

Digital Health Interventions for Adolescent and Young Adult Cancer Survivors

abstract This narrative review describes the evidence regarding digital health interventions targeting adolescent and young adult (AYA) cancer survivors. We reviewed the published literature for studies involving Internet, mHealth, social media, telehealth, and other digital interventions for AYA survivors. We highlight selected studies to illustrate the state of the research in this unique patient population. Interventions have used various digital modalities to improve health behaviors (eg, physical activity, nutrition, tobacco cessation), enhance emotional well-being, track and intervene on cancer-related symptoms, and improve survivorship care delivery. The majority of studies have demonstrated feasibility and acceptability of digital health interventions for AYA survivors, but few efficacy studies have been conducted. Digital health interventions are promising to address unmet psychosocial and health information needs of AYA survivors. Researchers should use rigorous development and evaluation methods to demonstrate the efficacy of these approaches to improve health outcomes for AYA survivors.

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INTRODUCTION

Digital health can be broadly defined as the use of technology in the promotion, prevention, treatment, and maintenance of health and health care.^{1,2} Digital health includes electronic health (eHealth), mobile health (mHealth), health information technology, wearable devices, telehealth, and telemedicine. Such technology can be used in multiple ways, including for information delivery, two-way communication, or longitudinal assessment.³ Digital health is particularly relevant for adolescents and young adults (AYAs), who are pervasive users of technology. In the general population, 93% of adolescents ages 13 to 17 years and 99% of young adults ages 18 to 29 years use the Internet.^{4,5} Most connect to the Internet with mobile devices; 88% of teenagers and 98% of young adults are smartphone or cell phone users. In addition, the vast majority of teens (89%) and young adults (90%) report using at least one social media site (eg, Facebook, Instagram, Snapchat, Twitter).⁴

AYA cancer survivors are a growing group of survivors ages 15 to 39 years who were diagnosed with cancer during childhood, adolescence, or young adulthood.⁶ There are over 379,000 childhood cancer survivors in the United States, and approximately one in every 530 young adults

ages 20 to 39 years is a cancer survivor.⁷ The AYA years are a unique developmental period characterized by autonomy and identity development, pursuit of education and career goals, establishment of financial independence, independent living, and formation of intimate relationships.⁸ It is also a period of increasing mental health problems and risk-taking behaviors.⁹ AYA cancer survivors face multiple challenges including disruptions to education, employment, and social milestones, and coping with ongoing late effects from their treatment.^{10,11} A majority of survivors will develop at least one chronic health condition¹² that will require life-long follow-up care. However, AYAs are often lost to follow-up, do not have adequate knowledge of their cancer treatment history and late-effects risks,¹³ and engage in health-compromising behaviors at rates similar to their peers.^{14,15} Thus, interventions to improve AYA survivors' health behaviors and address their unmet psychosocial needs are greatly needed.^{16,17}

Digital health interventions have been increasingly examined to overcome barriers to AYA survivors' participation in health promotion interventions, including their geographic mobility, relatively small number of AYAs at single institutions, and lack of time and competing priorities.¹⁸ Such

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technology aligns well with AYA preferences for program delivery, use of technology in their daily lives, and use of technology for seeking health information and support.¹⁹⁻²² For example, up to 92% of AYA survivors use the Internet to seek health information, but have concerns about trustworthiness of the information and lack of tailoring to their needs.²³ AYA survivors also use mobile devices and online support forums to exchange emotional and informational support and to connect with other survivors.^{19,24}

In this review, we extend prior reviews of psychological and health promotion interventions for AYA cancer survivors^{16,17,25-27} to examine the evidence for digital health interventions targeting AYA survivors. We searched PubMed and Google Scholar using combinations of the following search terms: adolescent, young adult, cancer, survivor, digital, eHealth, mHealth, telehealth, and social media. We also reviewed the reference lists of published studies for additional relevant articles. We highlight primary results from select studies that use the Internet, mHealth, social media, telehealth, and other emerging digital modalities to illustrate the state of the research targeting this unique patient population (Table 1). As can be seen by the studies described, this is an emerging area of research primarily composed of feasibility studies with methodologic weaknesses, such as a lack of control groups and small sample sizes.

