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Review

Web-based cognitive interventions on subjective cognitive impairment in cancer survivors: A systemic review

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ABSTRACT

Objective: Cancer survivors have experienced subjective cognitive impairment (SCI) when they received cancer diagnoses or treatments. Their psychosocial and emotional statuses were also impacted. With the advancement of web technologies, web-based cognitive interventions have been implemented in the management and the alleviation of the SCI, the psychosocial distress, and the emotional distress in cancer survivors. This review aimed to summarize the intervention contents of web-based cognitive interventions for SCI, and to explore the effects of the interventions on SCI, psychosocial status, and emotional health.

Methods: Six databases (CINAHL Plus, Cochrane Library, Embase, APA PsycInfo, PubMed and CNKI) were searched from the establishment of databases up to December 2023. Literature references were also manually searched for related articles.

Results: This review contained 21 studies that covered the contents of web-based cognitive interventions, such as computer-assisted cognitive training, online cognitive rehabilitation, cognitive behavior therapy with the Internet, telehealth physical exercise, and web-based mindfulness interventions. The effects of web-based cognitive interventions positively impacted SCI for cancer survivors. Also, these interventions showed varying degrees of effectiveness in alleviating psychosocial and emotional distresses.

Conclusion: By summarizing five types of cognitive intervention contents delivered via web technology, this review demonstrated that web-based cognitive interventions optimized SCI and overall psychosocial and emotional statuses for the cancer survivors. It is recommended that future research focus on the development of customized web-based cognitive interventions for individuals with SCI, along with their psychosocial and emotional statuses.

What is known?

- Cognitive impairment symptoms and long-term adverse effects are frequently reported in cancer survivors. Following the cancer diagnoses and treatments, these cancer survivors experience subjective cognitive impairment, including memory loss, inattention, and delays in executive function. These issues impact their quality of life, emotional health, marital and social relationships, as well as career activities.
- Various types of cognitive interventions have been increasingly developed and integrated with web technology to alleviate and improve subjective cognitive impairment.

What is new?

- The results of this review integrated the current types of web-based cognitive interventions, which showed varying degrees of improvement in subjective cognitive impairment, psychosocial status and emotional health.
- Tailored web-based cognitive interventions of individual psychosocial and emotional statuses concerned are needed to optimize subjective cognitive impairment and promote overall wellness.

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1. Introduction

Cancer is one of the most concerning and severe issues worldwide. According to the reports from the World Health Organization (WHO), global cancer rates are predicted to climb further, with an estimated 27.50 million new diagnoses and 16.30 million deaths by 2040 [1]. Notably, the survival rate of individuals with cancer has increased dramatically due to the advancements in medical technology and early detection of cancer. For example, it's estimated that there will be up to 26 million cancer survivors in the United States by 2040 [2]. While survival is a cause for celebration, it is essential to be aware that the survivors may experience long-term adverse effects associated with cancer treatments. Cancer and its treatments have a variety of physical and psychological consequences on individuals with cancer, such as pain, exhaustion, neurocognitive dysfunction and its consequences, psychosocial stress, and emotional distress [3].

Researchers have discovered that individuals with non-central nervous system (CNS) cancer experience cognitive impairment, such as memory loss, poor concentration, and delayed executive function [4,5]. The symptoms of cognitive impairment and its long-term adverse effects are frequently noted and reported following the cancer diagnoses and treatments. The survivors exhibited subjective cognitive impairment (SCI), which impacted their quality of life (QoL), psychological and emotional statuses, marital and social relationships, and professional activities [4,6,7]. Stewart [8] proposed the concept of SCI, which refers to the phenomenon of individuals reporting or recognizing cognitive impairment. Researchers have recognized and analyzed SCI to identify the survivors at risk for cognitive impairment (including complement objectively undetectable or unmeasured cognitive impairments), to manage their cognitive function, and to promote their individual mental and emotional well-beings [9,10].

Based on the available cognitive intervention programs for patients, alongside the broad application of network technology and the rapid advancements of telemedicine, researchers have developed more convenient, flexible, and intelligent cognitive intervention programs incorporating web-based technology. Web-based interventions widely utilize the Internet approaches, such as websites, computer software, mobile applications, emails, and other social media platforms [11]. Various types of web-based interventions targeting cognitive function have been developed, like computer-assisted cognitive training (CT) [12,13], online cognitive rehabilitation (CR) [14,15], cognitive-behavioral therapy (CBT) with Internet [16,17], telehealth physical exercise [18], and web-based mindfulness interventions [19]. These interventions have shown to have beneficial effects on the SCI, psychosocial distress, and emotional distress for the patients. The mechanism of action of the five types of interventions on SCI and other psychosocial or emotional outcomes may lie in the following aspects: CT focuses on retraining brain cognitive function through practice, assisted by using computerized training [20]; CR aims to restore the cognitive skills that have been lost or impaired, thereby improving their daily functions [9], and is increasingly being integrated with online technology; CBT encompasses a wide range of therapeutic approaches, mainly focusing on cognitive techniques to change unrewarding thought patterns, beliefs, attitudes, and actions [21]; Telehealth physical activity intervention utilizes informational and communicational techniques to estimate, monitor and/or supervise physical activities or other healthcare activities aimed at alleviating cognitive symptoms and relieving fatigue [22]; Web-based mindfulness interventions help the participants to focus attention on the current moment, be open-mind to one's surroundings, and develop the personal capacity and QoL [23].

