2024

Longitudinal Effects Of Adolescent Digital Media Use On Sleep, Cardiometabolic Health, And Mental Health

Caroline Watson
University of Alabama at Birmingham

LONGITUDINAL EFFECTS OF ADOLESCENT DIGITAL MEDIA USE ON SLEEP, CARDIOMETABOLIC HEALTH, AND MENTAL HEALTH

by

CAROLINE WATSON

AARON FOBIAN, COMMITTEE CHAIR
CHRISTOPHER HENRICH
DUSTIN LONG

A THESIS

Submitted to the graduate faculty of The University of Alabama at Birmingham,
in partial fulfillment of the requirements for the degree of
Master of Arts

BIRMINGHAM, ALABAMA

2023

LONGITUDINAL EFFECTS OF ADOLESCENT DIGITAL MEDIA USE ON SLEEP, CARDIOMETABOLIC HEALTH, AND MENTAL HEALTH

CAROLINE WATSON

MEDICAL CLINICAL PSYCHOLOGY

ABSTRACT

Background

Digital media use has become an integral part of society and may contribute to adverse physical and mental health outcomes, particularly among adolescents. However, few studies have examined the longitudinal effects of adolescent digital media use across the transition from adolescence to young adulthood. As adolescents present as a high-risk group for the adverse effects of digital media use on mental and physical health, the present studies identified digital media use trajectories from adolescence into young adulthood and examined these trajectories as predictors of sleep duration, cardiometabolic health, and mental health outcomes in young adulthood.

Methods

Participants (Mage=15.53; 56.86% female, 66.89% White) from The National Longitudinal Study of Adolescent and Adult Health database who provided digital media use data in Waves I-IV were included. A group-based modeling approach was used to identify trajectories of digital media use across Waves I-IV. General linear models assessed the relationships between trajectory group and sleep duration, body-mass-index, waist-to-height ratio, cholesterol, triglycerides, C-reactive protein, blood pressure, depressive symptomology, working memory, and short-term memory. Logistic regression

models assessed the relationship between trajectory group and type 2 diabetes, anxiety, and depression diagnoses, suicidal ideation, and suicide attempts. Logistic regression models also assessed the relationship between parental support, family connectedness, face-to-face interactions with peers, and self-esteem as predictors of digital media use trajectory group.

Results

Four digital media use trajectories emerged: Group 1 “increase” (9.97%), Group 2 “low” (73.36%), Group 3 “decrease” (13.94%), and Group 4 “high” (2.73%). Individuals with low patterns of digital media use (Group 2) had 1) lower body-mass-index as compared with individuals in Groups 1, 3, and 4, 2) lower waist-to-height ratio as compared with individuals in Groups 1 and 4, 3) higher high-density lipoprotein as compared with individuals in Group 1, 4) increased short-term memory as compared with individuals in Group 4, and 5) decreased odds of suicide attempts in the past 12 months at Wave IV as compared with individuals in Groups 3 and 4.

Conclusions

Longitudinal patterns of low digital media use had a significant protective effect on physical and mental health outcomes in young adulthood, including lower body-mass-index and waist-to-height ratio, higher high-density lipoprotein and short-term memory, and decreased odds of suicide attempts in the past 12 months at Wave IV.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table *Page*

LIST OF FIGURES

Figure *Page*

INTRODUCTION

Digital media use has grown substantially in recent years with an estimated 4.88 billion users worldwide.[1,2] This number is alarming considering increased evidence of the adverse effects of digital media use on both physical and mental health. With regard for physical health, previous literature suggests that increased digital media use may contribute to risk for overweight or obesity,[3] chronic inflammation,[4] high blood pressure, dyslipidemia,[4-6] and insufficient sleep,[7-9] all of which contribute to increased risk for heart disease, certain types of cancer, type II diabetes, and premature death.[10] With regard for mental health, increased digital media use has been associated with increased rates of anxiety and depression,[11,12] suicidal ideation, suicide attempts,[13-17] and decreased cognitive ability.[18] While previous research has identified the negative effects of digital media use on physical and mental health via cross-sectional studies, few studies have examined the longitudinal effects of digital media use across the transition from adolescence to young adulthood. This gap in literature is critical, as digital media use continues to grow an estimated 9% year-on-year, particularly among adolescents.[1,2]

