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# Association between sensory processing sensitivity and quality of life among cancer patients: a mediation and moderation of resilience and social determinants

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## Abstract

**Background** Individuals with sensory processing sensitivity (SPS) tend to be overreactive in response to negative environmental stimuli. More is known about the positive relationship between SPS and quality of life (QoL); nevertheless, less is known regarding the roles of resilience and social determinants in this association. This research aimed to investigate the potential mediation effect of resilience and the moderation effect of social determinants on the relationship between SPS and QoL in a large sample of Chinese cancer patients.

**Methods** We used the most recent datasets from an ongoing project conducted in southwest China. A two-stage random sampling strategy with a probability proportionate to sample size (PPS) design was adopted. The associations between resilience, SPS, and QoL were evaluated using a linear regression model. Path analysis was adopted to examine the mediation of resilience.

**Results** Resilience was positively associated with quality of life, while increased sensory processing sensitivity was negatively associated with quality of life. The restricted cubic spline analysis revealed that as resilience increased, the coefficients of quality of life rapidly increased across all domains. Conversely, the coefficients for quality of life gradually decreased with the escalation of sensory processing sensitivity. Resilience was a significant mediator, accounting for 21.88% of the total SPS-QoL association. The mediation effect of resilience varied across ethnicity and sex.

**Conclusion** Sensory processing sensitivity was significantly associated with quality of life in cancer patients, and promoting resilience could mitigate this negative impact. However, the effect of resilience varies across sex and ethnicity. Therefore, targeted resilience promotion interventions, especially those integrating social characteristics, should be considered for implementation.

**Keywords** Resilience, Cancer, Quality of life, Social determinants, Sensory processing sensitivity

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## Background

Cancer is a major global public health threat [1]. In China alone, estimates suggest approximately 4.82 million new cancer cases and 3.21 million cancer-related deaths in 2022 [2]. Being diagnosed with cancer can profoundly impact the quality of life (QoL) for patients. For instance, a substantial proportion of cancer patients report emotional distress (37.8%) [3], pain (44.5%) [4], limited physical activity (78%) [5], and social isolation (41.6%) [6]. Importantly, quality of life is a determinant of survival in cancer patients. Existing studies have well demonstrated that an adverse quality of life significantly contributes to subsequent poor survival outcomes [7, 8]. Identified major associated factors for quality of life have been documented including social determinants, like ethnicity and economic status [9], treatment-related [10] and psychological factors [11]. Recently, there is increasing emphasis on examining the processing and response to negative environmental stimuli among cancer patients within the field of cancer psychology and quality of life.

Sensory processing is defined as the capacity to analyze, modulate, and organize incoming sensory information, enabling adaptive responses to environmental stimuli [12]. Variability in sensory processing is frequently observed. Individuals with a lower sensory threshold, who tend to overreact in response to environmental stimuli, are identified as having sensory processing sensitivity (SPS) [13]. Exposure to negative stimuli is linked to various health outcomes in individuals with sensory processing sensitivity. Pain, anxiety, depression, gastrointestinal and other physical symptoms are commonly reported in previous studies [14–17]. Most importantly, sensory processing sensitivity is one of the decisive factors affecting quality of life. A recent systematic review suggested that SPS could negatively impact quality of life [13]. Evidence from a longitudinal study further supports the association between sensory processing sensitivity and quality of life (SPS-QoL): high levels of sensory processing sensitivity predict poorer quality of life [18]. In consideration of the profound consequences associated with sensory processing sensitivity and its intimate correlation with quality of life, it becomes imperative to mitigate the adverse impact of sensory processing sensitivity on overall quality of life.

Despite the established positive association between sensory processing sensitivity and quality of life, implementing direct interventions targeting sensory processing sensitivity poses significant challenges. Above all, the inherent stability of sensory processing sensitivity as a trait prevents effective intervention [19]. Additionally, the empirical evidence regarding programs designed to address sensory processing sensitivity and their efficacy remains limited. We identified only two studies of

modest sample size that aimed to improve quality of life through targeted interventions addressing sensory processing sensitivity [20, 21]. In this context, the identification of additional modifiable factors that contribute to the relationship between sensory processing sensitivity and quality of life is pivotal for the promotion of quality of life in cancer patients.

Recent advancements in positive psychology have positioned resilience at the forefront of promoting quality of life [22]. Resilience refers to the inherent capacity of an individual to effectively cope with challenging events or emotional adversities [23]. Resilience is significantly associated with many psychological factors including sensory processing sensitivity: individuals with higher levels of sensory processing sensitivity generally report lower levels of resilience [24]. Additionally, accumulated evidence consolidates the association between resilience and quality of life in cancer patients [22]. Evidently, resilience may function as a mediator in the relationship between SPS-QoL, and enhancing resilience has the potential to improve the quality of life associated with sensory processing sensitivity. However, limited research has been conducted to examine this potential mediating effect.

Compared with the general population, cancer patients with sensory processing sensitivity are more vulnerable due to their frequent exposure to negative environmental stimuli. Therefore, in the current study, using the latest datasets from southwest China, we aimed to provide a systematic analysis of sensory processing sensitivity and quality of life in cancer patients. The hypothesized mediation effect of resilience will be further analyzed. We tested the following two major hypotheses:

**Hypothesis 1.** Sensory processing sensitivity is negatively associated with various domains of quality of life (physiology, psychology, social relationships, and environmental).

**Hypothesis 2.** Resilience functions as a mediator in the relationship between sensory processing sensitivity and quality of life.

This study additionally aimed to explore the following research questions: 1) whether social determinants moderate the mediation model involving resilience, sensory processing sensitivity, and quality of life? 2) is there a linear dose-response relationship between resilience, sensory processing sensitivity, and quality of life?

## Method

### Study design and setting

The current study analyzed the latest dataset from a large and ongoing project conducted in southwest China, which focuses on physical and psychological well-being

in cancer patients. A two-stage random sampling strategy with probability proportionate to sample size (PPS) design was performed to produce participants. In the first stage, the third affiliated hospital of Kunming Medical University was randomly selected from all hospitals with cancer patients; in the second stage, based on the estimated sample size, a total of 9 inpatient departments were randomly selected, and all initially included patients were selected from these units. Following the sampling results, a cross-sectional study was conducted from September to December 2023 in the third affiliated hospital of Kunming Medical University, which is one of the largest cancer centers in southwest China.