Neuropsychological and web-based cognitive interventions are commonly applied to determine the improvements of specific cognitive functions. However, interventions focusing simultaneously on SCI, psychosocial status, and emotional status should be accessed [24–26]. As proposed by Green et al. [27], there are correlations between individuals' SCI and their psychosocial and emotional statuses. One framework, known as the Model of Factors Contributing to Cognitive Impairment (MFCCI), specifically states that psychosocial factors (coping performance exhibited by individuals affected by conditions such as fatigue and QoL) can impact the emotional health of the cancer survivors with SCI. These factors can either bolster or impede cognitive function. Emotional health was essential in SCI, as emotional status could impact attention, memory, decision-making, and overall cognitive performance. Both psychosocial and emotional distress influence the individuals with SCI collectively [27].

Moreover, this model demonstrates that to manage and optimize SCI, cognitive interventions are necessary to take the potential SCI-related factors and individuals' vulnerabilities into consideration [27]. Therefore, it's worthy to review and analyze the effects of cognitive interventions combined with web technologies on non-CNS cancers. Such interventions, tailored to individual needs and preferences, can provide flexible and accessible approaches to cognitive recovery [24].

Based on cognitive intervention suggestions from the MFCCI framework and the current study gaps, this review aims to: 1) summarize the intervention contents of the web-based cognitive interventions for SCI; and 2) integrate the intervention effects following the MFCCI guidance, encompassing intervention effects on SCI, psychosocial status (fatigue and QoL), and emotional health (anxiety and depression).

2. Methods

The Preferred Reporting Items for Systematic Reviews and Meta-analysis 2020 (PRISMA 2020) statement [28] provided guidance for the present review. No primary data collection from participants was performed and no ethical principle was involved in this review.

2.1. Search strategy

This review followed the PRISMA 2020 guidelines for literature retrieval and selection. Five electronic databases in English [Cumulative Index to Nursing and Allied Health Literature Plus with Full Text (CINAHL Plus), Cochrane Library, Excerpta Medica Database (Embase), American Psychological Association (APA PsycInfo), Public Medicine (PubMed)] and one in Chinese [China National Knowledge Infrastructure (CNKI)] were searched from the establishment of the databases up to December 2023. The Population, Intervention, Outcome, and Study design (PIOS) format was employed to guide the below search terms: "cancer" or "tumor" and "web" or "telemedicine" or "telehealth" or "computer" and "intervention" or "rehabilitation or "training" or "behavior therapy" or "education" and "cognitive impairment" or "cognitive complaint" or "subjective cognitive" and "randomized controlled trial" or "non-randomized controlled trial" or "quasi-experimental study" or "controlled before-after study" or "pilot study". Manual screening of references was also conducted. Detailed search terms and the screening process were presented in Appendix A and Fig. 1, respectively.

2.2. Inclusion and exclusion criteria

Articles matching the criteria below were incorporated: a) patients (aged 18 or older) with any type of cancer (but without