INTERNET INTERVENTIONS

Early applications of digital health interventions included static Web sites or CD-ROMs.^{33,36} More recent applications incorporate sophisticated elements of engagement within Web sites (eg, interactive tools, media, and gamification) or other digital health components (eg, text or short messaging service) delivered in conjunction with Web sites.³⁷ Internet-based interventions have been used to translate evidence-based interventions to the digital realm to increase access and convenience for participants, as well as reduce provider resources and costs needed to deliver interventions. For example, a randomized trial of a Web-based versus print smoking cessation intervention for young adult survivors of childhood and adolescent cancers demonstrated equivalency in cessation rates and quit attempts.³² These results support the use of the Internet to scale efficacious interventions.

Internet interventions have also been used as adjuncts to telephone or in-person interventions. For example, a weight loss intervention for child and adolescent acute lymphoblastic leukemia survivors used a combination of Web, text, and telephone counseling to promote weight loss and improve physical activity.³⁴ Other Internet interventions have targeted health promotion behaviors among AYA survivors using a custom-designed Web site,³¹ an adapted version of an effective Web-based program designed for adults,³⁰ or a commercially available fitness tracker and Web site.²⁹

Although the Internet offers great promise in delivering high-quality and tailored information to AYA survivors and increasing engagement outside of in-person meetings, a major challenge is the reliance on the user to initiate use.⁶⁸ A randomized pilot study of a Web-based portal to provide AYA cancer survivors with tailored treatment summaries and guidance regarding risk for late effects had low usage, with only 46% accessing the Web site and, of those, only one third logging in more than once.³⁵ Gilliam et al²⁸ demonstrated the feasibility of a Web-based token economy to promote adherence to a community-based face-to-face exercise intervention for child and adolescent survivors, but the intervention did not increase adherence to home exercise between sessions.

Although the majority of Internet interventions have focused on survivors, several studies targeted providers to improve the delivery of survivorship care. In the United States, the Passport for Care Web-based clinical tool was developed for providers to create individual patient survivorship care plans using guidelines-based recommendations for follow-up care.³⁶ Evaluation of a patient-focused portal is ongoing.³⁶ Similarly, in the Netherlands, a Web-based survivorship care plan portal was created to enhance communication among oncologists, family medicine providers, and survivors promoting guidelines-based shared care for long-term follow-up.³⁹

In sum, the Internet offers great promise in terms of convenience, access, and opportunities for engagement in behavioral interventions. There are few rigorously designed studies to make conclusions regarding the efficacy of Internet interventions for AYA survivors. However, it is encouraging that recent reviews have found evidence for the efficacy of Internet interventions

