Technology Use for Adolescent Health and Wellness

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abstract

As avid users of technology, adolescents are a key demographic to engage when designing and developing technology applications for health. There are multiple opportunities for improving adolescent health, from promoting preventive behaviors to providing guidance for adolescents with chronic illness in supporting treatment adherence and transition to adult health care systems. This article will provide a brief overview of current technologies and then highlight new technologies being used specifically for adolescent health, such as artificial intelligence, virtual and augmented reality, and machine learning. Because there is paucity of evidence in this field, we will make recommendations for future research.

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TECHNOLOGY OPPORTUNITIES FOR ADOLESCENT HEALTH

The speed at which new technologies have developed has changed the context of adolescent health and development. As opposed to computers, almost all adolescents (95%) have access to a smartphone, and this does not differ by sex, race, ethnicity, or income.[1] Almost half of teenagers say they are online almost constantly.[1] Adolescents today can be defined as "digital natives," meaning they cannot remember a time when technology was not all around them, and therefore, they are more adept at using it. Although risks associated with technology use are being investigated, unlike what is reported in popular media,[2] these associations (for example, between social media use and mental health outcomes) are more nuanced and related to different factors. For example, these associations are dependent on contextual factors,[3] the type of measurements used,[4] and the manner in which the technology is used[5,6] and have mostly been cross-sectional[4] and shown differing results.[7–9] Therefore, there is an inherent complexity to the nature between technology use and adolescent health, especially due to its ubiquity, and learning how to leverage and moderate technology use as opposed to restricting it is likely the best solution moving forward.[10]

Adolescents are actively engaged in using technology, especially social media, and feel that it is mostly a positive experience for them.[11] Capitalizing on this adolescent engagement, technology is widely thought to be a promising vehicle with which to build interventions that can also improve their health outcomes. Although adolescents value technology, they prefer using these tools as a way to enhance, not replace, the interaction and support they receive from their pediatricians.[12] Therefore, it is important to understand specifically how to integrate technology in the delivery of adolescent health care. The major health concerns during adolescence involve navigating a successful transition to adulthood, not only taking on the management of their health care needs (especially if they have chronic medical and mental health conditions)[13] but also establishing healthy behaviors while mitigating risks. These behaviors include driving, substance use, and sexual risk behaviors within the context of an individual's peer, family, school, neighborhood, and sociocultural-political environment, which may or may not be supportive. These challenges to adolescent health occur at an opportune time of rapid brain development, during which adolescents develop their cognitive control but are less likely to use it to inhibit decisions that lead to positive reward, especially in the context of peers.[14] As adolescents desire to become independent and differentiate from their parents, their parents may have less oversight of their decision-making process. Adolescents begin to manage whether they will adhere to a medication regimen or engage in a behavior that places risk on their health. As adults, personal support is minimized, and the question becomes whether technology is able to play a role in influencing healthy decision-making as well as increasing resilience and motivating use of healthy interventions at the right time and in the right place.

Several existing technologies offer opportunities for improving adolescent health and providing guidance for the development of future technologies. Observational studies show that sharing health care experiences online through sites like YouTube (the most popular social media site for adolescents[1]) may lead to decreased isolation, support, an exchange of coping strategies, and health care learning from shared experiences.[15,16] Employing these types of online peer components can enhance health interventions, as evidenced by an educational lupus Web site (www.facinglupustogether.com) that showed improved medication adherence in a group that discussed educational modules in a social media group, as opposed to independent journaling.[17] Online peer support for mental health conditions in adolescents has shown varied results depending on the type of disorder.[18] Of note, moderation by clinical experts[19–21] has been identified as a key component to foster comfort and safety in these groups.

Adolescents who develop skills to monitor their symptoms and self-manage their health may experience improved outcomes in disease knowledge and adherence.[22] Specifically, text messaging and mobile phone applications show modest evidence supporting their efficacy at improving adherence among healthy adolescents,[23] as well as those with chronic health conditions,[24] with more positive results around contraception continuation and adolescents with conditions such as attention-deficit/hyperactivity disorder.[25,26] A systematic review of adolescent technology-based interventions for diabetes mellitus showed improved rates of blood glucose monitoring and increases in self-efficacy but little clinical significance, with generally no difference seen in hemoglobin A1c.[27] A meta-analysis found serious games or mental contests with the goal of meeting an objective can be effective at increasing disease knowledge and improving self-management for adolescents who have chronic health conditions.[28] A self-management Web site for adolescents with inflammatory bowel disease in Denmark (https://young.constant-care.com/) prompts users to complete monthly symptom reports and mail in a fecal sample as well as complete bloodwork at a local laboratory.[29] These data are then interpreted and scored for symptom severity; results are sent to the patient with guidance and recommendations on whether to contact the hospital for further testing, evaluation, and/or treatment. Using this system resulted in less frequent outpatient visits and fewer disease-related school absences without any differences in disease severity.[29] Mobile directly observed therapy consists of using a mobile device to send videos of medication administration to a physician and has been shown to improve inhaler technique in asthma[30] and hydroxyurea adherence in sickle cell disease.[31] A mobile health intervention also improved inhaler adherence for adolescents using a pharmacist chat function.[32]