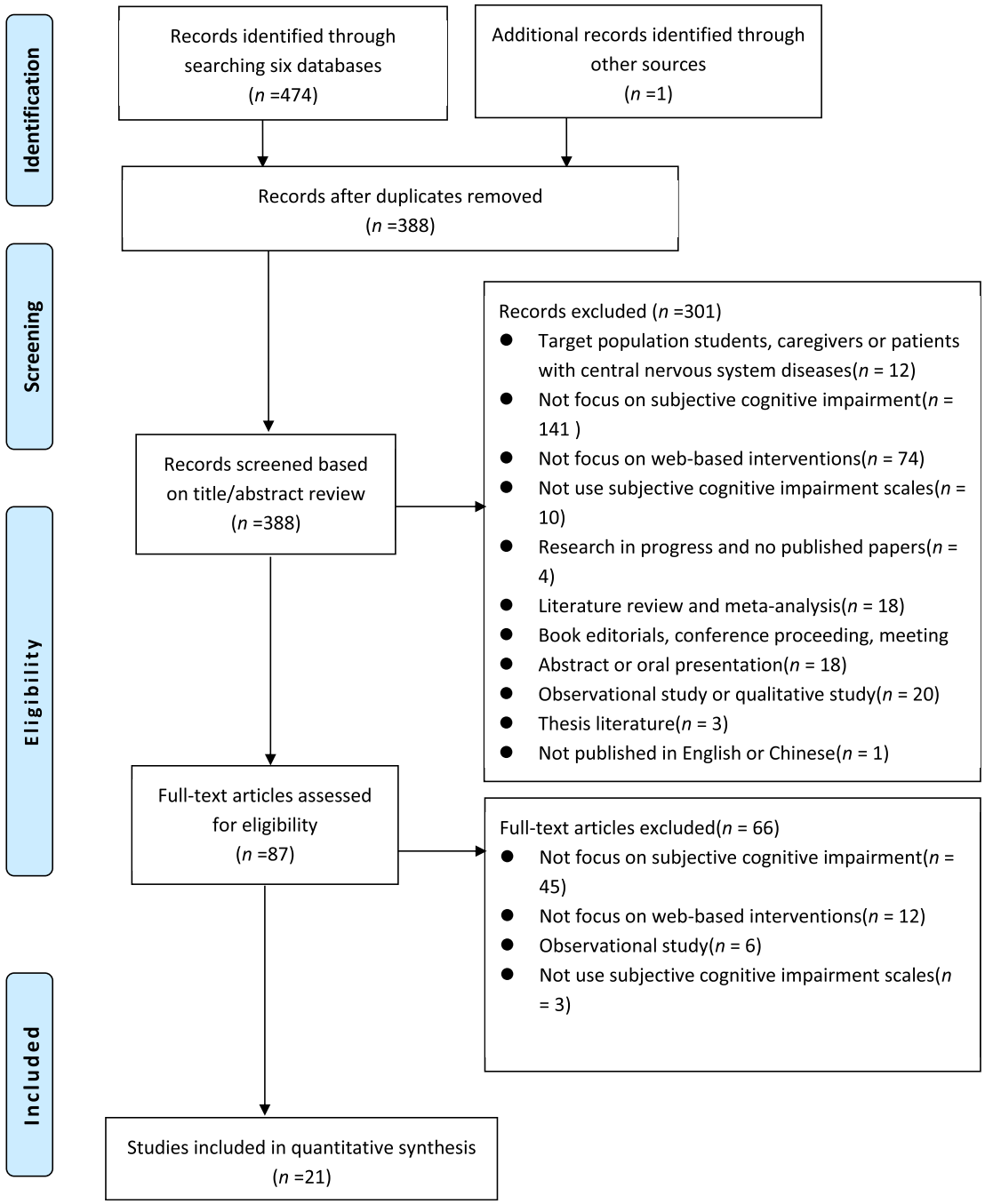

Fig. 1. PRISMA search flow diagram.

central nervous system disease or brain tumor); b) any forms of intervention (e.g., training, behavior therapy, rehabilitation, education, and intervention program), based on web technology, including computer, smartphone, email, internet/online application, telemedicine, software program, videoconference program; c) intervention outcomes included self-reported cognitive function scales measuring SCI; d) intervention studies included randomized controlled trials (RCTs) and non-randomized controlled trials; and e) articles published in English or Chinese in peer-reviewed journals. The following articles were excluded: a) commentaries, qualitative studies, reviews, dissertations, books and conference abstracts; and b) studies where the outcomes did not assess SCI or the psychological and emotional variables (e.g., fatigue, QoL, anxiety and depression) associated with SCI.

2.3. Data extraction and quality assessment

Data from each study were collected by one investigator and validated by another investigator independently. Any disagreements in the data extraction were resolved through discussions among the research team members. Different investigators extracted intervention details for each study independently. Appendix B summarizes the intervention characteristics of each eligible study, including the types of web-based cognitive interventions, the aims of the studies, and the intervention contents. Appendix C retrieved the details of the intervention outcomes, such

as study design, setting, participants, treatment, outcome measures and tools, as well as main results.

The quality assessment instrument of the Effective Public Health Practice Project (EPHPP) was used to measure the methodological quality of qualifying studies [29]. This assessment instrument is valid and reliable for systematic reviews.

3. Results

3.1. Study selection process

Fig. 1 shows the flowchart of the literature search. Through systematic and manual searching, 475 articles were initially retrieved, and 87 duplicates were deleted. After the titles and abstracts were reviewed, 301 publications were eliminated by the inclusion criteria. The remaining 87 studies were reviewed in total, and 21 were qualified for this review. Most discarded studies were those that failed to focus on SCI and web-based forms of cognitive intervention simultaneously.

3.2. Study methodological quality

Appendix A presents the detailed quality assessment for the 21 articles that were included. Three studies were rated as "strong", seventeen as "moderate", and one as "weak". Performance bias, resulting from a lack of blinding among researchers and participants, was the key factor influencing study quality. Due to its intervention contents, the study was rated weak and was still incorporated into this review.

3.3. Study characteristics

Appendix B summarizes and lists the characteristics of each included study, such as country, study design, and population characteristics. The studies were conducted in seven countries, including USA (n = 11, 52.4%), Australia (n = 3, 14.2%), Belgium (n = 3, 14.2%), Brazil (n = 1, 4.8%), China (n = 1, 4.8%), Denmark (n = 1, 4.8%), and the UK (n = 1, 4.8%). For the study designs, 17 were RCTs (n = 17, 80.9%); including 13 RCTs [14,15,17,30–39], two three-group RCTs [40,41], and two protocols of RCTs [16,42]. Two studies were mixed method studies (n = 2, 9.5%), including one qualitative interview and single group study [43], one RCT, and qualitative interviews [12]. Of the remaining two studies, one was a pilot study with a wait-list control (n = 1, 4.8%) [44], and the other was a single-group study protocol (n = 1, 4.8%) [45].

3.4. Target population

Of the 21 studies included in this review, 16 focused on single cancer type (breast cancer [12,17,31,33–38,40–42,44,45], colorectal cancer [43], and prostate cancer [39]), four aimed at multiple cancer types [14,15,30,32], and one did not report cancer type [16]). The target populations'' samples ranged from 20 to 191. The average ages of the participants for the included studies ranged from 37.86 to 75.40 years old. Ten studies reported the stages of participants, including stage I-III [17,33,35,36,38,44], stage 0-IV [30,31,40] and stage I-IV [34]. Eighteen studies specifically reported patients' cancer treatments with surgery, chemotherapy, radiotherapy, and hormonal therapy [12,14,15,17,30–41,44,45].

3.5. Intervention duration

The number of sessions per intervention in 18 studies ranged from 2 to 48, with an average of 6.80 sessions. Two studies involved multicomputer exercise tasks [12,31], and one contained physical walking exercises [35]. Nineteen studies reported the duration of each session, ranging from 20 to 180 mins. The duration of the intervention program ranged from 2 to 15 weeks, with an average duration of 8 weeks. Seventeen studies reported a follow-up period, ranging from post-intervention to 12 months after the intervention. The average follow-up period was 4.10 months. The frequency of follow-up ranged from 1 to 12 times, with an average of 2 times.