### Participants

Eligibility criteria included being aged 18 or older, having a confirmed pathological diagnosis of primary cancer, and being able to read and understand the questionnaire items. Patients were excluded if they had (1) severe mental health disorders, (2) any physical illness preventing participation in the investigation, or (3) observed communication problems.

### Measures

#### *Clinical and sociodemographic features*

A self-designed questionnaire was adopted to collect clinical and sociodemographic features. The participants were asked about their age, gender, ethnicity, employment status, educational attainment, place of residence, marital status, financial burden, religious or spiritual beliefs, types of cancer, cancer stage, and coexisting medical conditions. Religious or spiritual beliefs were assessed using the question: "Do you have any religious or spiritual beliefs?" with response options of "Yes" or "No". Financial burden was evaluated with the question: "What is your household's financial burden?" with response options including "slight financial burden", "moderate financial burden", and "heavy financial burden". Participants were asked about coexisting medical conditions using the question: "Do you have any other medical conditions?" with response options of "Yes" or "No". In the current study, four variables (sex, ethnicity, educational attainment, and place of residence) were selected as social determinants.

#### *Independent variables*

The independent variables of the current study were sensory processing sensitivity and resilience. Sensory processing sensitivity was measured using the 10-item Chinese version of the Highly Sensitive Child Scale (CHSC) [19, 25]. Previous studies support the use of the CHSC for assessing adults, and its robustness and effectiveness have been validated [25]. The CHSC consists

of ten items distributed across three dimensions: ease of excitation (EOE), aesthetic sensitivity (AES), and low sensory threshold (LST). This study is interested in the impact of negative environments. Therefore, the subscales EOE and LST, which assess sensitivity to negative environments, were used to measure the level of sensory processing sensitivity. Each item was rated on a scale ranging from 1 (not at all) to 7 (extremely). Higher scores indicate greater sensory processing sensitivity. The Cronbach's  $\alpha$  for CHSC, EOE, AES, and LST in the current study was 0.79 (95% CI: 0.77-0.81), 0.85 (95% CI: 0.83-0.87), 0.83 (95% CI: 0.80-0.86), and 0.86 (95% CI: 0.82-0.90), respectively. Psychological resilience was assessed using the Chinese version of the 10-item Connor-Davidson Resilience Scale (CD-RISC-10) [27]. The CD-RISC-10 is a validated and condensed version of the original 25-item CD-RISC. It consists of 10 items, each rated on a 5-point Likert scale ranging from 0 (never) to 4 (almost always). The combined score ranges from 0 to 40, with a higher score indicating better resilience. The Cronbach's  $\alpha$  for CD-RISC-10 in the current study was 0.91 (95% CI: 0.90-0.92). The total scores of CHSC and CD-RISC-10 were included in the analyses.

#### *Dependent variables*

The primary outcome of the present study was the quality of life, which comprised four domains. The Chinese version of the World Health Organization Quality of Life-Brief (WHOQOL-BREF) was used to evaluate the quality of life of cancer patients [26]. This scale consists of 29 questions, with 24 items comprising four domains: physiology, psychology, social relationships, and environment. Except for one item, all questions were assessed on a 5-point Likert scale ranging from 1 (very poor) to 5 (very good). A high combined score indicates superior quality of life within the corresponding domains. The Cronbach's  $\alpha$  for the Chinese version of WHOQOL-BREF in the current study was 0.90 (95% CI: 0.89-0.91). The total scores of each domain of QoL were included in the analyses.

#### *Data collection*

Preceding data acquisition, informed consent was received from all the participants. A self-administered questionnaire method was adopted for data collection. Participants were asked to complete the questionnaires independently, with adequate time and privacy. If participants needed assistance in completing the questionnaires, the investigators provided explanations. All investigators underwent pre-training and assessment. The clinical data, such as cancer types and staging, were further verified through reviewing medical records.

### Statistical analysis

All data sorting and analysis were performed in the R statistical system (Version 4.3.2, The R Foundation for Statistical Computing, Vienna, Austria). The sociodemographic and clinical features of cancer patients were depicted using descriptive statistics. Categorical variables were presented as frequencies and percentages. Interval data characteristics were reported as mean with standard deviation (SD).

The associations between resilience, sensory processing sensitivity, and the four domains of quality of life were estimated using a linear regression model. Specifically, univariate linear regression was used to identify variables relevant to the four domains of quality of life. If the variables showed a significant correlation with the dependent variables (significance level set at less than 0.05, two-tailed), they were considered as covariates for subsequent analyses. In the second step, all the covariates and independent variables were included in multiple linear regression to estimate the associations between resilience, sensory processing sensitivity, and the four domains of quality of life (to address multiple testing, the significance level was adjusted to less than 0.0125, two-tailed). Subsequent sensitivity analyses were conducted using multiple linear regression with restricted cubic spline (RCS) to explore the changes in coefficients with increasing levels of resilience and sensory processing sensitivity. We hypothesize a linear dose-response relationship, where increasing resilience and sensory processing sensitivity linearly affect patients' quality of life, either improving or declining it.

Path analysis was adopted to examine whether resilience is a significant mediator between sensory processing sensitivity and quality of life. Specifically, we simultaneously entered sensory processing sensitivity, resilience, and the four domains of quality of life into the path model to estimate the standardized path coefficients (significance level set at less than 0.05, two-tailed). It is possible that the mediation effect of resilience may vary across different social characteristics. Consequently, we conducted subgroup path analyses to investigate whether social determinants such as sex, ethnicity, educational attainment, and place of residence moderate the mediation effect of resilience.

### Ethics approval

Ethical approval was obtained from the Institutional Review Committee of Yunnan Cancer Hospital (ky2021133). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964

Helsinki Declaration and its later amendments or comparable ethical standards.

## Results

### Sociodemographic and clinical features of participants

Initially, a total of 1133 participants were included and completed the questionnaire. Fourteen participants were excluded due to missing cancer staging data, leaving 1119 respondents for analysis. The effective response rate was 98.76%. Of the study population, the mean age of the study population was 53.13 years (standard deviation: 11.47); the majority were female (59.6%) and of Han ethnicity (78.2%). Over half of the participants (56.7%) reported living in rural areas. Nearly two-fifths of the participants (40.1%) had received middle or high school education. Detailed characteristics relating to the participants are summarized in Table 1.

