Effects of an interactive coaching intervention on quality of life and psychological factors for colorectal cancer survivors: A single group pre and posttest design

Jaehee Yoon [a], HyunHae Lee [b], Heesook Son [b,*]

[a] *Wolchon Elementary School, 132, Mokdongjungang-ro, Yangcheon-gu, Seoul, 07989, South Korea*
[b] *Red Cross College of Nursing, Chung-Ang University, 84 Heukseok-ro, Dongjak-gu, Seoul, 06974, South Korea*

ARTICLE INFO

ABSTRACT

Objective: To develop and evaluate the effects of an interactive coaching intervention, using a self-management mobile application, on quality of life and physical and psychological factors for colorectal cancer survivors.

Methods: We developed a self-management mobile application providing social support services for post-treatment CRC survivors and evaluated its effects through baseline and post-intervention surveys. Using the biopsychosocial holistic model as the theoretical framework, automated interactive coaching technology was applied for six weeks to provide supportive services tailored for each user. To evaluate the effects of the application, self-efficacy, health practice index, depression, fear of cancer recurrence, and quality of life measures were administered to participants. A total of 34 men and 5 women were included in the analysis.

Results: Participants' mean age were 54.10 years and 78% of them had been diagnosed within the last five years. There were significant increases in self-efficacy (z = 2.09, p = .04), health practice index (t = 2.35, p = .02), and quality of life (t = 2.03, p = .05). More specifically, the emotional functional score increased (z = 2.23, p = .03) while both of the total symptom score (t = 2.10, p = .04) and the fatigue symptom score (z = 2.54, p = .01) decreased after six weeks of using the mobile application.

Conclusions: Interventions supporting colorectal cancer survivors' self-management are critical for addressing the challenges they face after treatment and improving their quality of life. Providing social support through mobile applications could be a good strategy in terms of usability and effectiveness.

1. Introduction

Colorectal cancer (CRC) is a prevalent form of cancer worldwide with a high mortality rate, and survivors of CRC face an array of physical and mental health problems even after treatment (Brown et al., 2016; Favoriti et al., 2016; Han et al., 2020; Soffer et al., 2020). Studies have reported that CRC survivors experience difficulties from intestinal dysfunction due to post-treatment health problems, changes in appetite, fatigue, pain, sleep deprivation, anxiety, depression, and fear of recurrence (Browne et al., 2011; Dau et al., 2020; Dekker et al., 2019; El-Shami et al., 2015; Jansen et al., 2010; McGeechan et al., 2022; Santin et al., 2015). However, research suggests that post-treatment CRC survivors receive inadequate support for managing these physical and psychological challenges (McGeechan et al., 2022; Wagland et al., 2016). Further, the disease treatment paradigm is shifting from hospitalized care to community-based care after discharge, resulting in patients' decreasing length of stay in hospitals. A shortened length of stay hinders patients' ability to sufficiently communicate with their healthcare providers and acquire the knowledge and skills needed for self-care (Kim et al., 2018). Additionally, like other types of cancers, CRC is becoming a chronic condition as survival rates increase (Davies and Batehup, 2010; Siegel et al., 2019). Hence, from the perspective of a cancer care continuum, community-based interventions that aid the post-treatment self-care of CRC survivors are essential to help them alleviate their challenges and improve their quality of life (QoL).

Interventions using mobile technology can be effective self-care tools for patients, as they efficiently impart appropriate health-related information (Cheong et al., 2018). In addition, South Korea features a high smartphone penetration rate (93%) as of 2019, with approximately 76% of adults aged 60 years and over using a smartphone (Cheong et al.,

2018), thereby providing good accessibility for mobile application (app)-based interventions. Mobile health can play a positive role throughout a user's cancer journey by enabling them to receive supportive services without temporal and spatial restrictions (Davis and Oakley-Girvan, 2015), and cancer survivors have widely accepted mobile applications—more so than other types of e-health information and communication technologies (Jansen et al., 2015; Jiang et al., 2017; World Health Organization, 2016).

Social support plays a critical role in CRC survivors' stress coping, resilience, and QoL (Costa et al., 2017). Moreover, social support helps survivors effectively engage in self-management and improve their QoL by buffering the adverse impact of factors such as psychosocial difficulties (Kim and Park, 2015). Therefore, mobile applications that provide social support services for CRC survivors would serve as effective interventions that can produce positive health outcomes by promoting survivors' self-management.

However, a literature review using CRC as a keyword revealed that research on mobile application intervention studies for CRC survivors have primarily focused on informatics; for example, we found a program for the management of adverse events from chemotherapy among cancer patients, including CRC patients (Kearney et al., 2009); a program for providing information for CRC patients (Kim and Park, 2019); and the ColorApplication mobile application which provides services focused on an introduction to CRC, description of its symptoms, and prevention (Yaacob et al., 2020). There is a notable lack of mobile applications that provide comprehensive social support services for CRC survivors. The mobile application Colorectal Cancer Along (ColorectAlong; Salmani et al., 2022), developed for CRC survivors, provides some degree of social support—namely, informational, emotional, and appraisal support—by presenting educational content, allowing users to rate their stress and pain, and providing tailored plans accordingly. Therefore, the app was rated as having a good level of usability, but its effectiveness has not been evaluated. Thus, this study aimed to develop and evaluate the effectiveness of a mobile application that provides social support services pertinent to CRC survivors' self-management.

2. Methods

In this study, we developed a self-management mobile application providing social support services for post-treatment CRC survivors and evaluated its effects through baseline and post-intervention surveys. We used the biopsychosocial holistic model as the theoretical framework. In the biopsychosocial holistic model, health is described as an outcome of the interactions between the factors in all domains (Thomas et al., 2008). The self-management mobile application was developed based on informational, emotional, and appraisal social support classified by House (1981). Further, automated interactive coaching technology was used to provide supportive services tailored for each user. We hypothesized that CRC survivors who used our self-management mobile application would show improvements in physiological and psychosocial domains, and ultimately their experience would improve their QoL, compared to the baseline.

2.1. Development

The mobile application was developed to run on an Android platform and could be downloaded from the Google Play Store. The mobile application was designed to periodically assess the user's self-care practice and provide automated conversational health coaching tailored to each user's needs based on the assessment results and barriers to practice. The algorithm for automated conversational health coaching in each type of social support service was written by first classifying the results of previous studies on the experiences of CRC survivors into mental and physical health problems and identifying the major difficulties and barriers. Then, health coaching content specifically addressing each major difficulty and barrier was developed with

reference to the existing literature, guidelines, and government-run websites (Supplementary 1).