To clarify these relationships, the present studies sought to identify digital media use trajectories from adolescence into young adulthood using The National Longitudinal Study of Adolescent and Adult Health (ADD Health) database and examine these trajectories as predictors of sleep duration, cardiometabolic health, and

mental health in young adulthood. The present study also sought to assess how social, emotional, and cognitive factors in adolescence predict digital media use from adolescence into young adulthood. We propose this to be a two-manuscript thesis. The first manuscript, “Longitudinal effects of adolescent digital media use on sleep duration and cardiometabolic health,” aimed to assess the longitudinal effects of adolescent digital media use on sleep and cardiometabolic health outcomes in young adulthood, including body-mass-index, waist-to-height ratio, low-density lipoprotein, high-density lipoprotein, triglycerides, C-reactive protein, and blood pressure. The second manuscript, “Longitudinal effects of adolescent digital media use on mental health,” aimed to assess the longitudinal effects of adolescent digital media use on mental health outcomes in young adulthood, including depressive symptomology, working memory, short-term memory, anxiety and depression diagnoses, suicidal ideation, and suicide attempts. The second manuscript also aimed to identify factors in adolescence that may contribute to digital media use trajectory group, including parental support, family connectedness, face-to-face interactions with peers, and self-esteem.

LONGITUDINAL EFFECTS OF ADOLESCENT DIGITAL MEDIA USE ON SLEEP AND CARDIOMETABOLIC HEALTH

CAROLINE WATSON, AARON FOBIAN, CHRISTOPHER HENRICH, DUSTIN LONG

In preparation for *Journal of Adolescent Health*

Format adapted for thesis

LONGITUDINAL EFFECTS OF ADOLESCENT DIGITAL MEDIA USE ON SLEEP DURATION AND CARDIOMETABOLIC HEALTH

In 2019, American adolescents ages 13-18 spent an average of 7.5 hours per day engaged with digital media.[1] Forty-five percent of adolescents reported using digital media "almost constantly," and 44% reported using digital media "several times a day".[2] In comparison, children ages 8-12 spent 3 hours per day on digital media, and adults 18 years and older spent 6.5 hours per day on digital media.[1,3] While there are many benefits to increased digital media use among adolescents (e.g., increased communication with peers, improved information processing skills, greater creativity), there is also evidence to suggest that digital media use may contribute to adverse physical health outcomes.[4]

Increased digital media use has been found to contribute to risk for overweight or obesity (OWOB).[5] The 2012 National Health and Nutrition Examination Survey found that adolescents who exceeded 2 hours of recreational screen time per day were 1.8 times more likely to have OWOB.[6] A more recent study found a positive relationship between digital media use and body mass index (BMI), and digital media use had the second highest impact on BMI following socio-economic status.[7] Research on the effects of interventions aimed at reducing screen time to prevent OWOB support these claims. A meta-analysis of eight trials found that all interventions targeting screen time had a significant effect on BMI reduction.[8] Digital media use is associated with poor dietary choices, increased food intake while viewing, decreased physical activity, and less energy

expenditure.[9-11] These factors are also associated with increased risk for OWOB, which may underlie the relationship between digital media use and OWOB.[5,9-11]

The relationship between digital media use and OWOB is alarming given the importance of maintaining a healthy weight during adolescence. As compared to adolescents with healthy weight, adolescents with OWOB are between 2.4 to 7.1 times more likely to have high cholesterol and triglycerides.[12] Further, adolescents with OWOB are at increased risk for chronic inflammation, high blood pressure, heart disease, certain types of cancer, type II diabetes, and premature death.[13] A recent study of 40,000 children and adolescents ages 3 to 17.9 found that adolescents with OWOB had a three times higher risk of death in early adulthood compared to adolescents with normal weight.[14] However, research on potential causal mechanisms underlying the relationship between digital media use and OWOB has been inconclusive.