3.6. Intervention delivery

Detailed explanations of intervention deliverers among 20 studies (one study did not report [32]) contained trained research staff or teams (n = 10, 50.0%) [12,14,16,30,33,36–39,43], psychologists or neuropsychologists (n = 5, 20.0%) [15,17,35,44,45], gynecologists with psychological support (n = 1, 5.0%) [31], the licensed professional counselors and family medicine physician (n = 1, 5.0%) [40], project coordinator (n = 1, 5.0%) [34], certified mindfulness trainers (n = 1, 5%), as well as physical education students and professionals (n = 1, 5.0%) [42]. All 21 articles reported web-based intervention delivery formats, including computer (n = 9, 42.9%) [12,15,31–34,36,38,39], videoconference devices (n = 5, 23.8%) [16,17,40,42,44], online software (mHealth apps, online platforms and website software) (n = 5, 23.8%) [14,30,41,43,45], and telephone or email (n = 2, 9.5%) [35,37].

3.7. Intervention contents

The web-based cognitive interventions of SCI included the following five aspects: computer CT, online CR, CBT with Internet, telehealth physical exercise, and web-based mindfulness intervention (Appendix B).

3.7.1. Computer cognitive training

CT focuses on retraining brain cognitive function through practice. Based on the performance of the participants, the computerized training program gradually increases the difficulties of tasks [20]. Eight studies developed and conducted computer-assisted programs, including the AquaSnap videogame [31], Dual n-back training program [33], Happyneuron program [34,45], CT for executive function skill [36], CT with music [12], and BrainHQ program [38,39]). Cognitive tasks or exercises from computers trained four cognitive domains for participants (attention, memory, executive function, and information speed), and participants were required to gradually complete training tasks or exercises. For example, CT tasks motivated players to complete repetitive and progressively difficult activities based on cognitive scores encoded in the video game [31]. To accomplish those tasks, participants need to adaptively respond via a keyboard and mouse [33]. The researchers supervised participants to fully engage in CT tasks, and then computers automatically promoted task training for the next session based on the participant's performance in completing the weekly tasks (e.g., performance feedback on completion speed and accuracy) [33,34,36,38,39,45].

3.7.2. Online cognitive rehabilitation

CR restores cognitive skills that were lost or impaired due to damage to improve daily function [9]. In this review, five studies developed CR programs for SCI improvements. Participants promoted speed and accuracy of cognition through neurocognitive learning (e.g., adaptive exercises) from a program called Insight [32]. Another online version program called eReCog contained four modules: counseling, setting goals, releasing therapy, and weekly homework assignments; it concentrated on individuals' cognitive function, physical health, and psychosocial status [14]. The

psychoeducation-based CR intervention "Emerging from the Haze" was delivered in the sessions, including the performance of cognition, psychosocial confounders of cognition, coping and buffer strategies, and home practice for cognitive domains among participants in the intervention group [44]. The interactive program RehaCom performed via online software and divided nine sessions into three modules (e.g., compensatory strategies, controlled stimuli, and feedback) to rehabilitate cognitive function [15]. The CRCweb program contained three modules (e.g., family engagement, symptoms management, and coping strategies) and encouraged the couples to participate, discuss, and cope with the cognitive problem together [43].

3.7.3. Cognitive behavioral therapy with internet

CBT is a behaviorally focused therapy that incorporates cognitive skill retraining, compensatory skills, psychoeducation, stress management, and companion support [46]. In this review, three articles combined CBT strategies into interventions via the Internet [16,17,30]. Cognitive skill retraining included writing reorganization journals [30], cognitive reconstruction [16,17], and self-awareness training of recognizing cognitive failure [17]. Compensatory skills contained self-directed training, oral rehearsal [17], and planning tasks involvement [16]. Psychoeducation for concerning SCI encompassed identifying body image with mental worksheets and therapeutic writing exercises [17,30], as well as coping with physical symptoms, side effects, and emotional distress [30]. Stress management covered mindfulness meditation [30], relaxation techniques and training [16,17], self-regulation [17], and realistic problem resolution [16]. Companion support came from survivors' testimonies, family and friends' interactions and needs [30], and a fuller understanding of survivors' emotional experiences through supportive therapy [17].

3.7.4. Telehealth physical exercise

Telehealth is a safe, cost-effective, and essential tool for monitoring and implementing physical activity programs in cancer populations [47]. Two studies combined telehealth and physical exercise for working on cognitive function. For example, individuals who completed telehealth multi-component movements, including arm-ups, balance, resistance, and stretching exercises, formed components of the main training program, which was instructed by professionals via the Google video platform [42]. In the Memory and Motion program, participants were enrolled and randomized to physical exercise intervention teams, which were tracked through a telehealth device, and participants set up moderate-intensity physical goals for themselves under the guidance of a trained clinical psychologist [35].

3.7.5. Web-based mindfulness intervention

Mindfulness practice is to focus on the current moment and be open-minded to what is being observed. It helps the participants to develop the personal capacity to replace automated, customized, and often judgmental responses with more mindful and skillful reactions [23]. Three studies adapted mindfulness intervention through web technology. An introductory course of the program "Envision the Rhythms of Life" centered on the individuals' mental images and sensory experiences. The mind-body linkage was set up through videoconference-delivered technology [40]. Being supervised by therapists via the telemedicine video software, the participants were encouraged to avoid maladaptive "passive imagery", construct adaptive "active imagery", and practice "target imagery" [40]. Two mindfulness-based cognitive function interventions with online supporting guided the participants' experiential mindfulness exercises, such as sharing experiences, group reflection, psychosocial education, and family practices review [37,41]. The participants in the mindfulness-condition group took intervention exercises of mindfulness as an alternative coping strategy for troubling thoughts or feelings [37]. Also, most group sessions and many home practices were documented weekly [41].