Behavior change interventions that require multiple strategies in an ongoing manner are amenable to the incorporation of technology components, which may ease acceptability and feasibility as opposed to in-person sessions and paperwork. These types of behavior change interventions show varying results. Several interventions addressing diet and physical activity as they relate to obesity and sedentary behavior show behavior change occurring in the context of education, goal setting, self-monitoring, and parental involvement[33] as well as increases in physical activity (including when wearable devices are used)[34] but have not shown differences in BMI.[35] An intervention employing exergaming (ie, exercise with a video game component) did show a decrease in BMI as well as other cardiovascular health indicators.[36] On the other hand, technologies have been developed to improve driver safety, including in-vehicle technologies that are more effective when they include parental involvement, because safe-driving applications may be less likely to be used without an incentive.[37] Promising technologies have also evolved in sexual health behavior change. Shafii et al[38] describe the implementation of an electronic-KIOSK Intervention for Safer Sex, an interactive computer-based intervention that uses a physician avatar and instructive video modules to provide personalized sexual health feedback; this intervention has shown nonsignificant reductions in all areas of adolescent sexual health risk, including unprotected sexual intercourse, sexually transmitted infections, and unwanted pregnancy.

With regard to substance use interventions, different methods have greater uptake; a health game was used more frequently than an informational Web site to result in improvements in tobacco-related health literacy.[39] A sex-specific, Web-basedintervention for drug use prevention showed long-termprevention of cigarette and electronic cigarette use.[40] In a marijuana use intervention, text messages directed at counseling regarding an adolescent's peer network (or unhealthy marijuana-using friends) helped youth meet goals of better managing their marijuana use.[41]

Combined, the existing research highlights the importance of including online social components while considering how to involve parents, incorporating serious gaming, and using technology to support self-management for chronic conditions to facilitate adolescents' healthy transition into adulthood. In the rest of this article, we will provide an overview of how new technologies are being used to support adolescent health, offering examples from various disease processes and populations as well as a summary with recommendations for future directions.

New Adolescent Health Technologies and Current Research

In this section, we will provide an overview of several new technologies that are now starting to be applied in medical settings. We will explore the ways in which these technologies are beginning to be used in efforts to optimize health outcomes for adolescent populations as well as their potential for future use (Table 1).

Artificial Intelligence

Artificial intelligence (AI) is being used in decision support and hospital monitoring, medical imaging and biomedical diagnostics (such as radiology and dermatology),[53] precision medicine and drug discovery, improving patient education materials,[54] digital medicine and wearable technology, and robot technology and virtual assistants.[55] AI has applicability and utility across the health care spectrum, from diagnosis, treatment, care coordination, and appointment scheduling to informing health policy and management decisions. Although AI is not new, the current era of big data, extensive patient registries in and out of electronic health records, ubiquitous use of smartphones, wearable devices, the Internet of things, enhanced computational power, and cloud computing allow for capabilities never seen before.[55]

The evidence for AI, specifically in diagnosis and treatment in pediatrics and adolescent medicine, is in the beginning stages. In radiology, computer-aided systems can assist with image interpretation, such as predicting bone age.[56] A pediatric registry of cervical spine injury was used to train a computer algorithm that predicted injury with a sensitivity of 93.3% and specificity of 82.3%, which is comparable to existing clinical decision rules.[57] A deep learning model used in critical care was able to predict mortality in critically ill children with a receiver