A few cross-sectional studies have demonstrated correlations between digital media use and higher levels of C-reactive protein (CRP). C-reactive protein—a biomarker of chronic inflammation found in the blood—is associated with increased risk for OWOB, atherosclerosis, heart attack, hypertension, and blood clots.[15-17] Thus, digital media use may contribute to higher CRP by increasing risk for OWOB, which may contribute to increased CRP.[18,19]

Digital media use has also been correlated with low high-density lipoprotein (HDL) levels, high low-density lipoprotein (LDL), high blood pressure, and tryglicerides.[20-22] High-density lipoprotein, or “good” cholesterol, removes excess cholesterol from the blood stream, and lower levels are associated with increased risk for coronary heart and artery disease.[23] Low-density lipoprotein, or “bad” cholesterol,

collects in blood vessel walls, and if too high, can result in high blood pressure, heart attack, stroke, and atherosclerosis.[23] Digital media use may contribute to low HDL and high LDL via decreased physical activity, which is a well-established risk factor for low HDL and high LDL.[9,24] Previous literature supports these claims, including one study which did not find a relationship between increased digital media use and cholesterol independent of physical activity.[25] Higher levels of physical activity are critical to cardiometabolic health, and digital media use contributes to physical inactivity among adolescents.[9,25] Similarly, digital media use may contribute to higher blood pressure which is also associated with physical inactivity.[26]

Research has yet to assess the effects of overall digital media use on type 2 diabetes. However, a recent longitudinal study found that watching television for more than 3 hours per day in childhood was associated with a 34% increased risk for type 2 diabetes in adulthood.[27] Digital media use may increase risk for type 2 diabetes given that high blood pressure, low HDL, high LDL, physical inactivity, and OWOB, are associated with increased digital media use and also risk factors for type 2 diabetes.[28]

Increased digital media use may also contribute to insufficient sleep among adolescents.[29] A recent literature review found consistent evidence relating increased digital media use and shorter sleep duration.[30] Another literature review reported that 90% of studies found associations between digital media use and delayed bedtime and/or decreased total sleep time.[31] Several other studies have associated increased screen time with later sleep onset, increased daytime sleepiness, and reduced sleep quality.[30,32,33] Preliminary research comparing the effects of different types of digital media use (i.e.,

laptop, video games, smartphone, etc.) suggest that total screen time, regardless of digital media type, is associated with delayed bedtime and shorter total sleep duration.[34]

The relationship between digital media use and sleep duration may also contribute to adverse cardiometabolic health outcomes. Cross-sectional and longitudinal studies among adolescents consistently report that insufficient sleep duration is associated with increased BMI and risk for OWOB.[35] A meta-analysis found children and adolescents with shorter sleep durations are at a 58% greater risk for OWOB, and each additional hour of sleep is associated with a 9% decreased risk for OWOB.[36] Accordingly, the American Academy of Sleep Medicine recommends that adolescents sleep 8-10 hours per night.[37] However, 70% of adolescents report insufficient sleep (<8 hours per night).[38] Pubertal changes may contribute to insufficient sleep, as adolescents' circadian clock is delayed by as much as 2 hours beginning at the onset of puberty.[39] However, adolescents are still required to wake up early to attend school, work, and extracurricular activities.[39] Social factors may also contribute to insufficient sleep, as adolescents are less likely to have enforced bedtimes and more likely to have time-consuming academic demands, part time jobs, and extracurricular and social activities.[40]

While many short-term and cross-sectional studies have assessed the relationship between digital media use and sleep and cardiometabolic health, the causal mechanisms underlying these relationships have not been confirmed. As increased digital media use is associated with shorter sleep duration and poorer cardiometabolic health, longitudinal studies that will clarify the casual mechanisms relating digital media use to sleep and cardiometabolic health are needed.[40,41] Further, research focused on adolescent health is critical given digital media use is most prevalent among adolescents.[1] Thus, the present

study aims to assess trajectories of digital media use across the adolescent transition to young adulthood and examine how trajectories predict sleep and cardiometabolic health outcomes in young adulthood including total sleep duration, BMI, waist-to-height-ratio (WHtR), HDL, LDL, type 2 diabetes, triglycerides, CRP, and blood pressure.