### Association of sensory processing sensitivity, resilience, and quality of life

Univariate linear regression identified potential covariates for quality of life. For the dependent variables of physiology and social relationships, covariates included occupation, educational attainment, place of residence, financial burden, and types of cancer. For the dependent variable of psychology, covariates comprised educational attainment, place of residence, and types of cancer. Regarding the dependent variable of environment, covariates involved occupation, educational attainment, place of residence, financial burden, religious or spiritual beliefs, and types of cancer (Table 2 and Table 3).

After controlling for possible covariates identified from univariate analysis, for every one-unit increase in resilience, the multivariable adjusted coefficients (b) for physiological, psychological, environmental, and social relationships were 0.0977 ( $p < 0.001$ ), 0.0850 ( $p < 0.001$ ), 0.0746 ( $p < 0.001$ ), and 0.0902 ( $p < 0.001$ ), respectively (Tables 2, 3, 4 and 5). Conversely, increased sensory processing sensitivity was negatively associated with quality of life in physiology (coefficient: -0.0513,  $p < 0.001$ ), psychology (coefficient: -0.0240,  $p < 0.001$ ), environment (coefficient: -0.0386,  $p < 0.001$ ), and social relationships (coefficient: -0.0342,  $p < 0.001$ ). The characteristics of the multiple linear regression models were summarized in Tables 2, 3, 4 and 5.

### Sensitivity analysis

In an effort to verify the reliability and ascertain the trend of association between sensory processing sensitivity and resilience in relation to quality of life, a sensitivity analysis was performed using the restricted cubic spline. After controlling for the previously mentioned covariates, a rapid increase was observed in the

**Table 1** Characteristics of the cancer patients

Features	n (%)	Mean (SD)
Overall	1119	
Age		53.13 (11.47)
Sex		
Male	452 (40.4)	
Female	667 (59.6)	
Ethnicity		
Han ethnicity	875 (78.2)	
Ethnic Minorities	244 (21.8)	
Employment status		
Employed	559 (50.0)	
Unemployed	560 (50.0)	
Educational attainment		
Primary school and below	376 (33.6)	
Middle and high school	449 (40.1)	
College and above	294 (26.3)	
Place of residence		
Rural	634 (56.7)	
Urban	485 (43.3)	
Marital status		
Single, divorced, and widowed	89 (8.0)	
Married	1030 (92.0)	
Financial burden		
Slight financial burden	179 (16.0)	
Moderate financial burden	461 (41.2)	
Heavy financial burden	479 (42.8)	
Having religious or spiritual beliefs		
Yes	88 (7.9)	
No	1031 (92.1)	
Types of cancer		
Lung cancer	267 (23.9)	
Bowel cancer	288 (25.7)	
Liver cancer	114 (10.2)	
Breast cancer	101 (9.0)	
Cervical cancer	165 (14.7)	
Endometrial cancer	50 (4.5)	
Ovarian cancer	63 (5.6)	
Other	71 (6.3)	
Stages of cancer		
I	193 (17.2)	
II	206 (18.4)	
III	274 (24.5)	
IV	172 (15.4)	
Cancer of unknown stage	274 (24.5)	
Coexisting medical conditions		
Yes	780 (69.7)	
No	339 (30.3)	
Sensory processing sensitivity		31.55 (7.07)
Resilience		25.63 (6.55)

**Table 1** (continued)

Features	n (%)	Mean (SD)
Quality of life		
Physiology		12.87 (2.13)
Psychology		12.59 (1.78)
Social relationships		14.51 (2.25)
Environment		12.81 (1.94)

coefficients (b) of quality of life across all domains with the increase in resilience (Fig. 1). Conversely, the coefficients (b) for quality of life gradually decreased with the escalation of sensory processing sensitivity (Fig. 2).

**Mediation analysis of resilience**

Hypothesized model showed a good fit: the goodness-of-fit index (GFI) was 0.99, and the root mean square error of approximation (RMSEA) was 0.039. A prominent mediation of resilience in the association between sensory processing sensitivity and quality of life was observed after fitting the model. The direct relationship from sensory processing sensitivity to quality of life was -0.6138, calculated based on an amalgamation of standardized coefficients: physiology (-0.1819), psychology (-0.1314), environment (-0.1688), and social relationships (-0.1317). The indirect association via resilience was -0.1720. Altogether, 21.88% of the total association (-0.7858) was mediated by resilience (Table 6).

**Moderation of social determinants**

It is possible that resilience could exhibit distinct mediation patterns when stratified by social determinants (sex, ethnicity, educational attainment, and place of residence). Consequently, we performed subgroup path analyses to examine the potential moderating role of social determinants. For ethnicity, a significant mediation role of resilience was identified in the Han ethnicity, accounting for 23.65% of the total association (Table S2), whereas the mediating role of resilience was insignificant in the ethnic minority subgroup (Table S2). The mediation of resilience accounted for 32.88% and 14.01% of the total association in the subgroups of males and females, respectively (Table S3). For educational attainment (Table S4), a significant mediation role of resilience was observed in individuals with higher educational attainment (Middle and high school: 19.04%; College and above: 23.31%). The mediation of resilience accounted for 16.38% and 23.03% of the total association in the subgroups residing in rural and urban areas (Table S5).

**Table 2** Association of sensory processing sensitivity, resilience, and quality of life (physiology) in cancer patients

