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Table 1 to 3 are available in the Supplementary Files section.

Effectiveness of a Combined Peer and Digital-led Intervention Program for College Students with High-Risk Sexual Behaviors: A Randomized Controlled Trial Based on the Behavior Change Wheel Model

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Abstract

Background: Risky sexual behavior (RSB) among college students is a major public health concern, leading to high rates of sexually transmitted infections (STIs) and adverse outcome. Traditional educational interventions often fail to translate knowledge into sustained behavioral change. The Behavior Change Wheel (BCW) theory provides a systematic framework for developing theory-informed interventions. This study aimed to develop and evaluate the effectiveness of a BCW-based intervention, combining peer and digital-lead intervention, to reduce RSB among Chinese college students.

Methods: A two-phase study was conducted. Phase 1 involved a qualitative study (n=15) to identify barriers and facilitators to safer sex, a literature review, and a Delphi expert consultation (n=13) to develop the intervention. Phase 2 was a randomized controlled trial to assess the effectiveness of the intervention. Seventy-six college students with a history of RSB were recruited and randomly assigned to the intervention group (n=38) and control group (n=38). The intervention group received a 6-week, peer and digital-lead ("SiLiang Health") intervention, while the control group received routine sexual health education. Primary outcomes were the frequency of RSB and risk perception. Secondary outcomes were psychosexual health and sense of shame related to sexuality. Assessments were conducted at baseline (T0), immediately post-intervention (T1), and one-month post-intervention (T2). Intention-to-treat (ITT) was used and data were analyzed using Generalized Estimating Equations (GEE).

Results: The analyses revealed significant group-by-time interaction effects on all

outcome variables. For the primary outcome of RSB frequency, the intervention group showed a marked decrease from a baseline mean (SD) of 3.42 (1.00) to 2.51 (0.69) at T1 and 1.97 (0.71) at T2, with the reduction being significantly greater than that in the control group ($p < 0.01$; Cohen's d at T2 = 0.87). Risk perception scores increased significantly in the intervention group from 2.03 (1.37) at baseline to 4.54 (1.30) at T1 and 4.51 (1.44) at T2, with a significant group effect ($p < 0.01$) and a large effect size (Cohen's d at T1 = -2.20). It also confirmed significant improvements in psychosexual health in the intervention group, with lower scores on the sexual cognition and sexual attitude subscales ($p < 0.01$), and a pronounced reduction in the sense of shame ($p < 0.01$), all effect sizes ranging from medium to large.

Conclusions: BCW theory-based intervention, combining peer-led group sessions and digital support, is effective to reducing RSB and improving sexual health outcomes among college students. This intervention model offers a practical and engaging paradigm for healthcare professionals and educators working in adolescent and young adult health.

Trial registration: Clinical registration number: NCT12345678(30/05/2024) .

Keywords: Risky Sexual Behavior, College Students, Behavior Change Wheel, Peer-led Intervention, Digital Health, Randomized Controlled Trial

Background

Risky sexual behavior (RSB), defined as sexual activities that may lead to sexually transmitted infections (STIs) and unintended pregnancies encompassing behaviors such as unprotected sex, multiple sexual partners, and casual sexual encounters, is highly prevalent among college students worldwide [1-4]. Global studies indicate that 26% to 63% of college students engage in RSB, and with significant variations across regions [5-7]. In China, a national surveys show that 31% of college students have engaged in penetrative sex, however, only 56.98% consistently use contraception [8-10]. Alarmingly, 5% of sexually active students have experienced unintended pregnancy, with 94% of these ending in abortion [8-10].Moreover, RSB is a major pathway for HIV transmission among youth, with young people accounting for nearly half of new global HIV infections [11] .These trends highlight RSB as a critical public health issue that jeopardizes the physical, psychological, and academic well-being of college students.

Despite various interventions—such as structured sex education, motivational interviewing, peer-led programs, digital tools, and environmental supports—existing approaches have shown limited long-term effectiveness in reducing RSB [12-18] . Structured educational curricula, while effective in improving knowledge, often fail to translate into behavioral change, suffering from low engagement due to the private topic and a one-size-fits-all approach, leading to a persistent “knowledge-behavior gap” where increased awareness fails to translate into safer sexual practices [19-21] Motivational interviewing, though effective in addressing ambivalence and enhancing

intrinsic motivation, is resource-intensive and impractical for widespread campus implementation [13, 22-24]. Environmental and policy interventions, such as improving access to condoms and sexual health services, face challenges related to stigma, low utilization, and regional disparities [17, 25-28]. Consequently, there is a critical gap in interventions that are both theoretically grounded and capable of achieving widespread, sustained impact. This gap underscores the need for interventions that move beyond information dissemination to address the multifaceted determinants of behavior, including psychological capability, social and physical opportunity, and reflective and automatic motivation.

The Behavior Change Wheel (BCW) is a comprehensive, theoretically grounded framework developed to systematically design effective behavior change interventions [5]. The core of BCW is the COM-B model, which posits that for any behavior (B) to occur, individuals must have the Capability (physical and psychological), Opportunity (social and physical), and Motivation (reflective and automatic). The BCW has been successfully applied to various health behaviors, including smoking cessation and chronic disease management [6, 7], but its application to RSB in college students is absent.

Peer-led education has emerged as a promising strategy for sexual health promotion. Peer educators can effectively model protective behaviors, challenge risky norms, and create a supportive environment for discussing sensitive issues [29, 30]. Systematic reviews confirm that peer-led programs can improve sexual knowledge, attitudes, and condom use skills among young people [29, 31].Sun et al. [30] and Odundo et al. [32]

demonstrated significant improvements in condom use attitudes and behaviors following peer education. However, the effectiveness of peer-led interventions might be heterogeneous, which depended on the knowledge, skills, and credibility of the peer educators themselves [33]. Without rigorous selection, training, and ongoing support, the fidelity and impact of these interventions can be compromised. Furthermore, evidence regarding their long-term efficacy and ability to address complex behavioral determinants like risk perception and self-efficacy remains inconclusive [33]. Concurrently, digital interventions offer advantages of accessibility, privacy, and scalability, which are crucial for addressing sensitive topics like sexuality [10, 34]. Utilizing platforms like mobile apps, social media, and virtual reality (VR), digital interventions can provide personalized, anonymous, and accessible sexual health information and support [35-37]. They can overcome geographical and temporal barriers, reaching students who might not seek face-to-face services. Studies have explored the use of social media for disseminating STI prevention information, interactive games to reduce risk-taking on dating apps, and even VR or virtual play to enhance empathy and risk perception [36,38,39]. These approaches are generally well-accepted by tech-savvy student populations. However, few studies have integrated these approaches within a robust theoretical framework like the BCW to create a multi-level intervention targeting the specific barriers faced by students with a history of RSB.