TABLE 1 Definition of New Technologies Being Used for Health

Term	Definition	Real-Life Example	Health Care Example
AI	An area of computer science in which computers are programmed to work and react like humans[42]	Smart assistants that use speech recognition, tailoring social media experiences, and new movie and/or television suggestions presented to you by a video-streaming service[43]	Different ML methods were used to develop an algorithm that would use physiomarkers to predict severe sepsis in critically ill children as early as 8 h before[44]
VR	Computers generate environments that are designed to feel and look real; devices track a user's motions to change the environment according to the user's actions[45]	Video game companies offer VR gaming experiences that are immersive	A VR game helped distract children with hematologic or oncological problems while getting venipuncture and resulted in decreased pain[46]
AR	Computers are used to generate scenes and images in the real world, displaying virtual projections in the real environment in a unified way[47]	Pokemon Go game; furniture retailer will allow users to visualize what furniture would look like in one's home	PediTape is a mobile application that estimates the wt of a child (who may not be able to be moved because of being critically ill) using a virtual measuring tape[48]
Passive sensing	Capturing data about a person without requiring their direct input (from smartphones, these data can include multiple sensors to note data such as speech characteristics, location, and activity, and physical sensors can also be embedded in the environment)[49]	Car navigation that uses Global Positioning System; a light sensor captures data on how much light is entering the device and adjusts the screen brightness in response to this input[49]	A sensor-based system was able to accurately predict blood glucose[50]
ML	A method in which computers use existing data to train or detect patterns and trends to improve decisions for future situations; it is an AI discipline[51]	Social media news feeds change on the basis of how a user uses social media; for example, if the user interacts with a friend, more content from that friend is displayed on their news feed	ML may be able to use computerized screening software to predict future problematic alcohol use in adolescents[52]

operating characteristic curve between 0.89 and 0.97.[58] In cystic fibrosis, AI was capable of predicting the most effective types of physiotherapy to improve overall health state.[59] Approaches to using AI to automatically detect seizure activity from computer analysis of EEGs are resulting in high sensitivity (93%) and specificity (94%).[60] On the basis of a sampling from 3 different ethnic groups, AI has been shown to be able to correctly classify patients with acne on the basis of severity with high accuracy (0.854).[53] AI has the potential to pull in data sources to predict suicidality in adolescents; although Instagram activity and social media language markers did not predict suicidality in adolescent Instagram users,[61] natural language processing using text in electronic health records shows more promise.[62] A supervised algorithm that pulled in diffusion MRI-based structural connectome data were able to predict, with 83% accuracy, depressive symptom reduction in adolescents receiving 3 months of cognitive behavioral therapy.[63]

The existing and potential benefits of AI in pediatrics and adolescent health are vast in nature, including improved efficiency and patient reach through expanding what a limited human workforce can accomplish. Regardless, potential harms include false-positive results (as with any test) and a lack of human empathy in decision-making. Also, in all technology, with big data from multiple sources being shared across multiple platforms, there are concerns about data privacy and security. Future research will need to measure for frequency of data breach as a potential adverse outcome.

Virtual Reality and Augmented Reality

Virtual reality (VR) and augmented reality (AR) have also been studied in multiple venues in health care, including whether VR and/or AR can enhance social, emotional, and daily living skills in children with autism.[64] Some benefits to using VR and/or AR as an intervention or treatment approach include simulating a real-life scenario in a more controlled fashion with therapist support and personalizing scenarios according to the patient's needs.[64] VR and/or AR may also be used to simulate environments that may elicit behaviors that are needed to confirm a diagnosis of attention-deficit/hyperactivity disorder[65] or anorexia nervosa[66] and assist in motor rehabilitation in children with cerebral palsy.[67,68] Furthermore, VR and/or AR have been used to distract adolescents from pain during wound care (especially patients with burns),[69–72] overcome phobias,[73] encourage physical activity,[74] screen for sports-related concussion,[75] and improve knowledge gain among healthy adolescents[76] as well as those with diabetes[77] or Down syndrome.[78] To date, evidence for the efficacy of VR and/or AR as technology-based interventions for adolescents remains unclear, although overall feasibility, acceptability, and preliminary efficacy data are encouraging.[67,68,79] The use of VR and/or AR does not come without risks or potential harm, such as eyestrain, nausea, sickness, dizziness, real-world injuries, loss of confidentiality, game transfer phenomena, digital fatigue with too much screen time, and possible psychological consequences, including VR and/or AR addiction.[80,81] Use of VR and/or AR may be cost-prohibitive for many patients, and current payment structures for such technologies are not yet delineated. Future research on effectiveness should also include cost-effectiveness analyses.[82]