Table 1. Highlighted Digital Health Intervention Studies for AYA Survivors

Intervention and First Author	Primary Health Outcome(s)	Design	Sample	Results
Internet-based interventions				
Gilliam ²⁸	Physical activity	Pre-post	20 adolescents ages 6-18 years	12 completers demonstrated significant improvements in physical functioning Adherence to home-based daily exercise log was low
Le ²⁹	Physical activity	Pre-post	19 AYAs ages 15-35 years	Low enrollment (13.4%) but good retention (79%) Nonsignificant increases in moderate-to-vigorous activity and VO ₂ max
Rabin ³⁰	Physical activity	RCT	18 young adults ages 18-39 years	86% would recommend intervention and 71% satisfied No significant differences between groups but estimated effect size for changes in physical activity were medium
Berg ³¹	Physical activity, alcohol, and smoking cessation	Pre-post	24 young adults ages 18-34 years	85.7% were satisfied with the program but unsatisfied with low level of tailoring to individual needs Reduction in binge drinking; no other significant changes in behaviors
Emmons ³²	Smoking cessation	RCT	374 adult survivors ages 18-55 years	Similar rates of cessation in Web and tailored print arms High rates of satisfaction with both arms
Hollen ³³	Substance use	RCT	243 adolescents ages 14-20 years	90% rated program positively Intermediate effects for change in risk motivation among low-risk adolescents that was not sustained at 12 months No differences in quality decision making between groups
Huang ³⁴	Weight management	RCT	38 adolescents ages 8-18 years	Fit4Life group showed improved negative mood compared with control No significant group differences on weight, but treatment effects by age
Kunin-Baston ³⁵	Cancer knowledge	RCT	52 AYAs ages 15-28 years	Web site use was low, but satisfaction among users was high No differences between intervention and standard care
Ewing ³⁶	Cancer information and social support	Pre-post	21 families; 12 adolescents ages 12-17 years	Web site usage was low (9 of 21 families logged in) Discussion groups were most frequently accessed
Stinson ³⁷	Self-management	Qualitative	22 adolescents ages 12-18 years	Adolescents found information credible and relevant Reported Web site would be useful when first diagnosed
Poplack ³⁸	Survivorship care	Cross sectional	84 clinicians	82% reported adhering more closely to guidelines when using Passport for Care, and 79% felt it enabled sharing information with survivors 90% reported satisfaction with Passport for Care

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Table 1. Highlighted Digital Health Intervention Studies for AYA Survivors (Continued)

Intervention and First Author	Primary Health Outcome(s)	Design	Sample	Results
Blaauwbroek ³⁹	Survivorship care	Cross sectional	80 adults/79 clinicians ages 19-56 years	Survivors found Web-based & written survivorship care plans user friendly Family doctors found survivorship care plan user friendly, and 83% performed screening according to guidelines
mHealth applications				
Jibb ⁴⁰	Pain management	Pre-post	40 adolescents ages 12-18 years	Fidelity affected by technologic & logistic challenges Intervention was acceptable to participants Significant improvements in pain, pain interference, health-related QOL
Wu ⁴¹	Oral medication adherence	Pre-post	23 AYAs ages 15-29 years	91% reported the app set-up instructions were clear 91% used the app at least once, and 65% reported the app was useful
Stinson ⁴²	Pain assessment	Pre-post	47 adolescents ages 9-18 years	Participants completed 81% of assessments 84% of participants "very much liked" or "liked" the app
Tomlinson ⁴³	Symptom assessment	Pre-post	40 adolescents ages 8-18 years	100% of participants noted the app was very easy to use 95% reported it was easy or very easy to understand
Baggott ⁴⁴	Symptom assessment	Pre-post	10 adolescents ages 13-21 years	Overall completion rate was 91%-97% 100% of participants reported the app was easy or very easy to use
Macpherson ⁴⁵	Symptom assessment	Pre-post	72 adolescents ages 13-29 years	100% of participants completed the assessment App was acceptable (89% found the questions to be clear) 83% supported the app version over a paper version
Rodgers ⁴⁶	Symptom management	Pre-post	16 adolescents ages 11-18 years	Acceptability ratings were high (average scores of 28.5-28.9 of 30) Usability ratings were moderate (average scores of 10.1-11.2 of 15) All were able to correctly use the program after a brief orientation
Kock ⁴⁷	Long-term follow-up	Pre-post	13 adolescents ages \geq 15 years	On average, the evaluation of the app (eg, suitability for its purpose) yielded a score of 130 of 147
Vollmer Dahlke ⁴⁸	Survivorship care delivery	Qualitative	4 AYAs, 18 health care professionals & cancer advocates	Survivors reported utility of cancer survivorship care plans and educational content in workshops
Social media				
Valle ⁴⁹	Physical activity	RCT	86 AYAs ages 21-39 years	Moderate-to-vigorous-intensity activity increased in both the Facebook physical activity group and the Facebook-based self-help comparison group Changes in light physical activity and weight loss were greater in the Facebook group compared with the self-help comparison group

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Table 1. Highlighted Digital Health Intervention Studies for AYA Survivors (Continued)