Thus, the aims of this study were: 1) develop peer and digital-lead intervention based on BCW theory for risky sexual behaviors in college students, and 2) evaluate the effectiveness of this intervention through a randomized controlled trial (RCT). We

hypothesized that college students receiving the BCW-based intervention would demonstrate a greater reduction in RSB frequency, higher risk perception, improved psychosexual health, and lower shame associated with sexuality compared to those receiving routine education.

Methods

Study Design and Participants

This was a parallel randomized controlled trial which conducted from October 2023 to December 2024. Phase 1 focused on intervention development based on BCW guideline. Phase 2 was a parallel-group, double-blind randomized controlled trial. We will report this clinical trial according to the Consolidated Standards of Trials (CONSORT) statement of randomized controlled trials. We have completed the registration in the Clinical Trials.gov (NCT12345678), and any major changes will be reported to the registry and updated accordingly.

Setting and participants

Participants were recruited from a university in Daqing City, Hei Longjiang Province, in northeastern China via online advertisements and campus channels. The inclusion criteria were: (1) full-time undergraduate student, (2) self-reported engagement in at least one type of RSB (unprotected sex, casual sex, multiple partners ≥2, or commercial sex) during their college years. Exclusion criteria included: (1) unwillingness to participate; (2) diagnosed severe mental illness such as schizophrenia, major depressive disorder, and bipolar disorder; (3) severe physical illness.

Sample size calculation

The sample size was calculated using the software of G-power 3.1, with power set to 0.90 and Alpha to 0.05, and the sample size was calculated to be at least 34 cases in each group, and taking into account the 10% loss of rate in this study, the total sample size was finally confirmed to be 76 cases, 38 cases in each of the two groups.

Randomization, allocation concealment, and blinding

Randomization was performed by an independent researcher (XY) who was not involved in participant recruitment or data collection. Using the "rand" function in Microsoft Excel, XY generated a blocked randomization sequence with a 1:1 allocation ratio to the intervention or control group. During this process, neither the researchers nor the participants will be aware of the group allocation in advance, thus ensuring allocation concealment. All the data will also be collected through the platform, thus ensuring blinding of the data collectors. Written informed consent was obtained from all participants before intervention. The study was approved by Harbin Medical University Ethics Committee (No. HMUDQ20231116201).

Intervention

Intervention Development

The peer- and digital-led intervention program was systematically developed following the eight-step process of the Behavior Change Wheel (BCW) framework[40] (Supplement table). The BCW's COM-B model (Capability, Opportunity, Motivation-Behavior) informed the identification of intervention functions and the design of specific behavior change techniques. The resulting program comprised six weekly thematic modules, each targeting distinct COM-B components to reduce risky sexual

behaviors among college students. The detailed intervention structure, including theoretical sources, intervention functions, content, and delivery format, is presented in Table 1.

Intervention Group

The intervention group received the routine sexual health education in university as the control group and also participated a multicomponent program combining structured group sessions led by trained peer leaders with ongoing support via a dedicated digital platform (Table 1).

Peer leaders training

Intervention Team: A multidisciplinary team was established, comprising a supervisory mentor, a sexual health education expert, a clinical physician for consultation, a psychological counselor, and a graduate student responsible for coordination and material preparation.

Peer Leaders: Undergraduate student peer leaders were recruited and trained. They underwent a 14-hour standardized training program delivered by the expert team, covering core sexual health knowledge, group facilitation skills, communication strategies, and ethical guidelines. Their competency was assessed through tests and simulated exercises prior to leading sessions.

Peer-Led Group Sessions

The intervention was delivered over six weeks, with one 90-minute session per week. Each session followed a standardized manual and focused on a specific theme based on

International technical guidance on sexuality education: An evidence-informed approach[39].

1. Sessions 1 & 2: Capacity Building

These sessions aimed to enhance *psychological* and *physical capability*. Activities included ice-breaking games to build trust, group discussions on sexual health concepts (e.g., social construction of sexuality, gender identity), quizzes on condom use, and behavioral simulations (e.g., role-playing attraction and communication scenarios) to translate knowledge into practical interpersonal skills.

2. Sessions 3 & 4: Motivation Building

These sessions targeted *reflective* and *automatic motivation*. Using persuasive communication, modeling, and motivational techniques, content covered managing sexual impulses, establishing healthy intimate relationships, practicing communication and sexual consent skills, and demonstrating correct condom use.

3. Sessions 5 & 6 : Opportunity Building

These sessions addressed *physical* and *social opportunity*. They involved training to recognize and respond to high-risk situations (e.g., substance use, online dating), interactive demonstrations on HIV self-testing, and environmental restructuring through discussions on peer influence and the creation of a supportive community. The final session included a graduation ceremony to reinforce commitment.

Digital Platform Support

To provide continuous, accessible, and theory-informed support beyond the time-limited group sessions, all participants in the intervention group were granted access to

the dedicated WeChat Official Account named “SiLiang”. The platform’s design was grounded in the opportunity and motivation components of the BCW framework, aiming to create a supportive digital environment and reinforce learned skills. Its use was integrated into the intervention protocol as both a supplementary resource and a component of specific session homework tasks. Platform engagement data (e.g., login frequency, module access) was passively collected to monitor adherence. The platform featured five core interactive modules, each with a defined operational protocol:

1. Knowledge Hub

This module served as a dynamic library for structured sexual health education. Content was pre-scripted and curated by the multidisciplinary research team, comprising short articles, infographics, and 2–3 minute animated videos. Information was organized into searchable categories mirroring the group sessions: Basic Knowledge (STIs, HIV transmission), Relationship Skills (consent, communication), and Practical Resources (contraception, testing) based on International technical guidance on sexuality education: An evidence-informed approach and publicity materials for science popularization from the Chinese CDC. A push notification was sent every Tuesday and Friday to alert users to new content. All materials were written at an accessible literacy level and reviewed for medical accuracy by the clinical doctor on the team(Fig. 1).