Variables	Dependent variable: Physiology					
	Univariate linear regression			Multiple linear regression		
	Coefficients (b) (95% CI)	Standard errors (SE)	P value	Coefficients (b) (95% CI)	Standard errors (SE)	P value
Age (years)	-0.0075 (-0.0184, 0.0034)	0.0055	0.1770			
Sex (ref: male)						
Female	-0.0295 (-0.2837, 0.2247)	0.1296	0.8200			
Ethnicity (ref: Han ethnicity)						
Ethnic Minorities	0.2246 (-0.0772, 0.5264)	0.1538	0.1440			
Occupation (ref: employed)						
Unemployed	-0.406 (-0.6543, -0.1577)	0.1266	0.0010	-0.0142 (-0.2767, 0.2483)	0.1338	0.916
Educational attainment (ref: primary school and below)						
Middle and high school	0.1454 (-0.1426, 0.4335)	0.1468	0.3220	-0.0873 (-0.3622, 0.1875)	0.1401	0.533
College and above	0.8378 (0.5170, 1.1586)	0.1635	<0.001	0.1146 (-0.2401, 0.4694)	0.1808	0.526
Place of residence (ref: rural)						
Urban	0.6937 (0.4453, 0.9421)	0.1266	<0.001	0.1621 (-0.1209, 0.4450)	0.1442	0.261
Marital status (ref: single, divorced, and widowed)						
Married	-0.2324 (-0.6932, 0.2284)	0.2349	0.3230			
Financial burden (ref: slight financial burden)						
Moderate financial burden	-0.1987 (-0.5647, 0.1673)	0.1865	0.2870	-0.1670 (-0.4961, 0.1622)	0.1677	0.32
Heavy financial burden	-0.5254 (-0.8895, -0.1614)	0.1855	0.0050	-0.2805 (-0.6173, 0.0562)	0.1716	0.102
Having religious or spiritual beliefs (ref: yes)						
No	-0.3231 (-0.7861, 0.1400)	0.2360	0.1710			
Types of cancer (ref: lung cancer)						
Bowel cancer	0.1188 (-0.2250, 0.4626)	0.1752	0.4980	0.0367 (-0.2815, 0.3549)	0.1622	0.821
Liver cancer	-1.5816 (-2.0344, -1.1288)	0.2308	<0.001	-1.2603 (-1.6806, -0.8400)	0.2142	<0.001
Breast cancer	-0.1596 (-0.6324, 0.3131)	0.2410	0.5080	-0.1325 (-0.5675, 0.3025)	0.2217	0.55
Cervical cancer	-0.3452 (-0.7460, 0.0555)	0.2043	0.0910	-0.2635 (-0.6404, 0.1135)	0.1921	0.171
Endometrial cancer	-0.9035 (-1.5271, -0.2799)	0.3178	0.0050	-0.7829 (-1.3575, -0.2082)	0.2929	0.008
Ovarian cancer	-1.1099 (-1.6768, -0.5431)	0.2889	<0.001	-0.8393 (-1.3607, -0.3179)	0.2657	0.002
Other	-0.4843 (-1.0247, 0.0561)	0.2754	0.0790	-0.5185 (-1.0149, -0.0221)	0.2530	0.041
Stages of cancer (ref: I)						
II	-0.0486 (-0.4665, 0.3693)	0.2130	0.8200			
III	-0.1616 (-0.5536, 0.2305)	0.1998	0.4190			
IV	-0.2127 (-0.6501, 0.2247)	0.2229	0.3400			
Cancer of unknown stage	-0.3305 (-0.7225, 0.0615)	0.1998	0.0980			
Coexisting medical conditions (ref: No)						
Yes	0.4711 (0.2011, 0.7412)	0.1376	<0.001	0.3639 (0.1192, 0.6086)	0.1247	0.004
Sensory processing sensitivity (One-score increase)	-0.069 (-0.0862, -0.0518)	0.0088	<0.001	-0.0513 (-0.0675, -0.0351)	0.0083	<0.001
Resilience (One-score increase)	0.1181 (0.1004, 0.1359)	0.0090	<0.001	0.0977 (0.0798, 0.1156)	0.0091	<0.001

The characteristics of the multiple linear regression model: adjusted R-squared=0.211,  $F_{16, 1102}=19.68$ ,  $p<0.001$

## Discussion

In the present study, we observed that sensory processing sensitivity and resilience were prominently associated with quality of life. Additionally, a significant mediating effect of resilience was identified in the relationship between sensory

processing sensitivity and quality of life. However, the mediating role of resilience was moderated by social characteristics such as sex and ethnicity. The results from this study contribute to a better understanding of how sensory processing sensitivity is related to quality of life via resilience.

**Table 3** Association of sensory processing sensitivity, resilience, and quality of life (psychology) in cancer patients

Variables	Dependent variable: Psychology					
	Univariate linear regression			Multiple linear regression		
	Coefficients (b) (95% CI)	Standard errors (SE)	P value	Coefficients (b) (95% CI)	Standard errors (SE)	P value
Age (years)	0.0020 (-0.0071, 0.0112)	0.0047	0.6620			
Sex (ref: male)						
Female	-0.1626 (-0.3756, 0.0504)	0.1086	0.1350			
Ethnicity (ref: Han ethnicity)						
Ethnic Minorities	0.0486 (-0.2048, 0.3020)	0.1291	0.7070			
Occupation (ref: employed)						
Unemployed	-0.1428 (-0.3519, 0.0662)	0.1066	0.1800			
Educational attainment (ref: primary school and below)						
Middle and high school	0.0583 (-0.1849, 0.3014)	0.1239	0.6380	-0.1085 (-0.3445, 0.1274)	0.1203	0.367
College and above	0.4981 (0.2273, 0.7688)	0.1380	<0.001	-0.0283 (-0.3236, 0.2670)	0.1505	0.851
Place of residence (ref: rural)						
Urban	0.4354 (0.2258, 0.6450)	0.1068	<0.001	0.1788 (-0.0508, 0.4083)	0.1170	0.127
Marital status (ref: single, divorced, and widowed)						
Married	-0.0096 (-0.3963, 0.3771)	0.1971	0.9610			
Financial burden (ref: slight financial burden)						
Moderate financial burden	-0.1191 (-0.4272, 0.1890)	0.1570	0.4480			
Heavy financial burden	-0.2201 (-0.5266, 0.0863)	0.1562	0.1590			
Having religious or spiritual beliefs (ref: yes)						
No	-0.1568 (-0.5454, 0.2318)	0.1981	0.4290			
Types of cancer (ref: lung cancer)						
Bowel cancer	-0.082 (-0.3745, 0.2106)	0.1491	0.5830	-0.1583 (-0.4344, 0.1178)	0.1407	0.261
Liver cancer	-0.4264 (-0.8117, -0.0411)	0.1964	0.0300	-0.2157 (-0.5808, 0.1494)	0.1861	0.247
Breast cancer	0.1968 (-0.2055, 0.5991)	0.2050	0.3370	0.2405 (-0.1373, 0.6182)	0.1925	0.212
Cervical cancer	-0.7742 (-1.1152, -0.4331)	0.1738	<0.001	-0.7756 (-1.1021, -0.4491)	0.1664	<0.001
Endometrial cancer	-0.4732 (-1.0038, 0.0575)	0.2705	0.0800	-0.4024 (-0.9011, 0.0962)	0.2541	0.114
Ovarian cancer	-0.8382 (-1.3206, -0.3559)	0.2458	<0.001	-0.6699 (-1.1226, -0.2171)	0.2307	0.004
Other	0.2076 (-0.2523, 0.6674)	0.2344	0.3760	0.1983 (-0.2325, 0.6291)	0.2196	0.367
Stages of cancer (ref: I)						
II	0.3227 (-0.0278, 0.6732)	0.1786	0.0710			
III	0.1007 (-0.2281, 0.4295)	0.1676	0.5480			
IV	0.2263 (-0.1406, 0.5932)	0.1870	0.2260			
Cancer of unknown stage	0.1907 (-0.1381, 0.5195)	0.1676	0.2550			
Coexisting medical conditions (ref: No)						
Yes	0.2658 (0.0387, 0.4930)	0.1158	0.0220	0.1614 (-0.0509, 0.3738)	0.1082	0.136
Sensory processing sensitivity (One-score increase)	-0.0441 (-0.0587, -0.0295)	0.0074	<0.001	-0.0240 (-0.0381, -0.0100)	0.0072	<0.001
Resilience (One-score increase)	0.0896 (0.0745, 0.1047)	0.0077	<0.001	0.0850 (0.0695, 0.1005)	0.0079	<0.001