Intervention and First Author	Primary Health Outcome(s)	Design	Sample	Results
Valle ⁵⁰	Physical activity	RCT	86 AYAs ages 21-39 years	Participants in the self-help group were more likely than participants in the Facebook physical activity group to indicate that group discussions caused them to become physically active and that group members were supportive Posts from participants (v moderators) elicited more comments and likes
Mendoza ⁵¹	Physical activity	Feasibility	60 adolescents ages 14-18 years	Participants wore the Fitbit on the majority of days No significant group differences between the intervention and usual-care groups in moderate-to-vigorous physical activity or sedentary time
McLaughlin ⁵²	Social capital, social support, depression, self-efficacy, QOL	Pre-post	14 AYAs ages 18-29 years	Participation in the social network was higher among individuals with weak bonding social capital, lower social support, and lower family interactions
Gibson ⁵³	Psychological and physical cancer effects	Qualitative	18 AYAs ages 11-25 years	Four themes identified: treatment & adverse effects, rehabilitation & moving on with life, relapse & ongoing treatment, and coming to terms with dying
Telehealth				
Campo ⁵⁴	Psychological symptom reduction	Pre-post	25 AYAs ages 18-29 years	85% of participants completed 75% of sessions All psychosocial outcomes except resilience showed significant change
Sansom-Daly ⁵⁵	Psychological symptom reduction	Case series	11 AYAs ages 15-24 years	Videoconferencing offers alternative solution for adolescents who may otherwise be unable to access mental health resources
Seitz ⁵⁶	Psychological symptom reduction	Pre-post	20 AYAs ages 20-36 years	Participants demonstrated significant decreases in PTSS, anxiety, fear of relapse/progression, and depression
Cantrell ⁵⁷	Promote hope	Pre-post	6 females	Web-based delivery was effective Online sessions promoted intimate meaningful conversations
Emerging digital health interventions				
Sabel ⁵⁸	Physical activity	RCT	13 adolescents ages 7-17 years	Body coordination improved by 15% No change in daily time spent doing moderate/vigorous physical activity
Kato ⁵⁹	Medication adherence	RCT	375 AYAs ages 13-29 years	Participants who played the cancer-targeted video game demonstrated better objective medication adherence, self-efficacy, and knowledge No group differences for QOL, stress, control, or self-reported adherence
Cox ⁶⁰	Working memory	RCT	68 adolescents ages 8-16 years	88% of the treatment sample completed the intervention The training was beneficial (70%) and time commitment acceptable (63%)
Hardy ⁶¹	Working memory	Pre-post	9 adolescents ages 10-17 years	Participants' working memory scores increased from baseline to follow-up
Gershon ⁶²	Psychological symptom reduction	Pre-post	59 adolescents ages 7-19 years	Participants had lower pulse rate and less report of pain using the distraction technique

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Table 1. Highlighted Digital Health Intervention Studies for AYA Survivors (Continued)

Intervention and First Author	Primary Health Outcome(s)	Design	Sample	Results
Laing ⁶³	Psychological symptom reduction	Qualitative	16 AYAs or family members ages 5-56 years	Digital stories offer therapeutic benefits in communicating about experience The further one is from diagnosis, the more reflective
Li ⁶⁴	Psychological symptom reduction	Quasi-experimental	122 adolescents ages 8-16	Intervention group had significantly fewer depressive symptoms No change in anxiety
Pereira ⁶⁵	Psychological symptom reduction	Case study	1 adolescent age 14 years	Video narratives are a way for patients to communicate needs to their medical team
Schneider ⁶⁶	Psychological symptom reduction, distraction	Crossover	20 women ages 18-55 years	Significant decreases in distress and fatigue when using virtual reality
Casillas ⁶⁷	Survivorship care delivery	Pre-post	37 AYAs ages 15-39 years	Text reminders were acceptable, and tailored suggestions were relevant Participants suggested forming AYA survivor networks