2. Interactive Scenarios

This module translated theoretical risk recognition into practical decision-making exercises. It contained 5 branching narrative scenarios developed from common risky

situations identified in formative research (e.g., “Drunk at a party,” “Pressure from a dating app match”). Users navigated the scenario by making choices at key decision points (e.g., “Go to a private room” vs. “Suggest getting water first”). Each choice triggered immediate, non-punitive feedback explaining the potential consequences and linking to relevant educational tips. One specific scenario was assigned as homework after Session 5, and users were required to submit a screenshot of their completion path to the peer leader(Fig. 2).

3. Virtual Services

This module facilitated direct access to resource linkage. It featured: a) A geolocator map showing nearby clinics offering confidential STI testing and counseling; b) A free mail-order service where users could request a discreet package containing condoms and oral HIV self-test kit(Fig. 3).

4. Self-service consultation service

This module aimed to build social opportunity and reduce shame through moderated agent interaction. A pre-formatted questions and answers interface that allowed users to submit anonymous questions to agent and sexual health education expert would review the reply content(Fig. 4).

Thus, this method ensures participants’ easy access to the platform and increases their engagement. In addition, during the course of the study, any adverse events can be reported to the ethics committee at any time by the investigators, who may also propose terminating or withdrawing from the study. All data are only accessible to the investigators, and only they are aware of this process.

The control group received the routine sexual health education in university during the clinical trial, which typically consists of optional lectures or promotional materials. They were offered the intervention materials and digital platform support at the end of final follow-up.

Data Collection

All participants had signed the informed consent form, which also includes a statement that the data from this study may be used for ancillary studies, and scan a code to join the group. Participants completed the questionnaire on-site via an online questionnaire platform (https://www.wjx.cn/vm/hnntjL0.aspx) at baseline (T0), post-intervention (T1), and one-month follow-up (T2), which might prevent oversight in necessary answers and mitigate the influence of human factors, thus ensuring the quality and integrity of the data. As an incentive, participants would receive prize voucher for each follow-up session and questionnaire. Our database was encrypted and only the members of the project group had access to the final collected data. Figure 5 illustrates the flowchart detailing the study's recruitment process, interventions, and follow-up.

Measures

Demographic variables

The demographic information included gender, age, monthly living expenses, number of child, family location, family type, family income, educational level of parents, relationship status, attitude towards premarital sex, and sexual orientation

Primary Outcomes

RSB Frequency: Self-reported number of RSB episodes in the past month.

Risk Perception: A single item: "How likely do you think you are to engage in RSB?" (1=extremely unlikely to 10=extremely likely).

Secondary Outcomes

Psychosexual Health

Measured using the College Student Psychosexual Health Questionnaire which was developed by Yang [41]. The questionnaire consists of 31 items and contains two subscales: Sexual Cognition and Sexual Attitude. Each item is a 5-Likerty rating (1 = completely disagree, 5 = completely agree). Lower scores indicate better psychosexual health. The Cronbach's α was 0.808 in this study.

Sense of Shame

Measured using the Shame Experience Scale which was developed by Qian [42]. The scale consists of 25 items and three subscales, higher scores indicate greater shame. The Cronbach's α was 0.775 in this study.

Statistical analysis

Data were analyzed using SPSS 25.0. For descriptive analyses, the continuous variables will be summarized using the mean and standard deviation (SD) or median and interquartile range (IQR). The categorical variables will be summarized using frequency (n) and percentage (%). All continuous variables are checked for normality. Both parametric and nonparametric statistical methods, including the independent sample t test, Chi-square test, Fisher's exact test and Wilcoxon rank-sum test, will be applied to compare the baseline characteristics between groups. The intent-to-treat (ITT) strategy was used to analyze the intervention impact. Generalized Estimating Equations

(GEE) was conducted to test the intervention effects. The models included group effect, time effect, and group-by-time interaction effects. Post-hoc pairwise comparisons with Bonferroni correction were conducted. Effect sizes were calculated by Cohen's d for significant effects.

Results

The demographic of the two groups at baseline

76 eligibility college students were enrolled and randomized into two groups (38 per group). In the intervention group, 35 completed the T2 assessment. In the control group, 35 completed T2 (Fig.5 The flowchart). ITT analysis was conducted to verify the effect of intervention. The average age was (18.79±1.23) in the control group and (19.21±1.73) in the intervention group. There was no significant differences in demographic characteristics and outcome measures at baseline between the two groups (all $p > 0.05$) (Table 2).

Intervention Effects

Risky Sexual Behavior (RSB) Frequency

GEE analysis revealed significant main effects for group (Wald $\chi^2 = 21.91$, $p < 0.001$) and time (Wald $\chi^2 = 13.48$, $p < 0.001$), but no significant was found in group-by-time interaction ($p = 0.566$). Post-hoc comparisons showed that the intervention group reduced significantly on RSB frequency from T0 to T1 (Mean Difference [MD] = -0.91, $p < 0.001$, $d = 1.06$) and from T0 to T2 (MD = -1.45, $p < 0.001$, $d = 1.67$). The control group showed no significant change from T0 to T1 ($p = 1.000$) and a smaller reduction at T2 (MD = -0.55, $p = 0.037$, $d = 0.57$). Crucially, the intervention group had

significantly lower RSB frequencies than the control group at both T1 (MD = -0.57, p = 0.009, d = 0.73) and T2 (MD = -0.71, p = 0.001, d = 0.87) (Table 3, Figure 6).

Risk Perception

There were significant main effects both on group (Wald $\chi^2 = 65.12$, $p < 0.001$), time (Wald $\chi^2 = 7.00$, $p = 0.008$), and group-by-time interaction (Wald $\chi^2 = 7.71$, $p = 0.005$). The intervention group's risk perception scores increased sharply from T0 to T1 (MD = 2.51, $p < 0.001$, d = -1.88) and remained high at T2. However, the risk perception increased smaller and occurred later (T0 to T2) in the control group. The intervention group's scores were significantly higher than the control group's at T1 (MD = 2.51, $p < 0.001$, d = -2.20) and T2 (MD = 1.40, p = 0.001, d = -0.92) (Table 3, Figure7).