Informational support refers to imparting knowledge or information. In this study, we selected information about a healthy diet, physical activity, alcohol use, and smoking habits for CRC prevention and management based on Korean and international CRC guidelines. All information was written based on existing literature and guidelines in the form of notecards. A professor specializing in oncology and an advanced practice nurse evaluated the content validity of the notecards. The notecards section was added under the information menu in the application. Further, tailored health coaching was provided to users by linking relevant information based on the results of their weekly evaluations indicating the categories that required improvement.

Emotional support was developed by considering the major emotional difficulties comprising symptoms of depression, anxiety, and sleep disorders, based on a review of qualitative studies on the experiences of CRC survivors. We developed an algorithm to periodically assess each type of emotional difficulty and the degree of and reasons for the difficulty experienced by the user and provide tailored information as conversational messages.

Appraisal social support helps users assess their own actions. In this study, we designed this support in a manner that enables users to evaluate their self-management and receive personalized information and positive rewards accordingly. With reference to the Korean-adapted version of the Health Practice Index (HPI) (Ezoe and Morimoto, 1994), which is consistent with previous CRC prevention guidelines, users evaluated their self-management across eight categories (i.e., stress, physical activity, work hours, drinking, smoking, balanced diet, breakfast, and sleep) (Yoon et al., 2021). Based on total HPI scores, users were classified into poor lifestyle (0–3), moderate lifestyle (4 or 5), and good lifestyle (6–8) groups (Ezoe and Morimoto, 1994), and each group was provided with lifestyle management information appropriate to their needs. Additionally, we added two items pertinent to dietary recommendations for CRC prevention, proposed by CRC prevention guidelines (Ministry of Health and Welfare, 2010; World Cancer Research Fund, 2018). For users who display poor lifestyle patterns in each evaluation category, we applied an algorithm to send text messages and provide information to address their barriers to a good lifestyle. Users who perform the evaluations, practice a healthy lifestyle, or show lifestyle improvements receive points that can be exchanged for a mobile gift card as a positive reward.

2.2. Study design

The effects of the mobile application were analyzed using a single-group pretest–posttest experimental design. Participants used the application for six weeks and completed baseline and post-intervention surveys.

2.3. Study participants

The inclusion criteria for the participants included: being an individual diagnosed with CRC and having completed the primary treatment process involving surgery, chemotherapy, and/or radiotherapy; being aged 19 years and older; being capable of installing and using a mobile application; and having no physical activity restrictions. Study participants were recruited by posting recruitment announcements on two self-help groups on Korean social media, from September 1 to 15, 2021. The sample size was determined using the G*Power 3.1.9.7 software, and the minimum sample size (medium effect size = 0.50, significance level = 0.05, power = 0.95) was calculated to be 54. Although 79 participants were initially recruited, 28 were excluded after the baseline survey for failing to register on the mobile application. Of the remaining 51 participants, 10 were excluded from the study (19.60%) for not using the mobile application, resulting in 41 participants being included in the final analysis.

2.4. Measures

The biopsychosocial holistic model was used as the conceptual framework for this study (Fig. 1). Demographic and health characteristics included gender, age, body mass index (BMI), clinical information, and self-rated health in the biological and psychological realm; and education level, marital status, cohabiting family, economic status, occupation, religion, family history, and social interactions in the social realm.

To evaluate the effects of the application, self-efficacy, depression, fear of cancer recurrence, and QoL measures were administered to participants, as these factors were reported to be effective based on a systematic review of web-based self-care intervention studies for cancer survivors (Kim and Park, 2015) and identified as predictors of self-care in the middle range theory of self-care of chronic illness (Ministry of Health and Welfare, 2010) with the available Korean instruments. Additionally, we assessed the changes in HPI scores, which were used as the framework for evaluation support in the application.

Self-efficacy (Foster et al., 2015) was assessed using the Korean version of the 11-item Cancer Survivors' Self-Efficacy Scale (CSSES) (Kim et al., 2019). The K-CSSES contains ten items rated on a ten-point scale (1 = *not at all confident* to 10 = *totally confident*), with higher scores indicating higher self-efficacy. Cronbach's α ranged from 0.86 to 0.92.

Depression (Kohout et al., 1993) was assessed using the Korean version of the Center for Epidemiologic Studies Depression scale (CESD-10-D) (Gao and Yuan, 2011). This ten-item tool is rated on a two-point scale (0–1). With a score of 3 as the cutoff, a score of 2 or lower indicates normal, and a score of 3 or higher indicates depressive tendencies (Bangerter et al., 2019).

Fear of cancer recurrence was assessed using the Fear of Cancer Recurrence Inventory Short Form (FCRI-SF) (Simard and Savard, 2015). We only used the items included in the short form of the Korean validated version (K-FCRI) (Shin et al., 2017). This tool comprises nine items rated on a five-point scale, and higher scores indicate greater anxiety regarding recurrence. Cronbach's α was 0.89 at the time of development (Simard and Savard, 2015).

QoL was assessed using the Korean version of the EORTC Quality of Life Questionnaire (QLQ-C30) ver.3. In this 30-item tool, Items 1–28 are on the functional and symptom scales and are rated on a four-point scale. Items 29 and 30 pertain to the global health status (QoL) and are rated on a seven-point scale. The functional and symptom scales each comprise subfactors. High scores on the functional scale represent healthy levels of functioning. High scores on the symptom scale represent high levels of symptomatology or problems. High scores for QoL represent high QoL. The score for each factor was calculated according the scoring manual of the QLQ-C30 ver.3.

The HPI used for the evaluation support intervention in the application was calculated as the total score. The score ranges from 0 to 8, and higher scores indicate a healthier lifestyle (Ezoe and Morimoto, 1994; Yoon et al., 2021).

2.5. Data analysis

Data were analyzed using SPSS version 28.0. Significance was set at $p < .05$, and confidence intervals (CI) were set at 95%. The participants' demographic and health characteristics were analyzed using frequencies and percentages. Usability was assessed based on the mobile app service utilization rate. The effects were analyzed by first evaluating the normality of the data on the differences between baseline and post-intervention measurements, and then using paired *t*-tests for normally distributed data and Wilcoxon's signed-rank test for non-normal data.