Abbreviations: AYA, adolescent and young adult; pre-post, pretest–post-test design; PTSS, post-traumatic stress symptoms; QOL, quality of life; RCT, randomized controlled trial; VO₂ max, maximal oxygen uptake (measure of cardiorespiratory fitness).

in related areas (eg, improving mental health in adults,⁶⁸ health outcomes in pediatrics⁶⁹).

mHEALTH APPLICATIONS

mHealth interventions have used text messaging/short messaging service or mobile applications (apps) to deliver interventions targeting a variety of health outcomes. One study examined the feasibility of using text message reminders to increase compliance with survivorship care recommendations and resource use.⁶⁷ Participants found the text messages to be acceptable, and they recommended adding a social networking component to the program.⁶⁷ Smartphone apps for AYA cancer survivors have targeted cancer-related symptoms, medication taking, post-treatment follow-up and survivorship, and other health behaviors. A main area of focus has been symptom assessment and management. Existing apps enable AYA patients to record ongoing symptoms, including pain,^{40,42} mucositis,⁴³ or multiple symptoms.^{44,45} For example, Macpherson et al⁴⁵ pilot tested an app that assessed a range of possible symptoms and provided a personalized visualization of symptom clusters. Preliminary evaluations of such symptom assessment apps indicate that they are feasible in terms of the time required to complete the symptom assessment and acceptable to patients in terms

of ease; patients were also generally compliant with prompts to complete the electronic assessments.⁴³⁻⁴⁵

Other apps have built on assessment to also provide real-time symptom management interventions.^{40,46} For example, Stinson et al⁴² piloted an app for pain assessment with adolescent patients with cancer that incorporated a game-based reward system. The assessment app was feasibly deployed, and adolescents reported high satisfaction. In a follow-up study, adolescents using the app received automated messages related to pain management when they reported experiencing pain. If participants reported persistent pain, a nurse contacted the adolescent to discuss other pain management strategies, such as potential medication changes.⁴⁰

In addition to symptom assessment and management, apps have been used to target other health behaviors, such as medication adherence and compliance with follow-up care. Results of initial feasibility and acceptability studies indicate that AYA patients find such apps easy to use.^{41,47} For example, 91% of participants offered an app to prompt oral medication taking used the app at least once, and 74% reported that the reminders provided by the app helped them to take their oral medications as prescribed.⁴¹ Apps have also been used as part of a larger intervention

package, including in an AYA cancer survivorship program with educational components for providers, advocates, survivors, and their families.⁴⁸ In this latter example, the app provided survivors with information on health behaviors and survivorship care plans.

Given the widespread use of smartphones among AYAs in general,⁴ apps offer a ubiquitous medium through which to deliver interventions for AYA survivors. Studies on app use in this population thus far have focused primarily on single-site, pretesting/post-testing designs, with initial feasibility and acceptability metrics. As the field develops, multisite studies and efficacy trials will be essential for extending the generalizability of results and documenting the symptom or health behavior outcomes associated with app use. Future work should also examine the potential benefits of using apps to connect survivors with support networks (eg, peers, their families), health care providers, and other digital health technologies (eg, fitness trackers, electronic medical record systems) in real-time across multiple settings.

SOCIAL MEDIA

Social media platforms can be used in health behavior interventions to reach diverse groups without geographic restrictions, provide a forum for information dissemination and exchange, and enable provision of support from peers, family, and health professionals. There is accumulating evidence from studies across target populations that interventions delivered via social media platforms have significant potential to facilitate health communications and promote an array of health-related behaviors.⁷⁰

Among AYA survivors, social media health promotion research has thus far primarily used Facebook. In an early study, Valle et al⁴⁹ conducted a randomized controlled trial of a Facebook-based physical activity intervention versus a self-help comparison among young adult cancer survivors. Self-reported moderate to vigorous physical activity increased equally in both groups over a 12-week period, although the participants in the Facebook group had significantly greater increases in light physical activity. Similar to other studies of social media-based interventions with different populations, participant engagement decreased over the course of the intervention, and greater engagement

was positively associated with changes in physical activity.⁵⁰ Several other recent pilot studies demonstrated encouraging feasibility results of Facebook-based interventions for AYA cancer survivors, but they have provided limited evidence of their efficacy with regard to increasing self-reported or objectively measured physical activity.^{29,51}