The characteristics of the multiple linear regression model: adjusted R-squared=0.152,  $F_{13, 1105}=16.44$ ,  $p<0.001$

This study produced results that further corroborate the findings of a great deal of the previous work on the association between sensory processing sensitivity and quality of life. The existing evidence suggests that the individuals with hypersensitivity generally experiences a high intensity of stimulation, engages in deep processing,

and interprets environmental subtleties, leading to a series of physical and psychological responses [28, 29]. Consequently, individuals with sensory processing sensitivity are prone to a poorer quality of life. Our research findings also provide supportive evidence for the mediating role of resilience in the relationship between

**Table 4** Association of sensory processing sensitivity, resilience, and quality of life (social relationships) in cancer patients

Variables	Dependent variable: Social relationships					
	Univariate linear regression			Multiple linear regression		
	Coefficients (b) (95% CI)	Standard errors (SE)	P value	Coefficients (b) (95% CI)	Standard errors (SE)	P value
Age (years)	0.0031 (-0.0085, 0.0146)	0.0059	0.6000			
Sex (ref: male)						
Female	-0.1243 (-0.3938, 0.1451)	0.1374	0.3650			
Ethnicity (ref: Han ethnicity)						
Ethnic Minorities	0.1762 (-0.1440, 0.4964)	0.1632	0.2800			
Occupation (ref: employed)						
Unemployed	-0.3095 (-0.5735, -0.0456)	0.1345	0.0220	0.0790 (-0.2131, 0.3711)	0.1488	0.596
Educational attainment (ref: primary school and below)						
Middle and high school	0.1055 (-0.2007, 0.4117)	0.1560	0.4990	-0.0691 (-0.3749, 0.2367)	0.1559	0.657
College and above	0.7968 (0.4559, 1.1378)	0.1738	<0.001	0.1812 (-0.2133, 0.5757)	0.2011	0.368
Place of residence (ref: rural)						
Urban	0.6651 (0.4011, 0.9292)	0.1346	<0.001	0.2963 (-0.0184, 0.611)	0.1604	0.065
Marital status (ref: single, divorced, and widowed)						
Married	-0.0758 (-0.5647, 0.4131)	0.24917	0.761			
Financial burden (ref: slight financial burden)						
Moderate financial burden	-0.2308 (-0.6197, 0.1582)	0.1982	0.245	-0.2065 (-0.5725, 0.1596)	0.1866	0.269
Heavy financial burden	-0.4467 (-0.8336, -0.0599)	0.1972	0.024	-0.2334 (-0.6075, 0.1408)	0.1907	0.221
Having religious or spiritual beliefs (ref: yes)						
No	-0.2555 (-0.7467, 0.2357)	0.2504	0.308			
Types of cancer (ref: lung cancer)						
Bowel cancer	-0.0395 (-0.4097, 0.3306)	0.1887	0.834	-0.1475 (-0.5014, 0.2063)	0.1804	0.413
Liver cancer	-0.9265 (-1.4140, -0.4390)	0.2485	<0.001	-0.6699 (-1.1360, -0.2038)	0.2376	0.005
Breast cancer	-0.2907 (-0.7997, 0.2183)	0.2594	0.2630	-0.2419 (-0.7252, 0.2414)	0.2463	0.326
Cervical cancer	-0.855 (-1.2865, -0.4235)	0.2199	<0.001	-0.8536 (-1.2726, -0.4347)	0.2135	<0.001
Endometrial cancer	-1.3447 (-2.0162, -0.6733)	0.3422	<0.001	-1.2273 (-1.8665, -0.5881)	0.3258	<0.001
Ovarian cancer	-0.8173 (-1.4276, -0.2070)	0.3110	0.0090	-0.5733 (-1.1536, 0.0069)	0.2957	0.053
Other	-0.3374 (-0.9192, 0.2444)	0.2965	0.2550	-0.3416 (-0.8941, 0.2108)	0.2816	0.225
Stages of cancer (ref: I)						
II	-0.2171 (-0.6604, 0.2262)	0.2259	0.3370			
III	-0.3424 (-0.7582, 0.0734)	0.2119	0.1060			
IV	-0.1328 (-0.5968, 0.3312)	0.2365	0.5750			
Cancer of unknown stage	-0.2888 (-0.7047, 0.127)	0.2119	0.1730			
Coexisting medical conditions (ref: No)						
Yes	0.2223 (-0.0652, 0.5099)	0.1466	0.1300			
Sensory processing sensitivity (One-score increase)	-0.0546 (-0.0731, -0.0362)	0.0094	<0.001	-0.0342 (-0.0523, -0.0162)	0.0092	<0.001
Resilience (One-score increase)	0.1035 (0.0842, 0.1227)	0.0098	<0.001	0.0902 (0.0704, 0.1101)	0.0101	<0.001