2.6. Ethical considerations

The study was carried out with ethical approval from the Institutional Review Board of Chung-Ang University (IRB No. 1041078-202106-HRSB-160-01). The recruitment poster contained detailed information about the purpose and procedures of the study. The authors provided further explanations to the candidates who contacted the telephone number on the recruitment poster, obtained informed consent, and provided instructions for downloading the mobile application. Minimal personally identifiable information was collected, stored, and managed as security documents, as per IRB regulations. The participants were compensated with 100,000 KRW for participation and approximately 20,000–30,000 KRW for points earned through participation in the app.
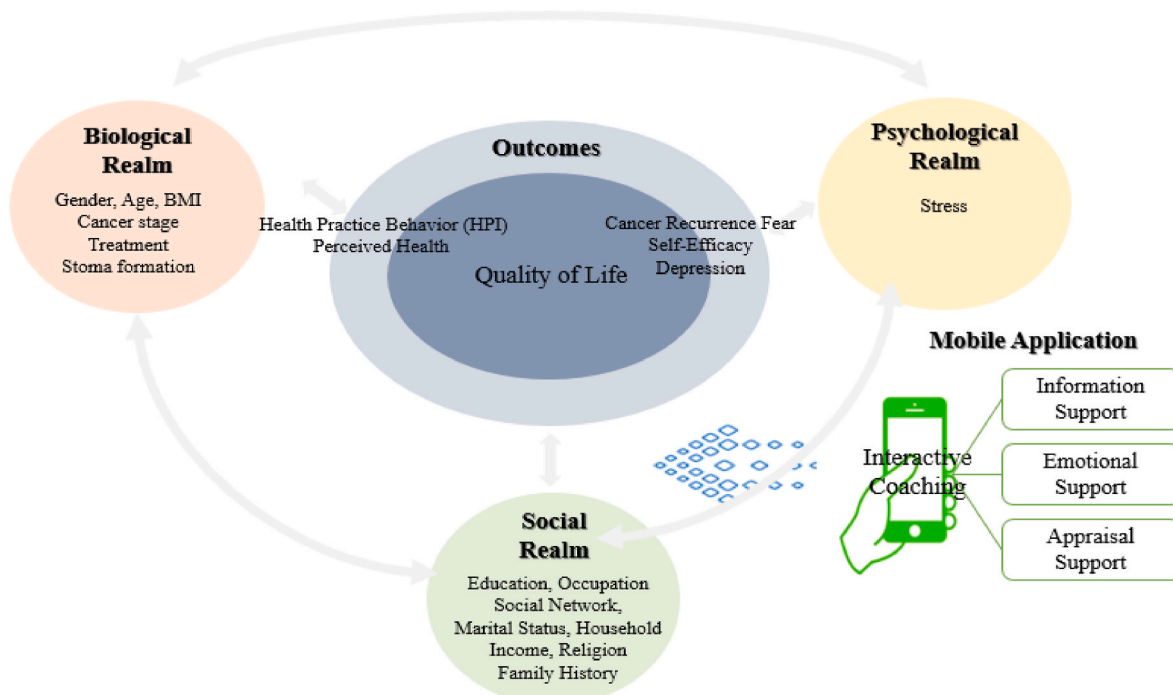

Fig. 1. Conceptual framework.

3. Results

The study sample included 34 (82.9%) men and 5 (17.1%) women. Participants' mean age were 54.10 years ($SD = 8.59$) and the most common age group was 50–59 years ($n = 16$, 39.0%). Participants were diagnosed with rectal cancer ($n = 25$, 61.0%) or colon cancer ($n = 16$, 39.0%), and 78.0% ($n = 32$) of them had been diagnosed within the last five years. The most common stage of cancer was Stage III ($n = 22$, 53.7%), and most participants had undergone surgery and chemotherapy. Approximately 9.8% ($n = 4$) of the participants had a stoma, and approximately 24.4% ($n = 10$) reported experiencing high or very high stress.

Of all the participants, 61.0% ($n = 25$) had a bachelor's degree or higher, 85.4% ($n = 35$) were married, and 92.7% ($n = 38$) lived with their family. The most common monthly income levels were <1.5 million KRW (29.3%, $n = 12$) and ≥5 million KRW (29.3%, $n = 12$). Most participants (90.2%, $n = 37$) did not have a family history of CRC, and most (65.8%, $n = 27$) attended one to four social gatherings per month (Table 1).

3.1. App usage analysis

Table 2 shows the participants' use of the mobile app. Weekly evaluation and counseling participation rates over the six weeks were analyzed. The mean score for evaluation completion was 5.46 out of 6 ($SD = 1.10$), and the mean counseling participation score was 4.61 out of 6 ($SD = 2.30$), showing that most participated in the weekly evaluation and counseling. Out of those who did not complete all six of the weekly evaluations, 14.6% completed five of them. Five participants completed fewer than four of the weekly evaluations, while 12.2% did not complete any of the weekly evaluations. The mean number of counseling sessions provided by the mobile app was 13.39 ($SD = 7.40$), and the mean number of counseling sessions completed by each participant was 11.84 ($SD = 8.19$).

3.2. Analysis of the effects of using the mobile app

Table 3 shows the effects of using the mobile app. After six weeks of using the mobile app, the participants showed significant changes in their HPI, cancer survivors' self-efficacy, and QLQ scores. Depression and fear of cancer recurrence tended to decline, but these changes were not statistically significant. The mean score for cancer survivors' self-efficacy significantly increased from 71.44 ($SD = 15.66$) to 73.32 ($SD = 14.26$; z = 2.09, $p = .04$).

There was a statistically significant increase in HPI from 5.10 ($SD = 1.36$) to 5.61 ($SD = 1.12$), showing that the participants engaged in healthier lifestyle practices ($t = 2.35$, $p = .02$). The HPI was measured weekly, and it rose continuously over the first three weeks (from 5.8 to 6.32) and slightly decreased thereafter.

QLQ scores indicated a statistically significant increase in QoL, from 69.11 ($SD = 19.74$) to 74.80 ($SD = 15.53$; $t = 2.03$, $p = .05$). There was also a significant increase in the functional score, from 77.18 ($SD = 18.14$) to 81.52 ($SD = 17.01$), to a healthy functional level ($t = 2.27$, $p = .03$). More specifically, the emotional functional score increased from 73.58 ($SD = 24.0$) to 81.10 ($SD = 24.44$), showing that the app helped improve participants' healthy emotional function ($z = 2.23$, $p = .03$). The total symptom score significantly decreased. from 25.27 ($SD = 17.58$) to 20.20 ($SD = 17.23$; $t = 2.10$, $p = .04$). More specifically, the fatigue symptom score significantly decreased from 34.15 ($SD = 23.36$) to 26.83 ($SD = 22.08$; z = 2.54, $p = .01$).

4. Discussion

CRC survivors face several challenges even after completing their treatment regimens (Mirkovic et al., 2014). Mobile app interventions have been shown to be an excellent method to help survivors cope with

Table 1
General characteristics of the study participants ($N = 41$).