In terms of other social media platforms, video-based approaches have been used in a number of studies. For example, McLaughlin et al⁵² developed their own social media site (LIFECOMMUNITY) for young adult cancer survivors that allowed individuals to create a blog and share messages, photographs, and videos with other participants. Participants were encouraged to create and share video narratives on different topics (eg, communicating with health care providers, coping with cancer). Participants with weaker face-to-face family and friend social networks used the social media site to a greater degree than individuals with stronger social networks. Interestingly, participants with preexisting strong social connections with other cancer survivors also used the site to a greater degree than individuals with fewer such connections.⁵² Thus, engagement in social media sites may serve the dual purpose of fulfilling potential deficits in support from family and friends and reaffirming or bolstering support from other cancer survivors.

Observing AYA survivors' use of existing social media platforms may lead to novel insights on how survivors express and receive social support in these digital mediums. For example, researchers have examined the content of posts in Twitter communities using cancer hashtags,⁷¹ online cancer support forums,²⁴ and video diaries in an online support community.⁵³ A list of organizations that use social media platforms to connect with AYA cancer survivors and other interested individuals is available elsewhere.²¹

Overall, social media-based research related to AYA cancer survivors is in its early stages and has consisted primarily of small-scale pilot and feasibility studies. Future studies should use larger sample sizes, rigorous research designs, and both subjective and objective outcome measures when possible, and expand to consider a broad array of social media platforms that may appeal to AYA cancer survivors (eg, Instagram, Snapchat).

TELEHEALTH

Telehealth is the use of technology such as videoconferencing to connect two or more individuals (eg, AYA survivor and health care provider) in replacement of an in-person connection.³ For example, an Internet cognitive-behavioral intervention to reduce post-traumatic stress symptoms and anxiety had AYA survivors engage in writing sessions online and connected them virtually with a therapist.⁵⁶ Similarly, group-based interventions have been successfully delivered using online videoconferencing. One example is a nurse-led intervention to enhance hope among young adult survivors of childhood cancer.⁵⁷ Another example is an instructor-led mindfulness-based self-compassion group intervention to reduce distress and improve psychosocial outcomes.⁵⁴ This study primarily recruited via social media, demonstrating the feasibility of recruiting and intervening online. Although there are ethical and clinical challenges associated with providing psychotherapy online, giving hard-to-reach groups access to evidence-based interventions is a major advantage.⁵⁵

Telehealth interventions have also been examined as a strategy for overcoming patient and provider barriers to long-term follow-up care. One study tested the feasibility of a telemedicine transition visit using videoconferencing between a primary care provider and a member of a survivorship care team. Primary care physician and AYA cancer survivor dyads communicated with a pediatric survivorship clinic team member who reviewed the patient's treatment summary and survivorship care plan. Patients and providers rated the intervention highly, but technologic limitations curtailed the feasibility of this model.⁷²

EMERGING DIGITAL HEALTH INTERVENTIONS

Emerging areas include the use of digital storytelling, video gaming, and virtual reality to address psychosocial and health care utilization concerns of AYA survivors. Digital storytelling involves the creation of a video narrative or personal story through the use of computer and multimedia tools combining video, images, music, voice narration, or other sounds. A qualitative study of 16 AYA survivors and their family members found that the process of creating a digital story provided AYAs and their family members new ways to communicate about and

make meaning of their cancer experience.⁶³ The results of a case study of an adolescent who created a video narrative demonstrated similar therapeutic benefits.⁶⁵