The characteristics of the multiple linear regression model: adjusted R-squared=0.131,  $F_{15, 1103}=12.23$ ,  $p<0.001$

sensory processing sensitivity and quality of life, a topic that has been inadequately addressed in previous studies. It is well established that resilience comprises comprehensive capabilities in coping with negative events, such as self-efficacy, positive perception, emotional and cognitive regulation [27, 30, 31]. It has been reported

that sensory processing sensitivity is significantly associated with cognitive problems [28, 29]. Latest research further observed decreased resilience-related abilities in groups with a higher level of sensory processing sensitivity [24, 32]. Meanwhile, all these abilities are significantly associated with quality of life [33]. Given the



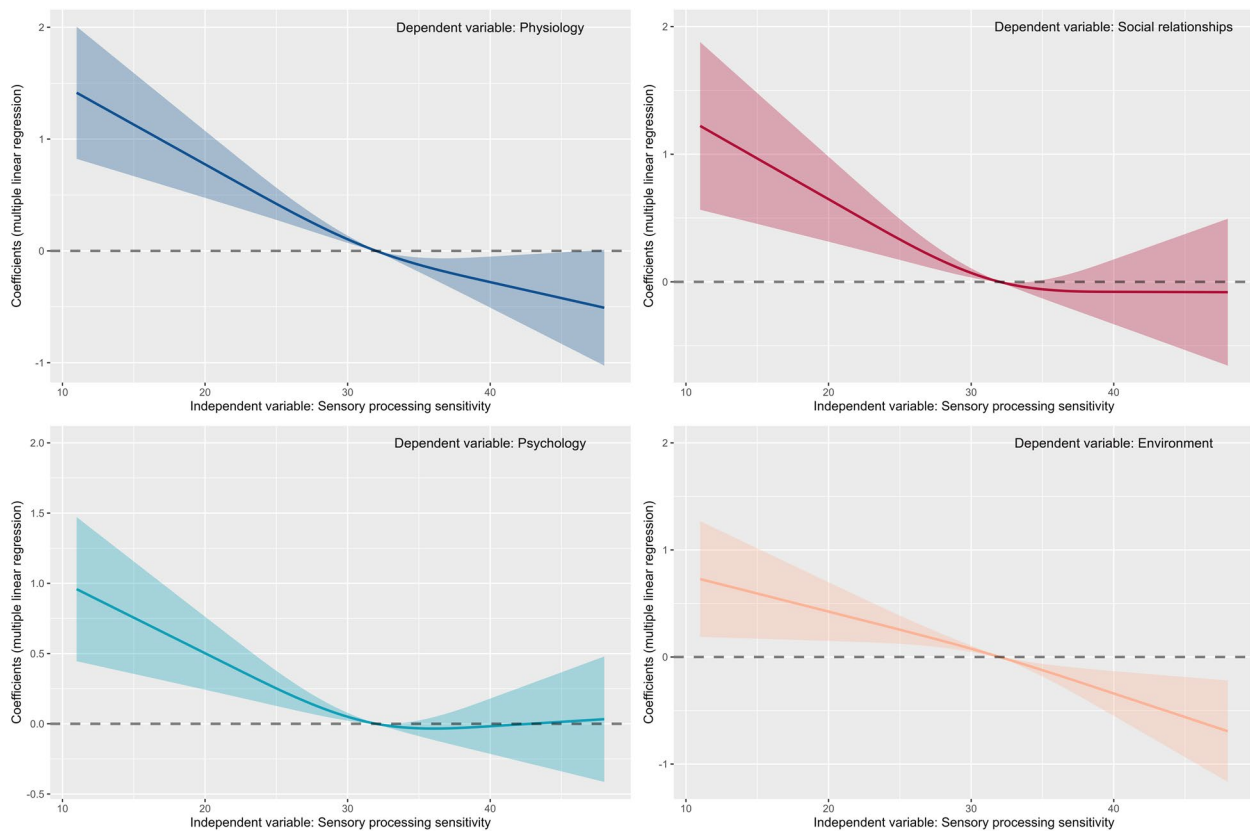
**Table 5** Association of sensory processing sensitivity, resilience, and quality of life (environment) in cancer patients

Variables	Dependent variable: Environment					
	Univariate linear regression			Multiple linear regression		
	Coefficients (b) (95% CI)	Standard errors (SE)	p value	Coefficients (b) (95% CI)	Standard errors (SE)	p value
Age (years)	0.0068 (-0.0031, 0.0167)	0.0050	0.1800			
Sex (ref: male)						
Female	-0.1315 (-0.3630, 0.1001)	0.1180	0.2650			
Ethnicity (ref: Han ethnicity)						
Ethnic Minorities	-0.0153 (-0.2906, 0.2599)	0.1403	0.9130			
Occupation (ref: employed)						
Unemployed	-0.6306 (-0.8549, -0.4063)	0.1143	<0.001	-0.1298 (-0.3699, 0.1103)	0.1224	0.289
Educational attainment (ref: primary school and below)						
Middle and high school	0.2825 (0.0225, 0.5424)	0.1325	0.0330	0.0094 (-0.2419, 0.2607)	0.1281	0.941
College and above	1.0391 (0.7496, 1.3286)	0.1476	<0.001	0.1891 (-0.1351, 0.5134)	0.1652	0.253
Place of residence (ref: rural)						
Urban	0.9338 (0.7110, 1.1565)	0.1135	<0.001	0.3861 (0.1275, 0.6447)	0.1318	0.003
Marital status (ref: single, divorced, and widowed)						
Married	-0.3128 (-0.7325, 0.1069)	0.2139	0.144			
Financial burden (ref: slight financial burden)						
Moderate financial burden	-0.0465 (-0.3775, 0.2845)	0.1687	0.783	-0.0457 (-0.3467, 0.2553)	0.1534	0.766
Heavy financial burden	-0.6395 (-0.9688, -0.3103)	0.1678	<0.001	-0.3718 (-0.6793, -0.0643)	0.1567	0.018
Having religious or spiritual beliefs (ref: yes)						
No	-0.4432 (-0.8647, -0.0217)	0.2148	0.039	-0.5176 (-0.8952, -0.1400)	0.1924	0.007
Types of cancer (ref: lung cancer)						
Bowel cancer	0.1197 (-0.1936, 0.4330)	0.1597	0.454	-0.0246 (-0.3155, 0.2662)	0.1482	0.868
Liver cancer	-1.3284 (-1.7410, -0.9158)	0.2103	<0.001	-1.0568 (-1.4399, -0.6738)	0.1952	<0.001
Breast cancer	-0.1788 (-0.6097, 0.2520)	0.2196	0.4150	-0.1755 (-0.5727, 0.2217)	0.2024	0.386
Cervical cancer	-0.7715 (-1.1367, -0.4063)	0.1861	<0.001	-0.7623 (-1.1067, -0.4179)	0.1755	<0.001
Endometrial cancer	-0.9442 (-1.5125, -0.3759)	0.2896	0.0010	-0.9234 (-1.4488, -0.3979)	0.2678	<0.001
Ovarian cancer	-0.7950 (-1.3115, -0.2784)	0.2633	0.0030	-0.5455 (-1.0224, -0.0686)	0.2430	0.025
Other	-0.1512 (-0.6437, 0.3412)	0.2510	0.5470	-0.1853 (-0.6395, 0.2688)	0.2314	0.423
Stages of cancer (ref: I)						
II	-0.1820 (-0.5625, 0.1985)	0.1939	0.3480			
III	-0.2422 (-0.5991, 0.1148)	0.1819	0.1830			
IV	0.0825 (-0.3158, 0.4807)	0.2030	0.6850			
Cancer of unknown stage	-0.2768 (-0.6338, 0.0801)	0.1819	0.1280			
Coexisting medical conditions (ref: No)						
Yes	0.1637 (-0.0835, 0.4109)	0.1260	0.1940			
Sensory processing sensitivity (One-score increase)	-0.0577 (-0.0734, -0.0419)	0.0080	<0.001	-0.0386 (-0.0534, -0.0237)	0.0076	<0.001
Resilience (One-score increase)	0.0948 (0.0783, 0.1112)	0.0084	<0.001	0.0746 (0.0582, 0.0909)	0.0083	<0.001