Characteristics	n	(%)
Biological & Psychological Realm		
Gender		
Men	34	(82.9)
Women	7	(17.1)
Age		
<39	2	(4.9)
≥40 and < 49	11	(26.8)
≥50 and < 59	16	(39.0)
≥60	12	(29.2)
Body mass index		
Underweight (<18.5 kg/m^2)	4	(9.8)
Normal (≥18.5 and < 23 kg/m^2)	15	(36.6)
Overweight (≥23 and < 25 kg/m^2)	6	(14.6)
Obese (≥25 kg/m^2)	16	(39.0)
Cancer type		
Colon cancer	16	(39.0)
Rectal cancer	25	(61.0)
Time since diagnosis		
<5 years	32	(78.0)
≥5 years	9	(22.0)
Cancer stage		
Stage I	5	(12.2)
Stage II	8	(19.5)
Stage III	22	(53.7)
Stage IV	6	(14.6)
Lymph node metastasis stage		
Stage 0	18	(43.9)
Stage I	17	(41.5)
Stage II	6	(14.6)
Surgery		
Yes	38	(92.7)
No	3	(7.3)
Chemotherapy		
Yes	37	(90.2)
No	4	(9.8)
Radiotherapy		
Yes	16	(39.0)
No	25	(61.0)
Stoma		
Yes	4	(9.8)
No	37	(90.2)
Time since treatment completed		
<5 years	37	(90.2)
≥5 years	4	(9.8)
Stress		
Very often	2	(4.9)
Fairly often	8	(19.5)
Almost never	26	(63.4)
Never	5	(12.2)
Social realm		
Education		
≤ Middle or high school	15	(39.0)
≥ College	25	(61.0)
Marital status		
Single	2	(4.9)
Married	35	(85.4)
Other	4	(9.8)
Single household		
Yes	3	(7.3)
No	38	(92.7)
Monthly income (Korean currency: won)		
<1,500,000	12	(29.3)
≥1,500,000 and < 3,000,000	9	(22.0)
≥3,000,000 and < 5,000,000	8	(19.5)
≥5,000,000	12	(29.3)
Currently employed		
Yes	22	(53.7)
No	19	(46.3)
Religion		
Yes	18	(43.9)
No	23	(56.1)
Family history		
Yes	4	(9.8)
No	37	(90.2)

(*continued on next page*)

Table 1 (*continued*)

Characteristics	n	(%)
Frequency of meetings with acquaintances		
Less than once a month	3	(7.3)
1–4 times a month	27	(65.8)
2–3 times a week	7	(17.1)
More than 4 times a week	4	(9.8)

Table 2

Evaluation of application use for six weeks (N = 41).

	n	M	SD	Minimum	Maximum
Weekly appraisals completed	41	5.46	1.10	2.00	6.00
Weekly advice response completed	31	4.61	2.29	0.00	6.00
Number of advice	31	13.39	7.40	0.00	32.00
Number of advice responses	31	11.84	8.19	0.00	32.00

their changed lives (Ayyoubzadeh et al., 2020) and promote their well-being (Lubberding et al., 2015; Mirkovic et al., 2014). However, existing mobile apps for CRC survivors provide fragmentary education, and only 32% of these apps were developed in collaboration with healthcare professionals, suggesting that most mobile apps do not provide professional services, which contributes to the low client satisfaction ratings (O'Neill and Brady, 2012). The mobile app developed and evaluated in this study was designed to provide comprehensive services, including informational, emotional, and appraisal support, based on a social support framework. Further, healthcare professionals (i.e., the study's authors) participated in the app's development process to enhance the expertise of the services provided.

In particular, since approximately 33% of the e-health services used by CRC survivors provide coaching, such as consultations (Mirkovic et al., 2014), incorporating automated, personalized coaching techniques is a key strength of our mobile app. Health coaching has been increasingly recognized as a useful strategy for meeting clients' chronic disease management needs (O'Malley et al., 2022). One study that developed a mobile app for CRC patients undergoing chemotherapy (Cheong et al., 2018) utilized interactive coaching techniques, allowing patients to chat in real-time with their coordinator via messages, and found that the patients showed significant improvements in their physiological symptoms. Personalized advice and communication with professionals are two high-priority needs for mobile apps among CRC survivors (Ayyoubzadeh et al., 2022; Husebø, 2021). This study highlighted the possibility of providing cost-effective health coaching services, one of the greatest interventional needs and a key supportive strategy for cancer survivors by confirming that automated health coaching services significantly improved patient outcomes. Similarly, recent studies that applied automated health coaching features reported that these services had comparable effects to services provided by humans (Schueller et al., 2017); and a digital coaching intervention study on cancer survivors who lost their jobs (Lo et al., 2021) reported that a high percentage of survivors returned to work.

In this study, the dropout rate after downloading the mobile app was approximately 19.6%. Despite the numerous strengths of e-health programs, poor engagement has been identified as a limiting problem, as evident from the dropout rates (up to 50%) in some digital interventions (Chow et al., 2020; Schueller et al., 2017). Our study's relatively low dropout rate may be attributable to the fact that weekly evaluations provided users with tailored support services. Too much support can negatively impact users' motivation and weaken their autonomy (Schueller et al., 2017). Providing simple services enhances the content's clarity (Schueller et al., 2017). Thus, strategies providing differentiated services tailored to each user should be employed to ensure good usability of mobile apps.

Table 3

Changes in main outcomes after six weeks of using the mobile application (N = 41).

		Pretest M	Pretest (SD)	Posttest M	Posttest (SD)	Z or t	p-value
Cancer survivors' self-efficacy		71.44	(15.66)	73.32	(14.26)	2.09	0.04
Depression		2.41	(2.56)	2.17	(2.51)	0.94	0.35
Fear of cancer recurrence		14.63	(6.68)	14.20	(6.54)	0.26	0.79
Quality of life questionnaire (QLQ)							
Global health status/QoL		69.11	(19.74)	74.80	(15.53)	2.03*	0.05
Functional score		77.18	(18.14)	81.52	(17.01)	2.27*	0.03
Physical functional score		82.44	(14.51)	84.39	(15.03)	1.05	0.29
Role functional score		82.11	(19.5)	83.74	(19.18)	0.98	0.33
Emotional functional score		73.58	(24.0)	81.10	(24.44)	2.23	0.03
Cognitive functional score		76.42	(25.27)	79.67	(19.55)	1.03	0.30
Social functional score		67.07	(29.22)	74.80	(27.92)	1.55	0.12
Symptom score		25.27	(17.58)	20.20	(17.23)	2.10*	0.04
Fatigue symptom score		34.15	(23.36)	26.83	(22.08)	2.54	0.01
Nausea symptom score		11.38	(19.87)	9.76	(20.74)	0.68	0.50
Pain symptom score		23.17	(27.1)	16.67	(24.15)	1.47	0.14
Health practice index		5.10	(1.36)	5.61	(1.12)	2.35*	0.02
Smoking	No*	13	(31.71)	16	(39.02)		
	5 packs or more	28	(68.29)	25	(60.98)		
Alcohol use	No**	35	(85.37)	36	(87.80)		
	High risk drinking***	6	(14.63)	5	(12.20)		
Breakfast	Almost every day**	30	(73.17)	32	(78.05)		
	Irregularly or never	11	(26.83)	9	(21.95)		
Sleep	7–8 h/day**	21	(51.22)	26	(63.41)		
	<7 h/day or > 8 h/day	20	(48.78)	15	(36.59)		
Working	<52 h/week**	23	(56.10)	28	(68.29)		
	≥52 h/week	18	(43.90)	13	(31.71)		
Physical Activity†	Yes**	27	(65.85)	33	(80.49)		
	No	14	(34.15)	8	(19.51)		
Healthy Diet‡	Yes**	25	(60.98)	27	(65.85)		
	No	16	(39.02)	14	(34.15)		
Mental Stress	Moderate or low**	35	(85.37)	32	(78.05)		
	High	6	(14.63)	9	(21.95)		

