta$ SAS T2-T1   | Continuous | SAS at T2 minus SAS at T1; negative values indicate anxiety reduction                       | Mediation, regression |
| $\Delta$ SDS T2-T1   | Continuous | SDS at T2 minus SDS at T1; negative values indicate depression reduction                    | Mediation             |
| $\Delta$ PCS T2-T0   | Continuous | PCS at T2 minus PCS at T0; positive values indicate improvement in physical quality of life | Mediation, regression |
| $\Delta$ MCS T2-T0   | Continuous | MCS at T2 minus MCS at T0; positive values indicate improvement in mental quality of life   | Mediation             |
| $\Delta$ SF-36 score | Continuous | T2 score minus T0 score; positive values indicate improvement                               | Outcome assessment    |