3.8. Intervention outcomes

Detailed intervention outcomes are presented in Appendix C. In accordance with the aims of this review and guidance of MFCCI, intervention effects of the web-based cognitive interventions on SCI, psychosocial status (QoL and fatigue), and emotional health (anxiety and depression) were summarized and analyzed in this review.

3.8.1. Effects of web-based cognitive interventions on SCI

A variety of scales have been used to measure SCI to examine intervention effect in the reviewed studies, including the Functional Assessment of Cancer Therapy Cognitive Function (FACT-COG) [12,14–17,30,33,40,42,44,45], the Cognitive Failure Questionnaire (CFQ) [31,34,37,41], the Patient-Reported Outcomes Measurement Information System (PROMIS) Applied Cognition Abilities and Concerns [35,38], the Beck Cognitive Insight Scale (BCIS), the Attentional Function Index (AFI) [43], the Behavioral Rating Inventory of Executive Function (BRIEF) [36], the European Organization for research and treatment of cancer QLQ-C30 for cognition (EORT QLQ-C30) [32], and the Patient Assessment of Own Functioning Inventory (PAOFI) [39].

Seventeen studies reported the outcomes of web-based cognitive interventions on SCI, and four reported their research protocols only [16,42,43,45]. Amongst the intervention programs, the computer-assisted CT interventions promoted cognitive function. For example, the program Aquasnap had a beneficial effect on perceived cognitive ability ($P = 0.029$), and the improvement in cognitive ability was higher at the three-month follow-up in the intervention group compared with the control group ($P = 0.006$) [31]. In the Dual n-back training, adaptive CT improved patients' cognitive performance over the long term. For example, the cognitive accuracy and working memory of participants were consistently improved ($P < 0.001$) after 12 daily training sessions [33]. Compared with the control groups, the intervention groups exhibited an increase in verbal learning ($P = 0.043$) [34] and improvement in self-rated executive function skills, such as planning, organization, and task supervision [36]. In the Computer-Assisted CT with Music (CACT + A) program, the participants reported enhancements in cognitive function and significant promotions in cognitive scores after the CACT + A intervention ($Z = 3.030$, $P = 0.002$) [12]. Cognitive scores showed trends of improvement in the intervention group as compared to the control group, with effect sizes ranging from $d = 0.10$ to $d = 0.20$ [38]. Response times improved over time ($P \leq 0.001$) and remained stable during the two-month follow-up period [39]. Overall, evidence pointed to the effectiveness of computer-aided CT interventions in improving individuals' SCI in a range of cognitive skills (e.g., accuracy, working memory, executive function, and response times).

Online CR interventions showed promising and persistent improvements in SCI [44]. The positive effects on working memory for the participants, with significant improvements, followed the online CR intervention ($P = 0.030$) [15]. Cognitive scores showed statistically significant differences at the three-month follow-up in comparison with baseline scores, indicating a trend of improvements in cognitive performance ($P = 0.020$) [15]. One study showed that the participants in the intervention group had a greater effect size in terms of improving daily work function as compared to those in the control group at the 3-month follow-up ($d = 0.36$) [14].

Moreover, cognitive performance in the intervention group markedly enhanced at 15 and 24 weeks ($P < 0.001$ and $P = 0.001$) and remained unchanged after six months [32]. In summary, online CR interventions impacted the cognitive performance of cancer survivors with SCI positively and sustainably. These interventions included the enhancements of working memory and everyday work function.

Two studies were CBT with internet interventions. This approach boosted cognitive performance and abilities during the corresponding sessions. The participants who took part in memory and attention sessions experienced improvements in both SCI ($P = 0.020$) and processing speed ($P = 0.030$) as compared to those in the control group [17]. Upon completion of the cognitive psychological intervention course, adherence to treatment moderated cognitive avoidance (interaction estimate = 0.050, $P = 0.040$) [30]. Additionally, the young participants were found to be more effective in attention control [30]. It is easy to recognize that CBT with Internet programs helped the patients to promote their concentration, memory and processing speed subconsciously.

In a telehealth physical exercise intervention, individuals with SCI showed no statistical significance, only the indications of potential group differences [35]. For the web-based mindfulness interventions, one telemedicine-delivered mindfulness intervention showed a significant improvement in SCI [40], and another showed a significant main effect of SCI post-intervention in the intervention group (post-intervention: $\beta = -12.77$, $P < 0.001$; three-month follow-up: $\beta = -12.68$, $P < 0.001$) [37]. The participants reported an increase in cognitive mindfulness skills as compared with those in the control group after the intervention ($P = 0.030$) and at the 3-month follow-up ($P = 0.030$) [41]. Overall, these trials suggested that web-based mindfulness interventions can effectively enhance the cognitive mindfulness skills of the participants and can potentially benefit individuals with SCI.

In brief, this review summarized that web-based cognitive interventions (e.g., computer CT, online CR, CBT with Internet, and web-based mindfulness interventions) had positive impacts on the cognitive function and abilities of individuals with SCI. Meanwhile, telehealth physical exercises showed no significant benefits. The overall findings suggested that web-based cognitive interventions could effectively improve cognitive performance and SCI for individuals. Further research is needed to explore the long-term effects and optimal strategies for implementing these interventions in clinical settings.