Note: *M* mean; *SD* standard deviation; *paired *t*-test; Wilcoxon signed rank test; ** positive health behavior; *** high risk drinking: men who drink more than 2 glasses per a day and women who drink more than 1 glasses a day; †Physical Activity: >2 h and 30 min of moderate intensity aerobic physical activity per a week (times of high intensity aerobic physical activity is calculated twice); ‡Healthy Diet: low fat, low sodium, and daily fruit and vegetable intake.

The fact that the participants in this study experienced positive changes in terms of QoL, healthy lifestyle, and self-efficacy after using the mobile app demonstrates its usefulness for post-treatment CRC survivors. Previous systematic reviews of e-health for CRC have reported inconsistent findings regarding the effects of e-health on self-efficacy (Mirkovic et al., 2014; Wan et al., 2022). A coaching application intervention study for breast cancer survivors (Chow et al., 2020) also found no significant changes in self-efficacy following the intervention. According to Bandura's social cognitive theory, positive feedback and success experiences boost an individual's self-efficacy (Davies and Batehup, 2010). One unique feature of our mobile app was the inclusion of appraisal support, which allowed users to evaluate their healthy

lifestyle practices pertinent to CRC prevention every week and receive tailored health coaching and positive rewards. Further, the HPI generally increased over the six weeks, showing a significant increase in healthy lifestyle practices after the mobile app use compared to the baseline. Such services provided by the mobile app and the improvement of healthy lifestyle practices served as positive feedback and success experiences, respectively, which had a positive impact on participants' self-efficacy. Because self-efficacy is an essential element of self-care (Davies and Batehup, 2010), success experiences and positive feedback are critical service strategies for augmenting the effectiveness of self-management interventions for CRC survivors.

QoL is the most widely assessed outcome measure of digital health interventions for cancer survivors (Escriva Boulley et al., 2018), and our participants showed significantly improved QoL. More specifically, statistically significant improvements were found in the fatigue symptom and emotional function scores. Fatigue is emphasized as an outcome that is improved by digital health interventions (Escriva Boulley et al., 2018). A systematic review of CRC eHealth (Mirkovic et al., 2014) reported that four studies measured fatigue as an outcome, with three showing significant improvements. Consistent with a systematic review finding that web-based self-management support interventions for cancer survivors effectively reduce fatigue (Kim and Park, 2015), the mobile app developed in our study—also a web-based self-management support intervention—significantly improved fatigue in CRC survivors. A primary reason that the app led to improved QoL, including fatigue and emotional functioning, possibly pertains to lifestyle modifications. A healthy lifestyle has several benefits for cancer survivors (Rabin, 2009). Systematic reviews on lifestyle interventions (e.g., physical activity, diet) for cancer survivors (Mishra et al., 2012; Roberts et al., 2017) have shown that these interventions effectively ameliorate negative emotions and fatigue and improve QoL. Studies on lifestyle among CRC survivors (Brandenbarg et al., 2018; Grimmett et al., 2011) have also reported that lifestyle is significantly associated with fatigue and QoL. Further, cancer survivors display a high need for supportive care from healthy lifestyle programs and are reported to use mobile apps for lifestyle modification, such as increasing physical activity (Jansen et al., 2015; Jiang et al., 2017). Further, lifestyle-related services are one of the most common e-health services offered to cancer survivors (Cuthbert et al., 2019; Mirkovic et al., 2014; Riley et al., 2011). Mobile health, such as mobile apps, is effective in improving lifestyles (Cheong et al., 2018), and the CRC survivors in our study also engaged in healthier lifestyle practices after using the mobile app. Physical activity and diet are more strongly linked to CRC than other cancers (World Cancer Research Fund and American Institute for Cancer Research, 2018). Thus, lifestyle services are essential features of supportive mobile app interventions for CRC survivors, considering the high needs, acceptance, effectiveness in improving the targeted parameter, and their impact on QoL.

While depression and fear of cancer recurrence tended to decline among the study's participants after using the app, this change was not statistically significant. E-health has been shown to be a potentially beneficial intervention strategy to address the fear of cancer recurrence among survivors (Smith et al., 2020); however, few studies have applied a mobile app and validated its effectiveness among CRC survivors. A systematic review of web-based psychosocial interventions for CRC patients currently undergoing treatment (Wan et al., 2022) reported that these interventions effectively improved depression among the patient population, but their effectiveness on depression in post-treatment CRC survivors was unclear. A study that evaluated a computer-tailored intervention for post-treatment CRC survivors (Golsteijn et al., 2018) observed that depression was effectively improved, but the intervention was limited to physical activities. Depression and fear of cancer recurrence are the most prevalent psychological challenges CRC survivors face (McGeechan et al., 2022; Mosher et al., 2016; Miroševič et al., 2019; Santin et al., 2015), and improving such negative feelings after treatment is critical to cancer survivorship care. Additional studies should

further evaluate whether e-health interventions for CRC survivors effectively improve depression and fear of recurrence.

4.1. Limitations

This study adopted a one-group pretest–posttest design, and the lack of a control group is one of its limitations. The effects of the intervention on depression and fear of recurrence should be further validated, as statistically significant results were not observed in the study because of the small sample size. Since most mobile app intervention studies are not randomized controlled trials (Davis and Oakley-Girvan, 2015), they need to present clear evidence on the effects of mobile apps on CRC survivors, including the one developed in this study.

Further, we evaluated the effects following six weeks of using a mobile app, which is the most common study duration for self-management interventions with cancer survivors (Cuthbert et al., 2019). However, given that CRC survivors need to engage in self-management efforts long term to cope with their changed lives, and that we applied automated coaching technologies that do not require human resources, further studies investigating the effects of the long-term use and usability of the mobile app could present insightful implications. Moreover, longitudinal follow-ups are crucial for assessing the retention of the effects of self-management interventions for cancer survivors. The few studies that did perform longitudinal assessments reported that the effects were not retained over the long term (Boland et al., 2018). The mobile app developed in this study supports the self-management efforts of CRC survivors. Since self-management is a lifelong task for this population, sustainability of the effects of an intervention is a critical aspect in evaluating the value of an intervention. Hence, further studies are needed to investigate not only the effects of a mobile app immediately after its use but also the duration for which these effects are sustained after discontinuing its use. Finally, our mobile app was rated as having good usability, based on the high completion rate and low user dropout rate. However, we did not directly evaluate the usability of the mobile app. Thus, the key aspects of usability—ease of input, screen readability, applicability to life, stable system features, and interactions—should be evaluated in the future (Ayyoubzadeh et al., 2020).