Video gaming has been explored as an intervention for physical activity and adherence for AYA survivors. For example, 13 adolescent brain tumor survivors participated in an active video gaming intervention with videoconference coaching to improve physical activity.⁵⁸ Despite small to modest improvements in energy expenditure and body composition, high patient-reported satisfaction with the coaching component provided preliminary support for this method of delivery.⁵⁸ Another video game intervention was used with AYAs to increase medication adherence by targeting behavioral correlates, including self-efficacy and locus of control. This 375-participant, multicenter randomized controlled trial (RCT) showed significantly improved levels of adherence among the intervention group.⁵⁹ Computerized cognitive remediation uses game-like exercises to improve working memory and has shown promise for acute lymphoblastic leukemia and brain tumor survivors.^{60,61} Virtual reality has been used to reduce anxiety and depression during medical procedures and chemotherapy for younger^{62,64} and older adult⁶⁶ cancer populations. Future exploration of virtual reality for AYA survivors is warranted.

SUMMARY AND FUTURE DIRECTIONS

Digital health technology offers immense promise for improving care and outcomes among AYA survivors across a variety of domains. Advantages and disadvantages of different digital modalities are listed in [Table 2](#). Investigators should carefully consider the goal of the intervention; the purpose of the technology (eg, to provide information, to prompt adherence to an intervention, to connect AYA survivors with peer support, to replace face-to-face counseling); the suitability of available commercial platforms versus custom products; resources for developing, maintaining, and analyzing data from the technology; and any training or support required to implement the intervention to select the most appropriate platform.^{73,74} Notably, health behavior change theory and techniques can be applied in any modality, although some modalities may be advantageous for certain techniques (eg, interventions relying on prompts may prefer to use mobile apps or

Table 2. Advantages and Disadvantages of Digital Health Modalities

Modality	Examples	Advantages	Disadvantages
Internet	Web sites	Near-universal access among AYAs	Relies on patient to initiate use
	Asynchronous forums	Web sites accessible across multiple devices	Concerns about privacy/confidentiality
	Chat/instant message	Opportunity for interactive elements	Technical expertise required to develop high-quality Web site
	Electronic health records	Asynchronous communication allows response at AYA's convenience	If site not mobile-responsive, may limit convenience and AYA willingness to access
		Cost effective over time	Asynchronous communication results in variable response times
mHealth	Text messaging	Real-time data collection and prompting	Concerns about privacy/confidentiality
	Smartphone applications	Cell phone use is nearly universal among AYAs	Requires developers or working with external companies to obtain data; companies may change policies over time
	Wearable devices (eg, fitness trackers)	Harness data from other smartphone components (eg, global positioning system, voice, camera)	Technical expertise required to analyze and interpret large amount of data collected by mobile/wearable devices
		Device and messaging costs are generally low	Requires ongoing support and modification to avoid obsolete technology
	Commercial apps available or can customize a new one		
Social media ⁷³	Facebook	Free and widely used commercial platforms available	Concerns about privacy/confidentiality
	Twitter	Social media already embedded into daily life of most AYAs	Participants may view intervention as intrusion to social network
	Instagram	Opportunities to use existing networks or create new peer support networks	Requires conversion or development of content in a format appropriate for social media platform
	Snapchat	Potential recruitment tool	Requires thoughtful engagement plan, but there is little existing research to guide strategies to promote meaningful engagement
		Generally low cost	May require developers or working with external programs to obtain usage data; existing social media platforms may change policies over time
	Avenue for dissemination of evidence-based practice	Institutional policies regarding professional use of social media and concerns about compliance with ethical standards (eg, seeming to provide diagnosis, informal interactions with patients in public context)	

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text messaging in response to triggers collected from mobile data, whereas interventions proposing to change social norms may prefer to use a social media platform).