Psychosexual Health

For total psychosexual health scores, group effect had significant (Wald $\chi^2 = 20.81$, $p < 0.001$). The intervention group's scores decreased significantly from T0 to T1 (MD = -9.28, $p < 0.001$, d = 0.96) and T0 to T2 (MD = -11.73, $p < 0.001$, d = 1.18), indicating psychosexual health had improved. The control group had no significant change in these time points. The intervention group had significantly better scores than the control group at T1 (MD = -6.05, p = 0.039, d = 0.62) and T2 (MD = -7.69, $p < 0.001$, d = 1.01). (Table 2, Figure 8). On Sexual Cognition, significant group (Wald $\chi^2 = 11.58$, $p = 0.001$) and time (Wald $\chi^2 = 6.95$, $p = 0.008$) effects were observed. The intervention group showed sustained improvement, with scores at T2 being significantly better than the control group (MD = -6.06, p = 0.002, d = 0.85) (Table 3, Figure 9A). At meanwhile, significant group (Wald $\chi^2 = 14.17$, $p < 0.001$) and time (Wald $\chi^2 = 5.67$, $p = 0.017$)

effects were found in Sexual Attitude. The intervention group's attitudes improved most markedly at T1, where they were significantly more positive than the control group (MD = -3.51, p = 0.002, d = 0.83) (Table 3, Figure 9B).

Sense of Shame

GEE analysis showed significant main effects for group (Wald $\chi^2 = 85.77$, $p < 0.001$) and time (Wald $\chi^2 = 19.90$, $p < 0.001$). The intervention group's shame scores decreased significantly from T0 to T1 (MD = -8.81, $p < 0.001$, d = 1.04) and maintain to T2 (MD = -13.34 from T0, $p < 0.001$, d = 1.74). The control group's scores showed no significant decrease. The intervention group's shame was significantly lower than the control group's at both T1 (MD = -15.43, $p < 0.001$, d = 1.87) and T2 (MD = -14.03, $p < 0.001$, d = 1.61) (Table 3, Figure 10).

Discussion

This study developed and evaluated a novel BCW theory-based intervention for reducing RSB among Chinese college students. The intervention program, which integrated peer and digital-lead form, proved to be effective. The results support our hypothesis, demonstrating significant improvements in the intervention group compared to the control group across all primary and secondary outcomes.

The substantial reduction in RSB frequency and the large effect sizes observed in this study align closely with the central premise of the Behaviour Change Wheel: sustainable behavior change requires simultaneous modification of Capability, Opportunity, and Motivation [40].The effectiveness of the intervention can be attributed to the synergistic interaction between its peer-led and digital components, each

targeting different aspects of the COM-B system in ways which traditional lecture-based education cannot. Firstly, the peer-led groups acted as a powerful mechanism for enhancing social opportunity and strengthening motivation. Evidence from school-based peer interventions, such as the STASH program in the UK, has shown that peer facilitators create a socially proximate, trustworthy environment that fosters openness and high engagement [43]. In the intervention, peer facilitators played a similar role: by sharing relatable experiences and modeling behaviors such as carrying condoms or asserting boundaries, they actively reshaped participants' perceptions of social norms. This normalization reduced the perceived social risks associated with advocating for protection. Moreover, consistent with research demonstrating the value of peer-based observational learning [44], the group setting enabled participants to rehearse refusal skills and condom negotiation in a safe, low-stakes environment. Such experiential practice builds psychological capability far more effectively than passive information reception, helping participants translate knowledge into real-world behavioral competence.

Complementing this, the digital resources fundamentally reconfigured physical opportunity and provided continuous support for capability and motivation. Digital sexual health interventions have been shown to improve access, privacy, and timely delivery of resources [45, 46]. The "SiLiang Health" platform served as an on-demand extension of the peer sessions, lowering logistical barriers by directly offering practical resources such as condom mailing—a strategy aligned with the BCW principle of making healthier choices easier to enact. Beyond information provision, the platform's

interactive modules, especially metaphor-based digital games, mirrored methods used successfully in other e-health behavior change programs, where simulated scenarios help users experience the consequences of risky decisions in a safe environment [47]. These immersive exercises engaged both reflective motivation (evaluating consequences) and automatic motivation (forming affective associations with risk). Crucially, the digital platform ensured continuity, filling a gap inherent to time-limited in face-to-face sessions. While peer groups provided intensive episodic support, the digital platform functioned as a persistent, private, and context-responsive resource. Students could revisit materials, re-assess their risk, or access support during moments of heightened vulnerability—such as before going on a date—mirroring the "just-in-time" intervention model increasingly recognized as essential in digital health. In summary, it was the intentional integration of peer-led and digital components—not either element alone—that produced the observed behavior change. Peer groups cultivated trust, reshaped norms, and strengthened practical skills, while digital tools provided ongoing access, reduced physical barriers, and supported moment-to-moment decision-making. This synergy produced a comprehensive system that enhanced capability, optimized opportunity, and reshaped motivation, offering a robust and replicable framework for improving youth sexual health behaviors within the BCW model.

The marked increase in risk perception within the intervention group represents a central mechanism of change when viewed through the BCW. Low perceived susceptibility is a well-established predictor of RSB, and recent studies continue to

show that adolescents who underestimate their vulnerability are more likely to engage in unprotected sex or multiple partnerships [48-50]. Drawing on BCW functions of education, persuasion, modelling, and training, the peer-led component made risk more personally relevant and socially validated. Peer facilitators used narrative storytelling, discussion of real-world consequences, and modeling of protective norms—strategies shown in contemporary peer-education research such as STASH to enhance credibility, emotional engagement, and reflective motivation among youth [43,51]. These social interactions not only heightened students' perceived susceptibility but also linked this awareness to actionable behavioral skills through rehearsal and guided practice, transforming abstract risk into concrete, manageable decision-making. Meanwhile, the digital platform strengthened and personalized these shifts through BCW functions of persuasion, education, enablement, and environmental restructuring. Interactive risk assessments provided individualized feedback that has been shown to improve risk calibration and motivate protective behavior in digital sexual health tools [52]. Graphic warnings, scenario-based modules, and immersive digital narratives deepened emotional salience, in line with evidence that vivid digital content enhances risk appraisal among youth [45, 53]. By embedding risk-focused resources into students' daily digital environments and pairing heightened perception with immediate pathways to action (e.g., condom access, service linkage), the intervention allowed reflective motivation to translate into timely behavior change. Together, the peer-led and digital elements formed a coherent BCW-informed system that recalibrated vulnerability, strengthened motivation, and facilitated safer sexual decision-making.