5. Conclusion

CRC survivors experience various challenges even after completing their treatment regimens, and they must engage in lifelong self-management. Social support to enhance their QoL and health must be weighed heavily in primary care. In this study, we developed a cost-effective, easy-to-use, and well-accepted mobile application for CRC survivors that provides personalized social support services. The mobile app improved users' self-efficacy, QoL, and lifestyle behaviors and featured high usability. We expect this mobile app to be useful for supportive care for post-treatment CRC survivors. In particular, the automated health coaching technology in our app highlights the potential of digital health coaching to overcome the existing shortcomings of health coaching that require human resources.

In addition, our findings show that personalized, positive feedback, success experiences, lifestyle practices, and health coaching services and content may serve as important elements augmenting the effectiveness and usability of self-care mobile apps for CRC survivors. These findings will serve as the foundational data for the development of more effective mobile apps in the future.

CRediT authorship contribution statement

Jaehee Yoon: Conceptualization, Methodology, Software, Data curation, Writing – original draft. **HyunHae Lee:** Methodology, Data curation, Writing – original draft. **Heesook Son:** Conceptualization, Methodology, Data curation, Investigation, Supervision, Validation, Writing – review & editing, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejon.2023.102413.

References

Ayyoubzadeh, S.M., Niakan Kalhori, R.S., Shirkhoda, M., Mohammadzadeh, N., Esmaeili, M., 2020. Supporting colorectal cancer survivors using eHealth: a systematic review and framework suggestion. Support. Care Cancer 28 (8), 3543–3555. https://doi.org/10.1007/s00520-020-05372-6.

Ayyoubzadeh, S.M., Shirkhoda, M., R Niakan Kalhori, S., Mohammadzadeh, N., Zakerabasali, S., 2022. A smartphone remote monitoring app to follow up colorectal cancer survivors: requirement analysis. JMIR Cancer 8, e18083. https://doi.org/10.2196/18083.

Bangerter, L.R., Griffin, J., Harden, K., Rutten, L.J., 2019. Health information–seeking behaviors of family caregivers: analysis of the health information national trends survey. JMIR Aging 2, e11237. https://doi.org/10.2196/11237.

Boland, L., Bennett, K., Connolly, D., 2018. Self-management interventions for cancer survivors: a systematic review. Support. Care Cancer 26, 1585–1595. https://doi.org/10.1007/s00520-017-3999-7.

Brandenbarg, D., Korsten, J.H.W.M., Berger, M.Y., Berendsen, A.J., 2018. The effect of physical activity on fatigue among survivors of colorectal cancer: a systematic review and meta-analysis. Support. Care Cancer 26, 393–403. https://doi.org/10.1007/s00520-017-3920-4.

Brown, S., Greenfield, D., Thompson, J., 2016. Knowledge and awareness of long-term and late treatment consequences amongst colorectal cancer survivors: a qualitative study. Eur. J. Oncol. Nurs. 20, 191–198. https://doi.org/10.1016/j.ejon.2015.08.005.

Browne, S., Dowie, A., Mitchell, E.D., Wyke, S., Ziebland, S., Campbell, N., Macleod, U., 2011. Patients' needs following colorectal cancer diagnosis: where does primary care fit in? Br. J. Gen. Pract. 61, e692–e699. https://doi.org/10.3399/bjgp11X606582.

Cheong, I.Y., An, S.Y., Cha, W.C., Rha, M.Y., Kim, S.T., Chang, D.K., Hwang, J.H., 2018. Efficacy of mobile health care application and wearable device in improvement of physical performance in colorectal cancer patients undergoing chemotherapy. Clin. Colorectal Cancer 17, e353–e362. https://doi.org/10.1016/j.clcc.2018.02.002.

Chow, P.I., Drago, F., Kennedy, E.M., Cohn, W.F., 2020. A novel mobile phone app intervention with phone coaching to reduce symptoms of depression in survivors of women's cancer: pre-post pilot study. JMIR Cancer 6, e15750. https://doi.org/10.2196/15750.

Costa, A.L.S., Heitkemper, M.M., Alencar, G.P., Damiani, L.P., da Silva, R.M.D., Jarrett, M.E., 2017. Social support is a predictor of lower stress and higher quality of life and resilience in Brazilian patients with colorectal cancer. Cancer Nurs. 40, 352–360. https://doi.org/10.1097/NCC.0000000000000388.

Cuthbert, C.A., Farragher, J.F., Hemmelgarn, B.R., Ding, Q., McKinnon, G.P., Cheung, W. Y., 2019. Self-management interventions for cancer survivors: a systematic review and evaluation of intervention content and theories. Psycho Oncol. 28, 2119–2140. https://doi.org/10.1002/pon.5215.

Dau, H., Safari, A., Saad El Din, K.S., McTaggart-Cowan, H., Loree, J.M., Gill, S., De Vera, M.A., 2020. Assessing how health information needs of individuals with colorectal cancer are met across the care continuum: an international cross-sectional survey. BMC Cancer 20, 1031. https://doi.org/10.1186/s12885-020-07539-0.

Davies, N.J., Batehup, L., 2010. Self-Management Support for Cancer Survivors: Guidance for Developing Interventions. Macmillan Cancer Support, London.

Davis, S.W., Oakley-Girvan, I., 2015. Mhealth education applications along the cancer continuum. J. Cancer Educ. 30, 388–394. https://doi.org/10.1007/s13187-014-0761-4.

Dekker, E., Tanis, P.J., Vleugels, J.L.A., Kasi, P.M., Wallace, M.B., 2019. Colorectal cancer. Lancet 394, 1467–1480. https://doi.org/10.1016/S0140-6736(19)32319-0.

El-Shami, K., Oeffinger, K.C., Erb, N.L., Willis, A., Bretsch, J.K., Pratt-Chapman, M.L., Cannady, R.S., Wong, S.L., Rose, J., Barbour, A.L., Stein, K.D., Sharpe, K.B., Brooks, D.D., Cowens-Alvarado, R.L., 2015. American Cancer Society colorectal cancer survivorship care guidelines. CA Cancer J. Clin. 65, 428–455. https://doi.org/10.3322/caac.21286.