Machine Learning and Passive Sensing

Machine learning (ML) is a discipline of AI that has been used in the area of passive sensing. Passive sensing is a method that is being increasingly used and often involves using data that are being automatically captured on smartphones and wearable devices to predict health status. Researchers have used multiple ML techniques[83] to develop algorithms that translate passive data (eg, accelerometer or how fast someone is moving; light sensor or detecting ambient light both indoors and outdoors; communication or tracking frequency of calls and messages) by means of real-time monitoring and computational analysis into data that may provide insight into a person's inner state. For example, heart rate variability captured by wristbands has been found to accurately predict pleasure, happiness, fear, and anger through use of artificial neural network–based classification with a range of 82% to 93.4%.[84] Furthermore, these interventions have been tailored for delivery at more pertinent moments (also called just-in-time adaptive interventions). For example, an intervention for homeless adolescent mothers involves a wearable wristband to measure electrodermal activity as a marker of stress and to time the notification of stress signals to prompt the adolescent to use emotion regulation support.[85] A socialization intervention for children with autism spectrum disorder, which used the wearable Google Glass with an AI-driven component that uses ML in real time to indicate an individual's emotion, showed improved socialization.[86]

Investigation is currently underway to determine if passive sensing can predict depressive symptoms and suicidal thoughts and behaviors in adolescents.[87] ML is being used to understand whether emotional dysregulation can be described by automated facial expression coding,[88] whether pain can be predicted by objective measures in sickle cell disease,[89] and whether adolescent suicidal behavior can be predicted from natural language processing of data from the electronic health record.[90] Electronic momentary assessment involves capturing self-reported data in the moment in an effort to decrease biases, which may be related to memory, and has been more feasible to employ with the ubiquity of smartphones. Electronic momentary assessment has been used widely in observational research, but more recent studies explore whether ecological momentary interventions can be delivered at the time when a person is symptomatic. Studies show that these types of interventions may reduce anxiety[91] and be effective in reducing desire among adolescents and young adults to use marijuana.[92]

The potential benefits of using ML and passive sensing in adolescents includes opportunities to use real-time monitoring to enhance self-management through the use of just-in-time interventions. Although smartphone use is ubiquitous, not all adolescents will have adequate data plans; therefore, interventions relying on smartphones and expensive wearables may be limited. Parental monitoring may, at times, obscure an adolescent's access to such devices. Future research should explore whether such interventions improve long-term clinical effects.

Summary and Recommendations

There has been growing evidence to support the potential benefits of using personal technologies to optimize health outcomes in adolescents, although their cost-effectiveness remains unclear.[93,94] This is a dynamic field that will continue to develop over time at a fast pace. There have been some interventions used daily (eg, AI in electronic health records) that pediatricians need to be aware of and anticipate where the field may be moving to stay up to date with these evolving technologies and provide feedback and input as the end users. As technology advances, payment structures and policy changes need to be responsive and adaptable to allow for the wide dissemination and implementation of different technology-based interventions that have been shown to be efficacious in improving care delivery and health outcomes with high acceptability by adolescents. Taking a user-centered iterative approach and involving adolescents and their parents in all stages of developing these interventions is key to optimizing their uptake as well as their potential efficacy and cost-effectiveness.[95] Accessibility of technology should be offered at low or no cost for all adolescents with potentially subsidized options, especially for data and Internet access. These technologies have the potential to empower adolescents in managing their health needs as they transition to adulthood. It is also important to be mindful of potential unintended harmful consequences of using these technologies, highlighting the need for ongoing monitoring. Potential harmful effects include, but are not limited to, data ownership, loss of confidentiality, and data privacy (eg, some adolescents have perceptions that their data are private online). The most promising areas include using data that are already being captured or are easy to capture to provide insight into diagnosis, monitoring, and intervention as well as to expand the reach of innovative technologies to underserved adolescents, which include racial and ethnic minorities and rural populations. Future research priorities should include cost-effectiveness analyses, validating whether technologies that are found to be effective in adult populations show the same applicability and acceptability in adolescents, and monitoring the degree to which access to new technologies further exacerbates existing health disparities for underserved adolescents or expands reach to those with limited access. Pediatricians should neither shun new technologies nor accept them wholeheartedly without review but always advocate for and consider the best interests of adolescents by carefully balancing the risks and benefits of using and recommending these technologies to optimize health outcomes, including physical, emotional, and social well-being, in this vulnerable population.

ABBREVIATIONS

AI: artificial intelligence
AR: augmented reality
ML: machine learning
VR: virtual reality

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