3.8.2. Effects of web-based cognitive interventions on psychosocial status

For fatigue: Twelve web-based cognitive intervention studies measured fatigue, in which eight reported the intervention outcomes and four described study protocols only [16,42,43,45]). In the online CR interventions, the participants reported reduced fatigue at post-intervention, which did not maintain at 12-week follow-up [14]. One study showed that the intervention group had lower levels of fatigue at 15 weeks ($P = 0.020$) [32]. In the studies by Myers et al. [44] and Santos et al. [15], no significant alleviation for fatigue was observed following the intervention. The CBT with Internet intervention resulted in moderate to greater effects on fatigue over the two months follow-up period [17]. In the web-based mindfulness interventions, the positive effects on fatigue were durable and persisted over time. One study observed clinically meaningful alleviations for participants' fatigue after the telemedicine-delivered mindfulness interventions ($P \leq 0.002$) [40]. Analysis from the within-group results showed moderate to large effects on fatigue at post-intervention and three-month follow-up (post-intervention: 0.46, three-month follow-up: 1.16) [37]. Moreover, the reduced impacts on fatigue remained after a three months follow-up ($P = 0.010$) [41].

For QoL: Twelve studies incorporated QoL in the outcomes, in which, 10 reported the intervention findings and two described the study protocols only [16,42]). In the computer CT interventions, significant improvements were observed in physical health over time ($P < 0.050$) [31]. A small-to-medium effect size for improving QoL was also observed (general health perceptions: $d = 0.30$ and perceived health changes: $d = 0.60$ [38]. CBT participants who undertook the online memory and attention sessions testified a moderate effect size for QoL ($d = 0.43$) [17]. Improvements in QoL occurred in the groups after the completion of mindfulness sessions. Both the intervention and the waitlist groups experienced clinically significant improvements in mental health and cancer-related QoL ($P = 0.011$ and $P = 0.004$) [40]. Other web-based cognitive interventions reported no significant favorable effect on QoL after the intervention [12,15,32,33,39,41].

Web-based cognitive interventions have yielded mixed results in addressing psychosocial distress. Some interventions (CBT with Internet and web-based mindfulness interventions) showed immediate benefits, and some maintained low levels of fatigue over time. The computerized CT and CBT sessions enhanced QoL, whereas the other sessions failed in immediate impact on QoL.

3.8.3. Effects of web-based cognitive interventions on emotional health

For anxiety: Fourteen studies evaluated the web-based cognitive intervention for anxiety, in which 11 reported the outcomes, and three described the protocol only [16,42,45]. One finding indicated that anxiety was improved through repeated CT exercises ($P < 0.050$) [31]. In one online CR program, the participants testified to lower levels of anxiety 15 weeks after the intervention ($P = 0.020$) [32]. The trends of the CBT with Internet interventions revealed decreases in anxiety for the participants who completed the intervention [17,30]. Two web-based mindfulness interventions demonstrated significant changes in emotional distress. One intervention group exhibited lower emotional distress levels than the corresponding control group at three months post-intervention ($P = 0.030$) [41]. Additionally, the within-group effect sizes for emotional distress were medium-to-large (post-intervention: 0.55 at and three-month follow-up: 0.81) [37]. No significant reduction in anxiety was evident in the other web-based cognitive interventions [15,33,34,40,44].

For depression: Nine studies reported the outcomes of web-based cognitive interventions on depression, and two described study protocols only [16,42]. Dual n-back training, a computerized CT program, showed a remarkable remission on depression ($P = 0.040$) [33]. The participants in the CR intervention group achieved improvement in depression scores as compared to the control group ($P = 0.030$) [15]. Three months after the mindfulness intervention, depression trended downward in overall emotional distress ($P = 0.030$) [41]. Other web-based cognitive interventions reported no significant effect on depression [17,34,36,44].

The web-based cognitive interventions varied widely in their efficacy in reducing individuals' emotional distress. For mood relief, CT, CR, CBT, and mindfulness interventions were highly effective in reducing anxiety or depression. However, other interventions were less effective in relieving emotional distress.

4. Discussion

This review summarized the web-based cognitive intervention contents on SCI based on 21 studies and the corresponding intervention effects of a web-based intervention on SCI, psychosocial status (fatigue and QoL), and emotional health (anxiety and depression). The following discussion will follow the aims of this

review: incorporating intervention contents and intervention effects.

4.1. Contents of web-based cognitive interventions

This review concluded that there are five types of web-based cognitive interventions: computer-assisted CT, online CR, CBT with Internet, telehealth physical exercise, and web-based mindfulness interventions. With the guidance of MFCCI, those interventions were formulated targeting the vulnerabilities of the patients who experienced SCI.

Computer-assisted CT predominantly consisted of multiple and repetitive visual games or tasks. Notably, they were not limited to computer games only. Researchers combined cognitive stimulation tasks with adaptive physical exercises (e.g., warm-ups, aerobic exercises, and stretching) [45], relaxation videos [39], and music albums [12] to potentially enhance cognitive functions. The rapid response and repetitive CT tasks induced fatigue for the participants, downgrading the expected improvement effects on memory and executive function [39]. Therefore, assisting relaxation videos are of great importance to reduce this induced fatigue. Moreover, researchers have proposed that CT with music could be a component of standard home interventions since the patients reported positive experiences related to their memory abilities and daily QoL during post-intervention interviews [12]. Thus, the intervention contents were developed practically based on the characteristics of the participants with SCI.