Escriva Boulley, G., Leroy, T., Bernetière, C., Paquienseguy, F., Desfriches-Doria, O., Préau, M., 2018. Digital health interventions to help living with cancer: a systematic

review of participants' engagement and psychosocial effects. Psycho Oncol. 27, 2677–2686. https://doi.org/10.1002/pon.4867.

Ezoe, S., Morimoto, K., 1994. Behavioral lifestyle and mental health status of Japanese factory workers. Prev. Med. 23, 98–105. https://doi.org/10.1006/pmed.1994.1014.

Favoriti, P., Carbone, G., Greco, M., Pirozzi, F., Pirozzi, R.E.M., Corcione, F., 2016. Worldwide burden of colorectal cancer: a review. Update. Surg. 68, 7–11. https://doi.org/10.1007/s13304-016-0359-y.

Foster, C., Breckons, M., Cotterell, P., Barbosa, D., Calman, L., Corner, J., Smith, P.W., 2015. Cancer survivors' self-efficacy to self-manage in the year following primary treatment. J. Cancer Surviv 9, 11–19. https://doi.org/10.1007/s11764-014-0384-0.

Gao, W.J., Yuan, C.R., 2011. Self-management programme for cancer patients: a literature review. Int. Nurs. Rev. 58, 288–295. https://doi.org/10.1111/j.1466-7657.2011.00907.x.

Golsteijn, R.H.J., Bolman, C., Volders, E., Peels, D.A., de Vries, H., Lechner, L., 2018. Short-term efficacy of a computer-tailored physical activity intervention for prostate and colorectal cancer patients and survivors: a randomized controlled trial. Int. J. Behav. Nutr. Phys. Activ. 15, 106. https://doi.org/10.1186/s12966-018-0734-9.

Grimmett, C., Bridgewater, J., Steptoe, A., Wardle, J., 2011. Lifestyle and quality of life in colorectal cancer survivors. Qual. Life Res. 20, 1237–1245. https://doi.org/10.1007/s11136-011-9855-1.

Han, C.J., Yang, G.S., Syrjala, K., 2020. Symptom experiences in colorectal cancer survivors after cancer treatments: a systematic review and meta-analysis. Cancer Nurs. 43, E132–E158. https://doi.org/10.1097/NCC.0000000000000785.

House, J., 1981. Work Stress, and Social Support. Addison-Wesley, Reading, Massachusetts.

Husebø, A.M.L., 2021. Stakeholders' perspectives on ehealth support in colorectal cancer survivorship: qualitative interview study. JMIR Cancer 7, e28279. https://doi.org/10.2196/28279.

Jansen, F., van Uden-Kraan, C.F., van Zwieten, V., Witte, B.I., Verdonck-de Leeuw, I.M., 2015. Cancer survivors' perceived need for supportive care and their attitude towards self-management and ehealth. Support. Care Cancer 23, 1679–1688. https://doi.org/10.1007/s00520-014-2514-7.

Jansen, L., Koch, L., Brenner, H., Arndt, V., 2010. Quality of life among long-term (⩾ 5 years) colorectal cancer survivors—systematic review. Eur. J. Cancer 46, 2879–2888. https://doi.org/10.1016/j.ejca.2010.06.010.

Jiang, Y., West, B.T., Barton, D.L., Harris, M.R., 2017. Acceptance and use of ehealth/mhealth applications for self-management among cancer survivors. Stud. Health Technol. Inf. 245, 131–135. https://doi.org/10.3233/978-1-61499-830-3-131.

Kearney, N., McCann, L., Norrie, J., Taylor, L., Gray, P., McGee-Lennon, M., Maguire, R., 2009. Evaluation of a mobile phone-based, advanced symptom management system (ASyMS) in the management of chemotherapy-related toxicity. Support. Care Cancer 17, 437–444. https://doi.org/10.1007/s00520-008-0515-0.

Kim, A.R., Park, H.A., 2015. Web-based self-management support interventions for cancer survivors: a systematic review and meta-analyses. Stud. Health Technol. Inf. 216, 142–147.

Kim, B.Y., Park, K.J., Ryoo, S.B., 2018. Effects of a mobile educational program for colorectal cancer patients undergoing the enhanced recovery after surgery. Open Nurs. J. 12, 142–154. https://doi.org/10.2174/1874434601812010142.

Kim, K., Park, W., 2019. Effects of mobile navigation program in colorectal cancer patients based on uncertainty theory. J. Korean Acad. Nurs. 49, 274–285. https://doi.org/10.4040/jkan.2019.49.3.274.

Kim, S.H., Lee, B.G., Lee, J.Y., Kim, S.J., Hur, M.H., Lee, M.H., Han, M.S., 2019. Psychometric evaluation of a Korean version of the cancer survivors' self-efficacy scale. Cancer Nurs. 42, 509–514. https://doi.org/10.1097/NCC.0000000000000691.

Kohout, F.J., Berkman, L.F., Evans, D.A., Cornoni-Huntley, J., 1993. Two shorter forms of the CES-D (center for epidemiological studies depression) depression symptoms index. J. Aging Health 5, 179–193. https://doi.org/10.1177/089826439300500202.

Lo, J., Ballurkar, K., Fox, S., Tynan, K., Luu, N., Boyer, M., Murali-Ganesh, R., 2021. A digital coaching intervention for cancer survivors with job loss: retrospective study. JMIR Cancer 7, e31966. https://doi.org/10.2196/31966.

Lubberding, S., van Uden-Kraan, C.F., Te Velde, E.A., Cuijpers, P., Leemans, C.R., Verdonck-de Leeuw, I.M., 2015. Improving access to supportive cancer care through an ehealth application: a qualitative needs assessment among cancer survivors. J. Clin. Nurs. 24, 1367–1379. https://doi.org/10.1111/jocn.12753.

McGeechan, G.J., Byrnes, K., Campbell, M., Carthy, N., Eberhardt, J., Paton, W., Swainston, K., Giles, E., 2022. A systematic review and qualitative synthesis of the experience of living with colorectal cancer as a chronic illness. Psychol. Health 37, 350–374. https://doi.org/10.1080/08870446.2020.1867137.

Ministry of Health and Welfare, 2010. National Cancer Prevention Practice Guidelines. Colorectal Cancer. http://www.mohw.go.kr/react/jb/sjb030301vw.jsp?PAR_MENU_ID=03&MENU_ID=032901&CONT_SEQ=336761. (Accessed 10 April 2022).

Mirkovic, J., Kaufman, D.R., Ruland, C.M., 2014. Supporting cancer patients in illness management: usability evaluation of a mobile app. JMIR mHealth uHealth 2, e33. https://doi.org/10.2196/mhealth.3359.

Miroševič, Š., Prins, J.B., Selič, P., Zaletel Kragelj, L., Klemenc Ketiš, Z., 2019. Prevalence and factors associated with unmet needs in post-treatment cancer survivors: a systematic review. Eur. J. Cancer Care 28, e13060. https://doi.org/10.1111/ecc.13060.