The digital health interventions reviewed in this article targeted a range of health behaviors and outcomes, including physical activity, risk

behaviors, psychosocial well-being, symptom management, and survivorship delivery and care. These interventions mostly demonstrated feasibility and acceptability among AYA survivors, but rigorous efficacy studies have generally not yet been conducted. Future work should address important AYA-specific concerns, such as successful health care transition (eg, to adult

Table 2. Advantages and Disadvantages of Digital Health Modalities (Continued)

Modality	Examples	Advantages	Disadvantages
Telehealth	Videoconferencing	Increases access to those at great distance or unable to access in-person interventions	Concerns about privacy/confidentiality
	Remote delivery of group intervention	Can facilitate collaboration among professionals (eg, cancer specialist and general practitioner)	Concerns about quality/limited information compared with face-to-face interaction
	Online counseling	Allows patients to connect with one another even if geographically widespread May replace or supplement in-person support	Equipment and informational technology requirements Legal concerns Concerns about reimbursement for services Participants may require technical support
Digital storytelling	Video narratives	Provides a platform for education and communication	Limited research on benefits
	Digital scrapbooks	Allows patient creativity Patient centered	Concerns about privacy/confidentiality May be difficult to disseminate Requires production time/costs
Video gaming	Active video games for exercise or physical activity	Appealing or fun to AYAs	Availability of technology
	Games related to memory or cognitive rehabilitation	May be used to reinforce health behaviors or simulate alternative consequences in safe environment Games can adapt level of difficulty on the basis of user response	Development requires technical expertise Educational games difficult to compete with video game industry
	Virtual reality	Headset to play distracting game during medical procedure	Appealing or fun to AYAs Allows simulation of physical environments

Abbreviation: apps, applications; AYA, adolescent and young adult.

providers or to primary care providers); reproductive health and family planning; and promoting the social, economic, and employment outcomes of AYA patients with cancer.¹⁰ Despite the distinct psychological, developmental, and resource needs for this group, few studies have targeted AYA cancer survivors exclusively (instead of grouping them with a broader age range of adult or pediatric survivors).

Characteristic of early intervention work, the studies reviewed primarily used single-arm and feasibility designs. The majority of RCTs conducted thus far tested Internet interventions, which were one of the earlier digital health modalities established. Although RCTs are the traditional gold standard in research, the relatively slow nature of these designs poses problems with outdated and changing technology by the end of the trial.⁷⁵ Other rigorous research designs have been recommended to optimize technology-based interventions, including single-case or n-of-1 designs,

factorial designs, and sequential multiple assignment randomized trials (for review, see Dallery et al⁷⁵).

Engaging AYA cancer survivors is challenging^{18,35,76}; thus, future digital health interventions should consider methods for enhancing user engagement, which can be assessed subjectively (eg, using surveys or interviews with participants) and objectively (eg, frequency and duration of logins, proportion of intervention material viewed). There are insufficient data from studies of AYA cancer survivors to draw conclusions about user engagement. However, results of studies from other populations suggest that user engagement is positively associated with the efficacy of digital interventions.⁷⁷ A variety of approaches have been found to enhance user engagement, including gamification, use of prompts, and tailoring of content.⁷⁸⁻⁸⁰

In conclusion, the research to date is promising in that many digital health interventions

are feasible and acceptable to AYA survivors. However, more work is needed to evaluate the effectiveness of such interventions in changing behaviors and improving health outcomes. There are many ongoing trials of digital health interventions for this group, particularly in mHealth and multicomponent Internet interventions. We recommend involving AYAs early in the development and usability testing of digital health interventions to gain valuable feedback in creating a feasible intervention.³⁷ We recommend the use of a staged framework to design and evaluate a new intervention, focusing on understanding user and design needs,⁸¹ to help researchers decide whether and how to develop digital health solutions for AYA survivors. Although technology poses challenges in terms of the rapidly

changing landscape of technical advances (in contrast to the slower speed of academic research) and the initial and ongoing expense of maintaining technology, there are numerous advantages that make it particularly powerful for AYA survivors. As technology is increasingly included in or becoming the primary modality of behavioral interventions, we recommend a team science approach to designing and implementing these interventions, including (but not limited to) behavioral scientists, computer scientists/human-computer interaction specialists, biostatisticians experienced in big data analysis, and mHealth/social media experts.

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