Online CR and CBT, along with the Internet, share similarities in their intervention contents. To ameliorate SCI, psychoeducation, cognitive skill sessions, relaxation management, and homework practices were introduced and developed in the intervention contents. Psychoeducation includes strategies for coping with cancer and managing disease symptoms [14–17,30,32,43]. Being receptive to online interventions and their tailored style of monitoring, the younger participants tended to benefit more from the online psychoeducation session than the elder participants ($P = 0.050$) [30]. Cognitive skill sessions focus on the cognitive ability of the patients, including cognitive reconstruction, cognitive compensatory strategy, and self-awareness or self-regulation training [14–17,44]. Cognitive skill sessions had profound and positive effects even during the follow-up period [14,17,32,44]. Combined with cognitive skills, relaxation management (stress and/or emotional management) course not only tackled the cognitive complaints but also alleviated the negative emotional distress of the patients [14,15,41]. It's worth noting that the patients expressed a preference for completing homework practices when they were busy recovering from work and juggling household chores. This preference stems from the convenience and accessibility of practicing or completing assignments at home using web-based technology [37,41,44].

Telehealth physical exercise is beneficial to the processing speed of the hospitalized patients, regardless of the type of treatment they received. Researchers suggested that interventions starting close to the time of surgery are advantageous to improve cognitive ability [35]. Moreover, home-based exercise under professional guidance as a component of telehealth physical exercise, conducted through a videoconferencing platform with real-time monitoring, has been shown to increase participation and adherence, reduce fatigue, and improve QoL and physical health [42].

Web-based mindfulness interventions include mindfulness exercises, mind-body connection, and self-reflection [37,40,41]. The participants engaged in meditation exercises, absorbed in self-reflection for the current moment, and took the open-mind views for their surroundings to manage SCI [23].

For the dosage of web-based cognitive interventions on SCI, the average number of sessions was 6.80, with each session ranging from 20 to 180 mins. According to MFCCI, formulating intervention sessions needs to incorporate the factors that impact the SCI and the vulnerabilities of the patients. In some cases, patients with SCI may have difficulties in completing intervention sessions. One systematic review [25] observed that there was no significant difference in the subgroup analysis when the CT session lasted more than 60 mins. This observation suggested that cognitive sessions over 30 mins could be acceptable [25].

The present review noted that the average duration of interventions was eight weeks. Consistently, other studies revealed that interventions lasting longer than six weeks had a positive impact on improvements in cognitive skills and SCI [24]. The mean follow-up period was 4.10 months, with an average frequency of two times in this review. A longer follow-up period enabled a more thorough assessment of the persistence of the intervention effects (six months follow-up compared to post-intervention, $P = 0.020$) [20]. Hence, future studies should focus on extended tailor-made sessions and web-based cognitive intervention programs with follow-ups exceeding four months to detect and manage cognitive impairment in the cancer survivors.

4.2. Effects of web-based cognitive interventions

4.2.1. Effects of web-based cognitive interventions on SCI

Findings have shown that web-based cognitive interventions had a positive impact on cognitive function for individuals with SCI. This is consistent with the previous study, which reported that information and communication technology significantly improved cognitive skills in old patients (e.g., complaints of memory loss improvement and better concentration) (standardized mean difference, $SMD = 0.4$, 95%*CI*: 0.23 to 0.56, $P < 0.001$) [24]. Computer-assisted CT predominantly enhanced cognitive abilities of the patients with SCI. The survivors claimed improvements in cognitive ability, such as enhancement of work memory, self-perceived improvement of executive behaviors and faster speed in processing events [12,33,34,36]. The patients have also reported alleviations in SCI and mastery of cognitive skills, especially for the memory tasks in their daily lives. The intervention effects have been maintained even up to a six months follow-up, with successful improvements in memory and daily function [14,17,32,44]. This is in line with the previous review that CT interventions have modest and positive effects on improving SCI (SMDs ranging from 0.50 to 0.58, $P = 0.020$) [20]. Online CR, CBT with Internet and web-based mindfulness interventions provided cognitive skills sessions. Some participants stated that boosting memory helped improve daily functions after completing cognitive compensatory sessions [14]. Others expressed better cognitive abilities and overall well-being with more availability and willingness to complete homework practices [15]. Evidence from one study showed that comparative effect sizes for CR and CBT were higher than CT on alleviating SCI, which were 0.54 (95%*CI*: 0.03 to 1.05), 0.94 (95%*CI*: 0.43 to 1.44) and 0.47 (95%*CI*: 0.13 to 0.81), respectively [48]. Given the limited number of web-based cognitive interventions in this review, it is unlikely to pool sufficient data to justify the superiority of the reviewed programs in the present study.

4.2.2. Effects of web-based cognitive intervention on psychosocial status

The telehealth physical exercise cognitive intervention with moderate-intensity physical movements alleviated fatigue for the patients [35,42]. Web-based mindfulness interventions also demonstrated significant reductions of fatigue both immediately after the intervention and during the three months follow-up period [37]. However, computerized CT interventions did not report significant effects on fatigue. This is inconsistent with the

previous review, which revealed that physical exercise (e.g., yoga and qigong) and meditation interventions were effective in alleviating the symptom of fatigue (weighted mean difference = 5.29, 95% *CI*: 2.97, 7.61, $P < 0.001$) [49]. One study claimed that web-based cognitive interventions had a mitigating impact on individuals' fatigue, but the effectiveness of the intervention lasted only for a limited period of time [14]. It's plausible to suggest that the inconsistency of web-based cognitive interventions in relieving fatigue may be attributable to the curriculums and focus of interventions. For example, telehealth physical exercise [35] and mindfulness interventions [41] promote improvements in the body and mind for patients with SCI, while computerized CT [38] focuses mainly on re-exercising and developing individual cognitive skills. Further research is needed to assess the long-term effects of such interventions on fatigue in individuals.