The improvements in psychosexual health, particularly in sexual cognition and attitudes, indicate that the intervention fostered a more informed and positive framework for understanding sexuality. This is crucial for long-term sexual well-being beyond merely avoiding risk [54]. The reduction in the sense of shame is equally important. Shame is a significant barrier to seeking sexual health information and services [55]. The peer-led, supportive, and semi-anonymous (masks optional) group environment, combined with the privacy of the digital platform, created a safe space that normalized discussions about sexuality, thereby reducing feelings of isolation and self-stigma.

Our findings are consistent with the growing literature on the efficacy of peer-led and digital sexual health interventions [16,29,35,56]. However, this study adds value by systematically integrating these modalities within the robust BCW framework, ensuring that each component directly addressed a identified barrier from the COM-B analysis. The high satisfaction and feasibility metrics suggest that this blended model is well-suited to the preferences and lifestyles of modern university students.

This study has several limitations. Firstly, the sample was recruited from a single university in Northeast China, which may limit generalizability. Future research should conduct multi-center RCTs with larger and more diverse samples. Secondly, all measures were self-reported, which exist social desirability and recall biases, especially for sensitive behaviors like RSB. The use of anonymous online surveys aimed to mitigate this. Lastly, the specific contribution of the digital component versus the peer-led sessions warrants further investigation through factorial designs.

Conclusions

Peer and digital-lead intervention program based on BCW theory is effective strategy for reducing risky sexual behavior and promoting overall sexual health among college students. By systematically targeting the capabilities, opportunities, and motivations underlying sexual behavior, this intervention model offers a practical and engaging paradigm for healthcare professionals and educators working in adolescent and young adult health. It represents a significant step forward from traditional, knowledge-focused sex education towards a more holistic, behavior-centered approach.

List of abbreviations

BCW Behavior Change Wheel

RSB Risky sexual behavior

STIs sexually transmitted infections

ITT Intention-to-trea

GEE Generalized Estimating Equations

SD standardized deviation

COM-B Capability, Opportunity, Motivation-Behavior

VR virtual reality

RCT randomized controlled trial

MD mean deviation.

Declarations

Ethics approval and consent to participate

This study was conducted according to the Declaration of Helsinki and has been approved by the Harbin Medical University Ethics Committee (No. HMUDQ 20231116201). Written informed consent will be obtained from the participants before the baseline assessment.

Consent for publication

Not applicable

Availability of data and materials

The datasets analyzed during the current study are not publicly available due personal privacy information but are available from the corresponding author on reasonable request.

Competing interests

The authors declare no conflict of interest.

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Authors' contributions

RZ interviewed the participants and constructed the intervention programme. XYX randomized, allocated the participants. HX and HYZ contacted the professors and analyzed the data. TP provided the consultation for this study, QSL had written the draft. HZ designed the study and revise the manuscript.

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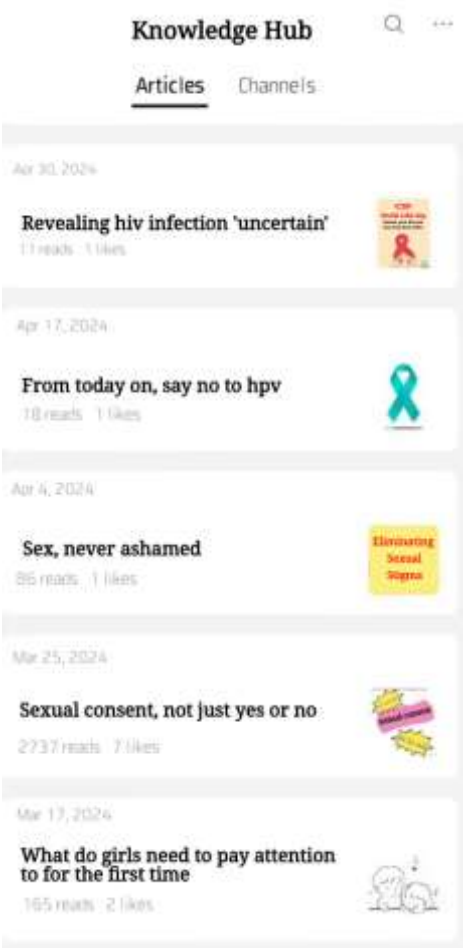