The characteristics of the multiple linear regression model: adjusted R-squared=0.205,  $F_{16, 1102}=19.03$ ,  $p<0.001$

above mechanisms, the risk for an adverse quality of life might be mitigated, even within the context of a higher level of sensory processing sensitivity, through enhanced resilience. While interventions oriented towards resilience, even in the short term, has been proven to achieve ideal effects [34]. Therefore, the findings from

the present study suggest that the improvement of resilience could be a more effective and practical approach for mitigating the poor quality of life risk associated with sensory processing sensitivity among cancer patients. Indeed, existing studies have reported validated intervention strategies for resilience [35, 36], exemplified by



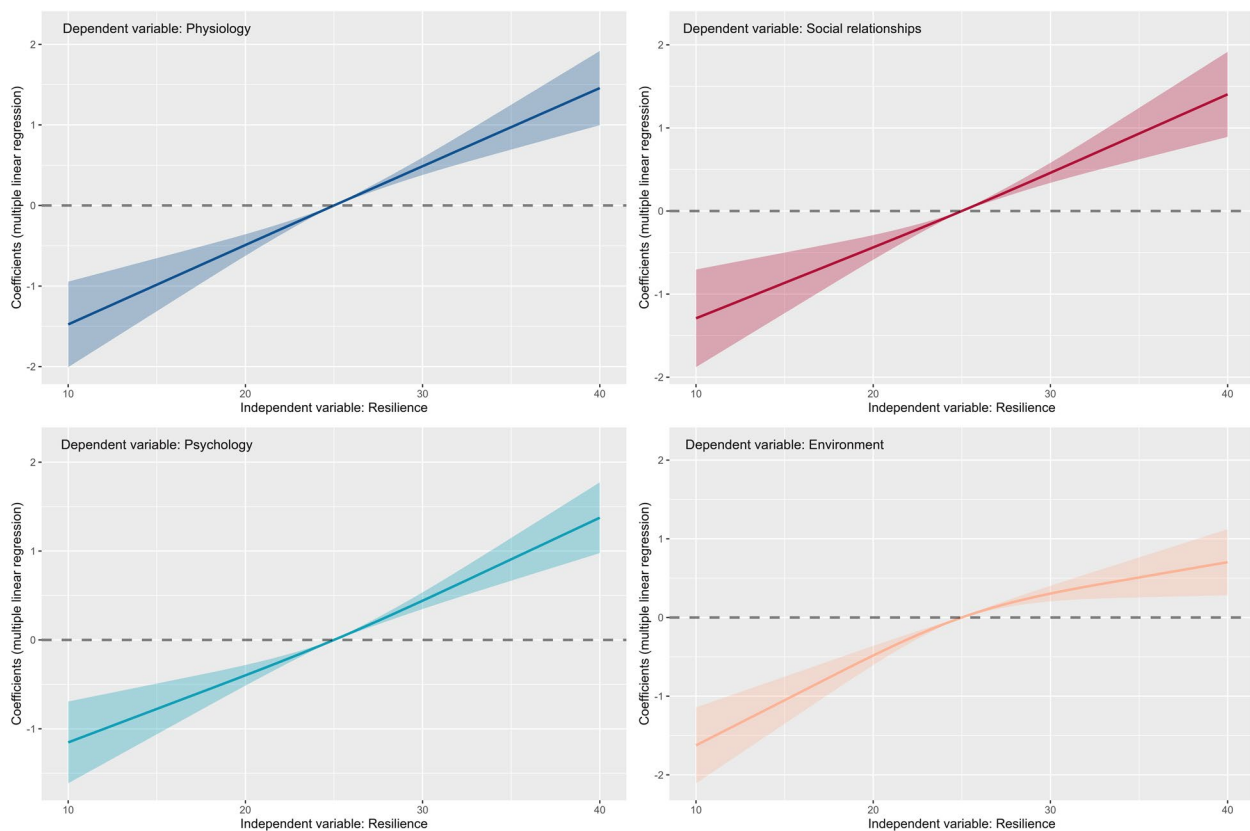
**Fig. 1** Association between sensory processing sensitivity and four domains of quality of life in the multiple linear regression with restricted cubic spline. Solid lines are point estimates of coefficients (**b**), shaded areas showing 95 % CIs by using restricted cubic spline (RCS). Covariates for the dependent variable of physiology and social relationships included resilience, occupation, educational attainment, place of residence, financial burden, and types of cancer. Covariates for the dependent variable of psychology included resilience, educational attainment, place of residence, and types of cancer. Covariates for the dependent variable of environment included resilience, occupation, educational attainment, place of residence, financial burden, religious or spiritual beliefs, and types of cancer. The test of nonlinear relationship between sensory processing sensitivity and four domains of quality of life: physiology ( $p=0.172$ ), psychology ( $p=0.034$ ), social relationship ( $p=0.066$ ), and environment ( $p=0.714$ )

established programs like Promoting Resilience in Stress Management (PRISM) and psychoeducational interventions (PEIs). After the interventions, both programs were observed to have a significant increase in resilience and improvements in quality of life.