Studies have found the transferred effects on improvements in long-term workability, enhancements of well-being, and daily QoL [31,38,39]. It reminds us to explore combinatorial approaches of web-based cognitive interventions for the cancer survivors with SCI.

4.2.3. Effects of web-based cognitive intervention on emotional health

Sessions that focused on psychoeducation, stress management, release therapy, and companion support have been found to have positive effects on emotional distress for the cancer survivors. Consistent with a previous study [50], delivering cognitive interventions via web technology had an equal effect on anxiety (*SMD* = −0.90, 95% *CI*: 1.19, −0.60) and depression (*SMD* = −0.62, 95% *CI*: 1.21, −0.03) as compared with the traditional delivery methods. Positive outcomes were observed for the participants in the control group who received CBT intervention, specifically in relation to SCI and depression [17]. The participants with emotional distress may benefit more from the sessions of psychoeducation and stress management [30]. Therefore, it is crucial to leverage the convenience and benefits of web-based technology while considering individual characteristics and uniqueness. This will help tailored cognitive interventions to assist cancer survivors in managing and improving their SCI and alleviating their emotional distress.

Of the 21 studies incorporated, eight cognitive scales were used to assess SCI for the participants. These discrepancies in the assessment tools may be the reason why the effects of web-based cognitive interventions on SCI varied [4]. Among the five types of web-based cognitive interventions in this review, it deserves our attention that the study population primarily consisted of patients with breast cancer. Researchers used to formulate cognitive intervention strategies to promote SCI for survivors with breast cancer [34,36,40]. Therefore, there is a need to develop standardized scales to assess SCI and to develop web-based interventions for survivors of different types of cancer.

To summarize, the use of web-based technology provides flexibility and convenience in accessing these cognitive interventions. As recommended by MFCCI, researchers should concentrate on developing comprehensive, personalized cognitive interventions for cancer survivors with SCI. Meanwhile, it is crucial to consider the individual psychosocial and emotional statuses when designing cognitive interventions via web technology. Furthermore, tailored web-based cognitive interventions would effectively address cognitive difficulties, promote overall well-being, and enhance accessibility for this population.

5. Limitations

Some limitations of this review need to be recognized. Firstly, the trials included in this review primarily focused on breast cancer survivors. There is a lack of information for the non-CNS cancer survivors who experience SCI due to cancer diagnoses or treatments. Secondly, since the primary outcomes of trials solely focused on SCI were found in a limited number of articles, we included the studies that assessed and reported SCI by cognitive scales, irrespective of whether these studies considered SCI as a primary outcome or not. Therefore, web-based cognitive interventions might be designed to improve the objective cognitive function, but they might have no remarkable effects on SCI. Thirdly, although the voluminous search terms had been conducted, the terms used may have excluded several relevant and interesting studies because of the novelty of the web-based interventions and the lack of standardized terminology. Finally, only publications in English and Chinese were included, which may have potentially excluded some relevant studies.

6. Implication of nursing practice

This review provides effective web-based interventions for nurses and other healthcare professionals, by providing a comprehensive summary on web-based cognitive interventions. It presents the integrated strategies for nursing providers to help cancer survivors cope with their SCI. Firstly, web-based cognitive interventions for cancer survivors with SCI can be customized and integrated with multiple components by clinic nursing providers. Meanwhile, it is vital for nurses to assess the individual factors (e.g., psychosocial factors and emotional distress) that impact SCI and then design web-based cognitive programs for non-CNS cancer survivors to alleviate SCI, psychosocial distress, and emotional distress. Secondly, researchers and clinical nurses can oversee the progress of each participant's cognitive intervention program under any circumstance. Meanwhile, cognitive interventions combined with any form of web technology allow participants to complete sessions without restrictions on time and space. Thirdly, to detect and evaluate the effects of web-based cognitive interventions, it is necessary for nurses to collaborate with a multidisciplinary team to conduct repeated assessments and long-term follow-ups. This collaboration is essential to obtain the rigorous outcomes of SCI and to ensure the sustainability of intervention effects in future research.

7. Conclusion

This review examined the contents and effectiveness of web-based cognitive interventions in alleviating SCI and improving psychosocial and emotional statuses based on MFCCI. The integrated five types of web-based cognitive interventions (computer CT, online CR, CBT with Internet, telehealth physical exercise and web-based mindfulness intervention) showed varying degrees of improvement in SCI for the patients with non-CNS cancers. Subsequently, the intervention outcomes of psychosocial and emotional statuses demonstrated discrepancies in alleviating psychosocial and emotional distress for these five types of web-based cognitive interventions. It is crucial to acknowledge the variabilities in the measurement scales and in their applications, which introduces some uncertainties in the findings. Therefore, caution should be exerted when interpreting the results for psychosocial and emotional consequences. Further recommendations include developing customized web-based cognitive interventions for individuals with SCI, along with their individual characteristics, psychosocial factors, and emotional status.

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CRediT authorship contribution statement

Ye Wang: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Project administration. **Yi Zhang:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - review & editing. **Rongyu Li:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing - review & editing. **Zheng Sun:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing - review & editing. **Qiuping Li:** Conceptualization, Methodology, Validation, Formal analysis, Funding acquisition, Writing - review & editing, Supervision, Project administration.

Data availability statement

All the data and materials are publicly available and could be found on the online.

Declaration of competing interest

The authors have no conflict of interest to declare.

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Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2024.06.004.

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