Figure 1 The page for users to browse knowledge hub

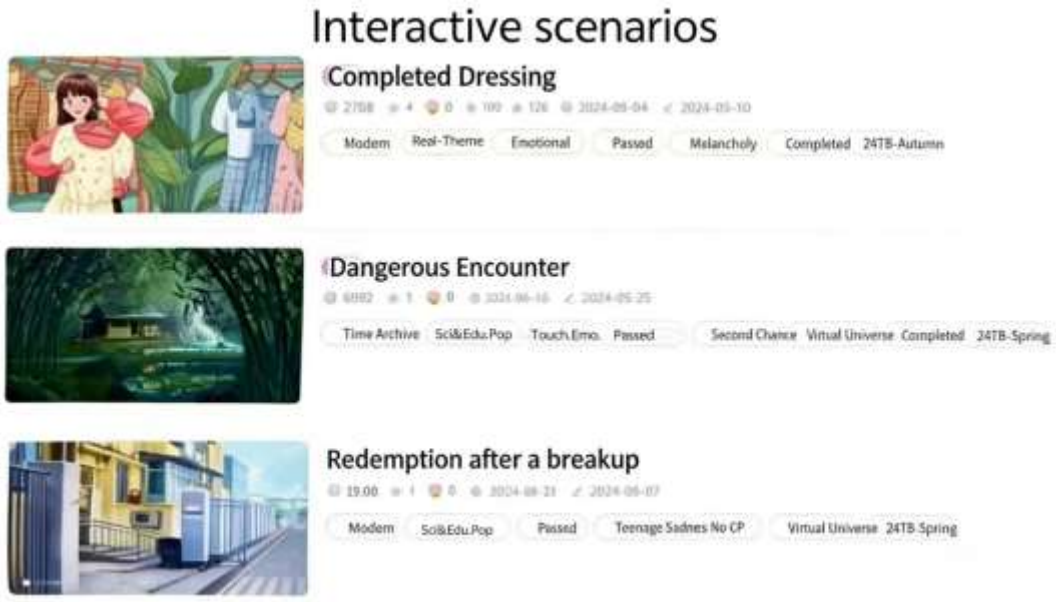


Figure 2 The page for users to browse interactive scenarios

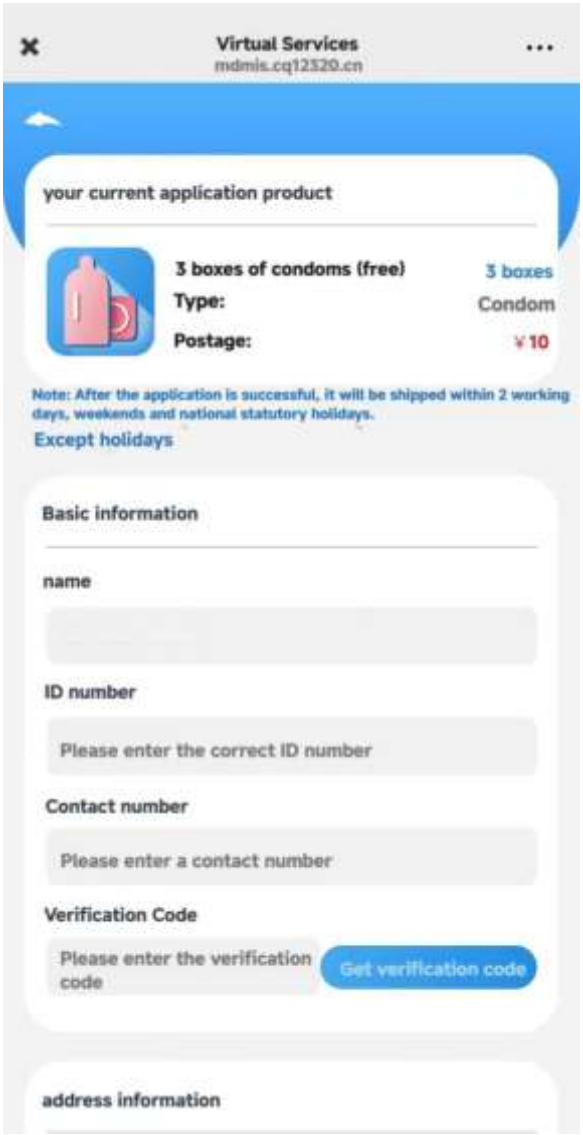


Figure 3 The page for users to browse virtual services

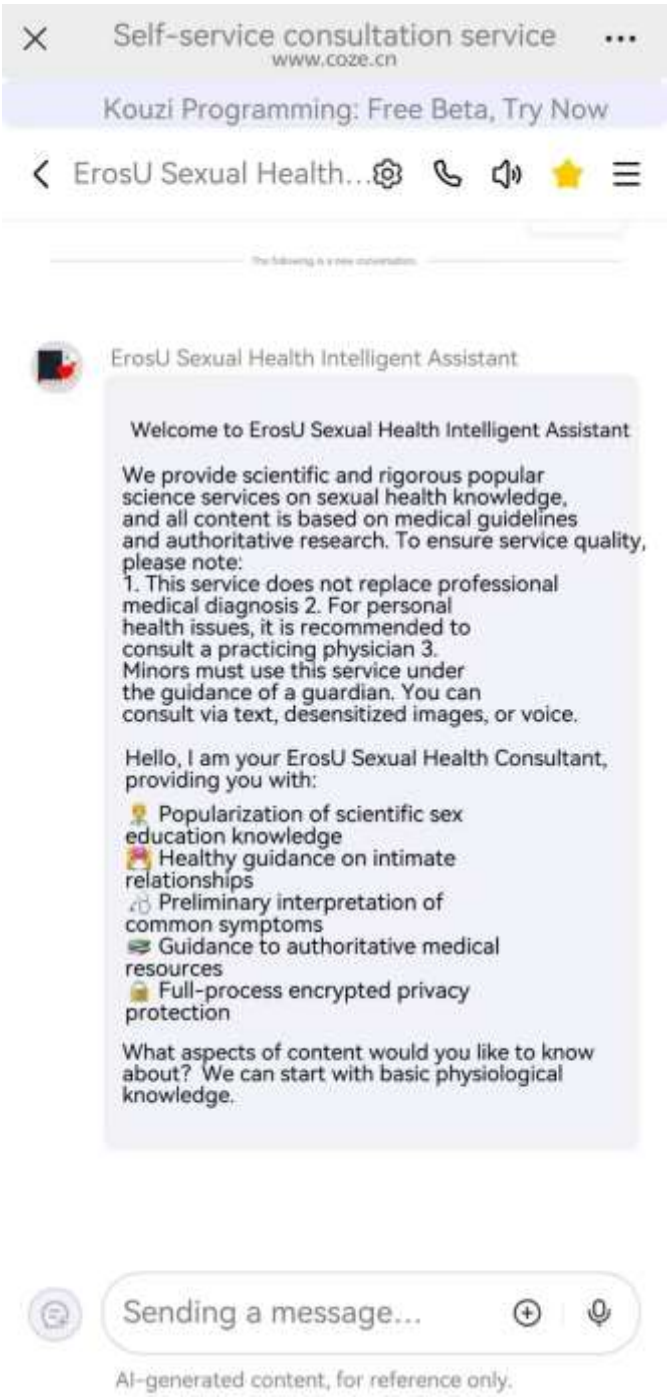


Figure 4 The page for users to browse self-service consultation service