However, we also retrieved a study on resilience-promoting interventions with a non-significant effect on improving quality of life [37], which suggests that a one-size-fits-all approach to intervention is likely ineffective since the mediating effect of resilience could vary across social characteristics. Another important finding of the present study was that the mediating effect of resilience in the association between QoL-SPS varied across sex and ethnicity. Disparities in resilience related to social characteristics have been reported in previous studies. For instance, a gender difference in resilience was identified in cancer patients, with poorer resilience observed in females [38]. Another study reported variation in resilience among different ethnicities [39]. Theoretical

studies suggest that human resilience comprises multiple interacting systems, encompassing a range of biological, psychological, social, and ecological systems [40]. Subsequent systematic reviews supported this multisystemic perspective, indicating that individuals' resilience likely depends on factors from multiple levels [41]. As a result, the level of resilience varies among individuals due to the diverse conditions of these elements. These study results suggest that the benefits derived from resilience promotion measures may vary among participants based on sex and ethnicity. In future research and interventions, it is worth focusing on resilience promotion approaches oriented towards integrating social characteristics.

The current study adopted a cross-sectional design to provide the first systematic examination of the mediating role of resilience in the association between sensory processing sensitivity and quality of life, as well as the moderation of social determinants in Chinese cancer



**Fig. 2** Association between resilience and four domains of quality of life in the multiple linear regression with restricted cubic spline. Solid lines are point estimates of coefficients (**b**), shaded areas showing 95 % CIs by using restricted cubic spline (RCS). Covariates for the dependent variable of physiology and social relationships included sensory processing sensitivity, occupation, educational attainment, place of residence, financial burden, and types of cancer. Covariates for the dependent variable of psychology included sensory processing sensitivity, educational attainment, place of residence, and types of cancer. Covariates for the dependent variable of environment included sensory processing sensitivity, occupation, educational attainment, place of residence, financial burden, religious or spiritual beliefs, and types of cancer. The test of nonlinear relationship between resilience and four domains of quality of life: physiology ( $p=0.965$ ), psychology ( $p=0.545$ ), social relationship ( $p=0.810$ ), and environment ( $p=0.017$ )

**Table 6** Path model of sensory processing sensitivity, resilience, and quality of life

Variables	<b>b</b> (95%CI)	SE ( <b>b</b> )	$\beta$	<b>p</b>
<b>Direct effect</b>				
Sensory processing sensitivity → Physiology	-0.0547 (-0.0710, -0.0385)	0.0083	-0.1819	<0.001
Sensory processing sensitivity → Psychology	-0.0332 (-0.0471, -0.0192)	0.0071	-0.1314	<0.001
Sensory processing sensitivity → Social relationships	-0.0420 (-0.0598, -0.0242)	0.0091	-0.1317	<0.001
Sensory processing sensitivity → Environment	-0.0463 (-0.0614, -0.0312)	0.0077	-0.1688	<0.001
<b>Indirect effect</b>				
Resilience → Sensory processing sensitivity	-0.1298 (-0.1836, -0.076)	0.0275	-0.1399	<0.001
Resilience → Physiology	0.1099 (0.0923, 0.1274)	0.0089	0.3388	<0.001
Resilience → Psychology	0.0846 (0.0695, 0.0996)	0.0077	0.3109	<0.001
Resilience → Social relationships	0.0971 (0.0779, 0.1164)	0.0098	0.2824	<0.001
Resilience → Environment	0.0878 (0.0715, 0.1041)	0.0083	0.2970	<0.001

*b* unstandardized coefficients,  $\beta$  standardized coefficients within roles, *SE* standard error

patients. The scientific study design and the large sample size further strengthened the validity of the findings that support the positive association between sensory processing sensitivity and quality of life in cancer patients. We found that cancer patients with sensory processing sensitivity were at risk of poorer quality of life, and promoting resilience could mitigate this risk. However, the effect of resilience varies across social determinants. Therefore, extensive social characteristics should be prioritized when designing and implementing intervention measures.

Several limitations should be mentioned in this study. First, causal inference cannot be reached due to the inherent limitations of the cross-sectional design. Therefore, additional studies using a prospective design are warranted. Secondly, caution should be taken when generalizing the findings, as the sample was selected from a single city in southwest China. In the future, multicenter studies or research with a nationally representative sample of cancer patients should be conducted. Third, the data for this study were collected using a self-report method, which inevitably introduces information bias.

## Conclusion

In this cross-sectional study, we further support the association between resilience and sensory processing sensitivity and quality of life. Resilience exhibited a prominent mediating role in the association between sensory processing sensitivity and quality of life. Significant social determinants such as sex and ethnicity showed a moderating effect on the mediation of resilience. This combination of findings suggests that cancer patients who maintain a higher level of sensory processing sensitivity are more likely to experience poorer quality of life. Therefore, resilience promotion interventions, especially those oriented towards integrating social determinants, should be designed and implemented for this high-risk population.

## Abbreviations

QoL	Quality of life
SPS	Sensory processing sensitivity
RCS	Restricted cubic spline

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12955-024-02283-6>.

Supplementary Material 1

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None.

## Consent to participate

Informed consent was obtained from all individual participants included in the study.

## Authors' contributions

HR and QH conceived the study; QY and JY conducted statistical analysis and drafted the manuscript; XX, YZ, XS, YX, NJ and YW assisted with data collection, cleaning, and statistical analysis; HR and QH critically revised the manuscript. All authors provided critical revision of the manuscript for important intellectual content.

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## Availability of data and materials

The manuscript's data are available from the corresponding author.

## Data Availability

The data have been deposited in the Mendeley Data (<https://doi.org/10.17632/26w7d27tdm.1>).

## Declarations

### Ethics approval and consent to participate

The study was conducted in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki Declaration and its subsequent revisions or similar ethical standards. Ethical approval was obtained from the Institutional Review Committee of Yunnan Cancer Hospital (ky2021133).

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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