Mishra, S.I., Scherer, R.W., Geigle, P.M., Berlanstein, D.R., Topaloglu, O., Gotay, C.C., Snyder, C., 2012. Exercise interventions on health-related quality of life for cancer survivors. Cochrane Database Syst. Rev. https://doi.org/10.1002/14651858.CD007566.pub2, 2012, CD007566.

Mosher, C.E., Winger, J.G., Given, B.A., Helft, P.R., O'Neil, B.H., 2016. Mental health outcomes during colorectal cancer survivorship: a review of the literature. Psycho Oncol. 25, 1261–1270. https://doi.org/10.1002/pon.3954.

O'Malley, D.M., Davis, S.N., Amare, R., Sanabria, B., Sullivan, B., Devine, K.A., Ferrante, J.M., Findley, P.A., Miller, S.M., Hudson, S.V., 2022. User-centered development and patient acceptability testing of a health-coaching intervention to enhance cancer survivorship follow-up in primary care. J. Cancer Educ. 37, 788–797. https://doi.org/10.1007/s13187-020-01883-2.

O'Neill, S., Brady, R.R., 2012. Colorectal smartphone apps: opportunities and risks. Colorectal Dis. 14, e530–e534. https://doi.org/10.1111/j.1463-1318.2012.03088.x.

Rabin, C., 2009. Promoting lifestyle change among cancer survivors: when is the teachable moment? Am. J. Lifestyle Med. 3, 369–378. https://doi.org/10.1177/1559827609338148.

Riley, W.T., Rivera, D.E., Atienza, A.A., Nilsen, W., Allison, S.M., Mermelstein, R., 2011. Health behavior models in the age of mobile interventions: are our theories up to the task? Transl. Behav. Med. 1, 53–71. https://doi.org/10.1007/s13142-011-0021-7.

Roberts, A.L., Fisher, A., Smith, L., Heinrich, M., Potts, H.W.W., 2017. Digital health behaviour change interventions targeting physical activity and diet in cancer survivors: a systematic review and meta-analysis. J. Cancer Surviv. 11, 704–719. https://doi.org/10.1007/s11764-017-0632-1.

Salmani, H., Nahvijou, A., Sheikhtaheri, A., 2022. Smartphone-based application for self-management of patients with colorectal cancer: development and usability evaluation. Support. Care Cancer 30, 3249–3258. https://doi.org/10.1007/s00520-021-06754-0.

Santin, O., Murray, L., Prue, G., Gavin, A., Gormley, G., Donnelly, M., 2015. Self-reported psychosocial needs and health-related quality of life of colorectal cancer survivors. Eur. J. Oncol. Nurs. 19, 336–342. https://doi.org/10.1016/j.ejon.2015.01.009.

Schueller, S.M., Tomasino, K.N., Mohr, D.C., 2017. Integrating human support into behavioral intervention technologies: the efficiency model of support. Clin. Psychol. Sci. Pract. 24, 27–45. https://doi.org/10.1111/cpsp.12173.

Shin, J., Goo, A., Ko, H., Kim, J.H., Lim, S.U., Lee, H.K., Song, Y.M., 2017. Validation study for the Korean version of fear of cancer recurrence inventory. J. Kor. Med. Sci. 32, 1792–1799. https://doi.org/10.3346/jkms.2017.32.11.1792.

Siegel, R.L., Miller, K.D., Jemal, A., 2019. Cancer statistics, 2019. CA Cancer J. Clin. 69, 7–34. https://doi.org/10.3322/caac.21551.

Simard, S., Savard, J., 2015. Screening and comorbidity of clinical levels of fear of cancer recurrence. J. Cancer Surviv. 9, 481–491. https://doi.org/10.1007/s11764-015-0424-4.

Smith, A.B., Bamgboje-Ayodele, A., Butow, P., et al., 2020. Development and usability evaluation of an online self-management intervention for fear of cancer recurrence (iConquerFear). Psycho Oncol. 29, 98–106. https://doi.org/10.1002/pon.5218.

Soffer, S., Klang, E., Tau, N., Zemet, R., Ben-Horin, S., Barash, Y., Kopylov, U., 2020. Evolution of colorectal cancer screening research in the past 25 years: text-mining analysis of publication trends and topics. Ther. Adv. Gastroenterol. 13, 1756284820941153. https://doi.org/10.1177/1756284820941153.

Thomas, S.A., Chapa, D.W., Friedmann, E., Durden, C., Ross, A., Lee, M.C.Y., Lee, H.J., 2008. Depression in patients with heart failure: prevalence, pathophysiological mechanisms, and treatment. Crit. Care Nurse 28, 40–55. https://doi.org/10.4037/ccn2008.28.2.40.

Wagland, R., Recio-Saucedo, A., Simon, M., Bracher, M., Hunt, K., Foster, C., Downing, A., Glaser, A., Corner, J., 2016. Development and testing of a text-mining approach to analyse patients' comments on their experiences of colorectal cancer care. BMJ Qual. Saf. 25, 604–614. https://doi.org/10.1136/bmjqs-2015-004063.

Wan, S.W., Chng, Y.J.D., Lim, S.H., Chong, C.S., Pikkarainen, M., He, H.G., 2022. A systematic review and meta-analysis on the effectiveness of web-based psychosocial interventions among patients with colorectal cancer. J. Adv. Nurs. 78, 1883–1896. https://doi.org/10.1111/jan.15258.

World Cancer Research Fund, 2018. Diet, Nutrition, Physical Activity and Colorectal Cancer. https://www.wcrf.org/wp-content/uploads/2021/02/Colorectal-cancer-report.pdf. (Accessed 5 April 2022).

World Cancer Research Fund, American Institute for Cancer Research, 2018. Diet, Nutrition, Physical Activity and Cancer: a Global Perspective—A Summary of the Third Expert Report. https://www.wcrf.org/wp-content/uploads/2021/02/Summary-of-Third-Expert-Report-2018.pdf. (Accessed 10 March 2022).

World Health Organization, 2016. From innovation to implementation: ehealth in the WHO European region. In: Regional Office for Europe. World Health Organization.

Yaacob, N.A., Mohamad Marzuki, M.F., Yaacob, N.M., Ahmad, S.B., Abu Hassan, M.R., 2020. Effectiveness of the ColorApp mobile app for health education and promotion for colorectal cancer: quasi-Experimental Study. JMIR Hum. Factors. 7, e15487 https://doi.org/10.2196/15487.

Yoon, J., Kim, J., Son, H., 2021. Gender differences of health behaviors in the risk of metabolic syndrome for middle-aged adults: a national cross-sectional study in South Korea. Int. J. Environ. Res. Publ. Health 18, 3699. https://doi.org/10.3390/ijerph18073699.