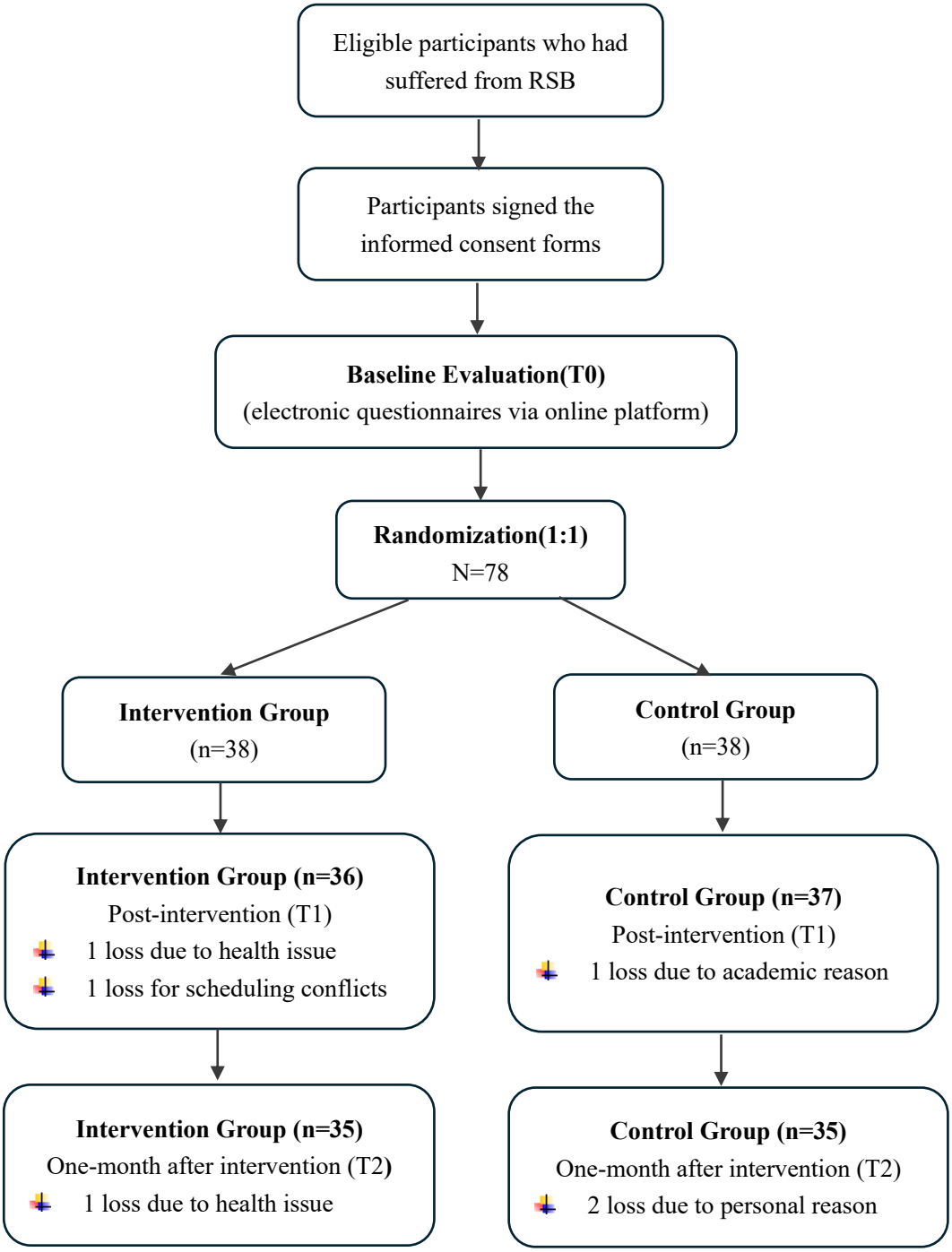


Figure 5 The flowchart of the study

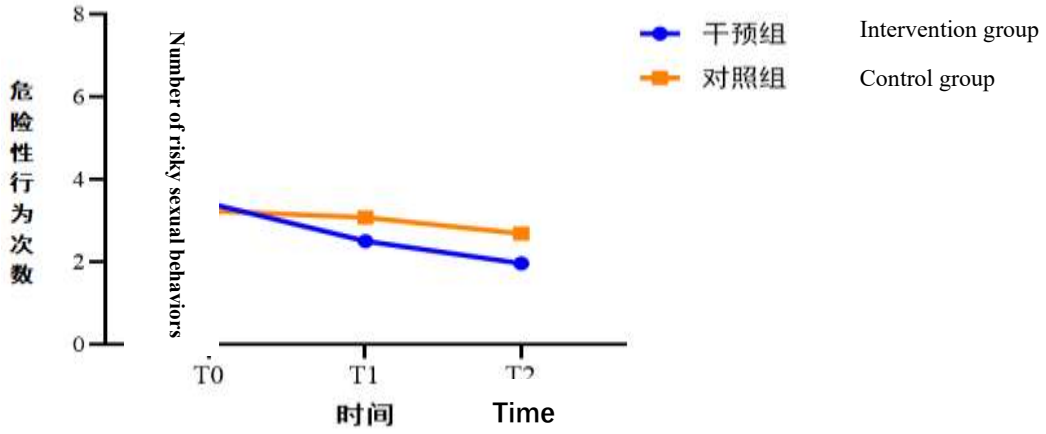


Figure 6 The comparation of risky behaviors between two groups

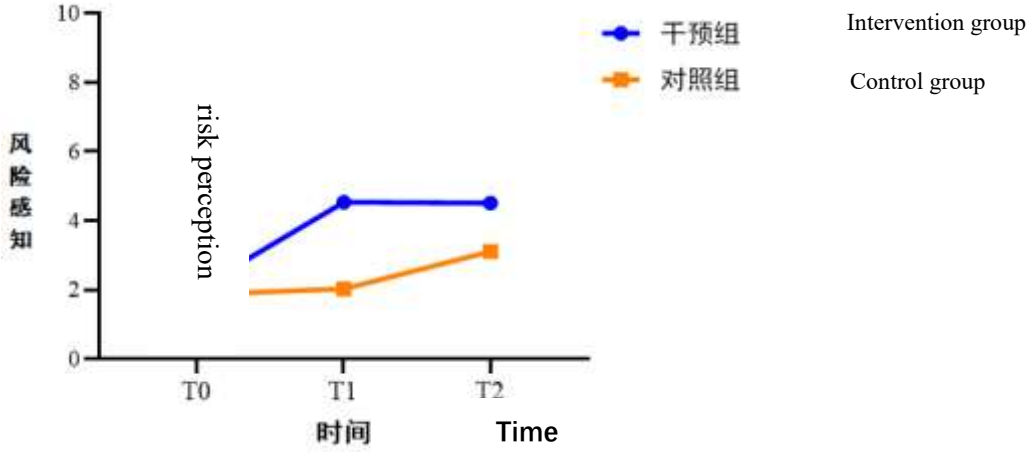


Figure 7 The comparation of risk perception between two groups

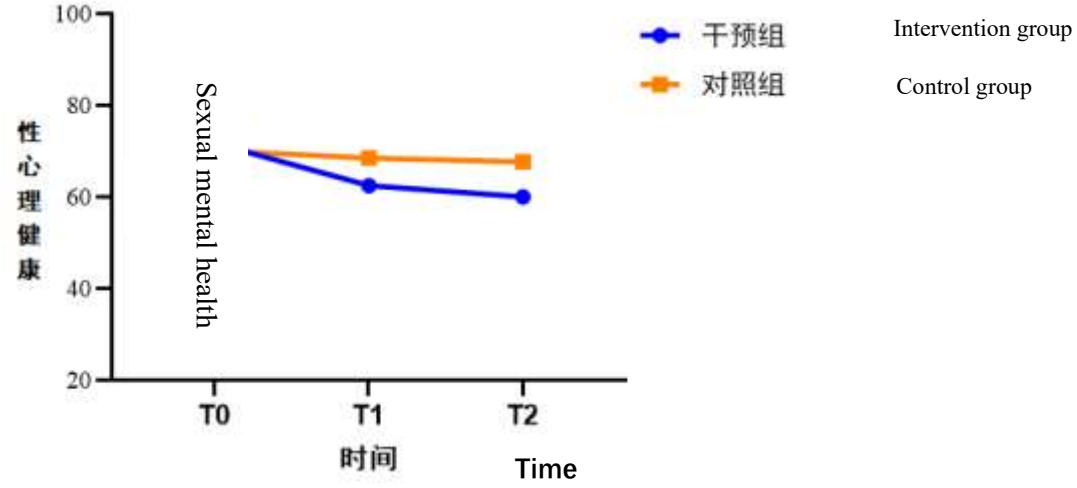


Figure 8 The comparation of Sexual mental health between two groups

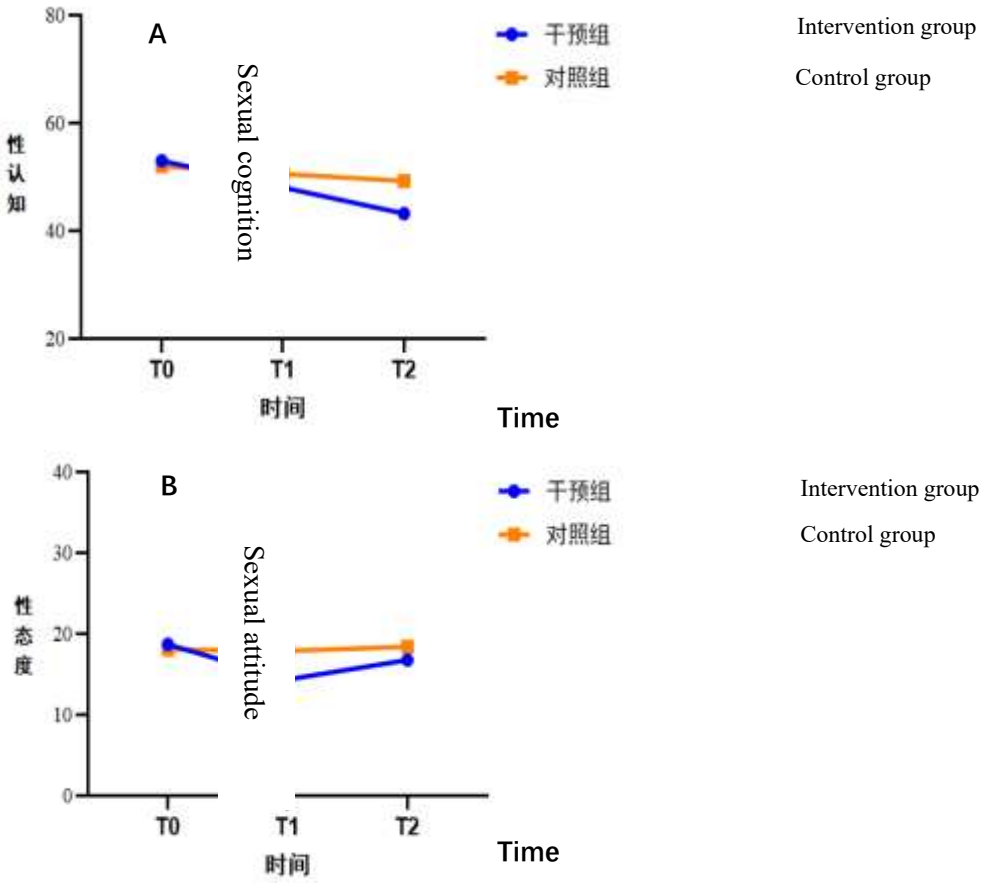


Figure 9 The comparation of Sexual cognition and sexual attitude

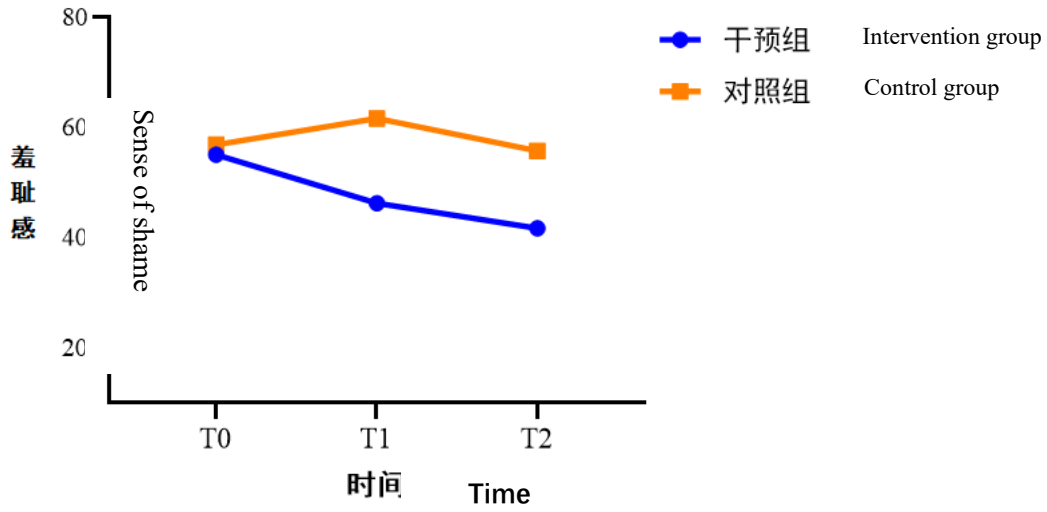


Figure 10 The comparation of Sense of shame between two groups

Supplementary Files

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