Methods

The present study utilizes data from the National Longitudinal Study of Adolescent to Adult Health (Add Health) database. The Add Health database is a nationally representative dataset that began data collection in 1994 via in-home and in-school questionnaires for parents and students across the United States.[42] Wave I was conducted from 1994-1995 and included 20,745 respondents ages 11-21. Wave II was conducted in 1996 and included 14,783 respondents ages 11-23. Wave III was conducted from 2001-2002 and included 15,197 respondents ages 18-28. Wave IV was conducted from 2008-2009 and included 15,701 respondents ages 24-34. Response rates at each wave ranged from 77.4-88.6%. The present study focuses on digital media use questions asked in Waves I-IV as predictors of sleep duration and cardiometabolic outcomes in Wave IV.

Participants

Participants were recruited from 80 participating high schools across the United States. The present study focuses on the sample of participants who responded to digital media use questions asked in Waves I-IV. Considering the goal of following participants from adolescence to young adulthood, participants over the age of 17 at Wave I were

excluded from analyses. Participants who reported current pregnancy status at Wave IV were also excluded from analyses.

Measures

Demographics. At Wave I, participants self-reported sex, date of birth, and race, and parents' self-reported total household income before taxes.

Digital Media Use. In Waves I-III, participants were asked, "How many hours a week do you watch television?", "How many hours a week do you watch videos?", and "How many hours a week do you play video or computer games?" At Wave IV, participants were asked "In the past 7 days, how many hours did you watch television or videos, including VHS, DVDs, or music videos?", "How many hours a week do you play video or computer games?", and "In the past 7 days, how many hours did you spend using the Internet, for example, accessing your email or using the web?" Responses were recorded in total hours and added to construct a single measure of digital media use for each participant at each wave. Participants who did not provide data on digital media use questions asked in Waves I-IV were excluded from final analyses.

Body Mass Index. Given adolescent BMI is age- and sex-specific, BMI percentile was utilized at Wave I (i.e., when all participants were adolescents), and BMI was utilized at Wave IV (i.e., when all participants were adults).[43] Accordingly, height and weight were self-reported by participants at Wave I and used to calculate BMI percentile using the Center for Disease Control and Prevention's Children's BMI Group

Calculator.[44] At Wave IV, height and weight were objectively measured and used to calculate BMI using BMI=kg/m^2.

Waist-to-Height-Ratio. At Wave IV, participants' waist and height circumference were determined using a fiberglass measuring tape and steel measuring tape, respectively. Waist-to-height ratio, which is thought to be a better indicator of cardiometabolic health than BMI, was calculated using the formula WHtR=waist circumference/height.[45,46]

Pregnancy Status. At Wave IV, participants self-reported pregnancy status by responding "yes" or "no" to the question "Are you pregnant now?" Participants who responded "yes" were excluded from final analyses.

Rurality. At Waves I and IV, interviewers were asked, "How would you describe the immediate area or street (one block, both sides) where the respondent lives?" At Wave I, response options included "rural," "suburban," "urban (residential only)," "3 or more commercial properties (mostly retail)," "3 or more commercial properties (mostly wholesale or industrial)," or "other." At Wave IV, response options included "rural farm," "rural town," "suburban," "urban (residential only)," "3 or more commercial properties (mostly retail)," "3 or more commercial properties (mostly wholesale or industrial)," and "other."

Physical Health. At Wave IV, participants were asked, "In general, how is your health?" Responses were recorded using a 5-point Likert scale with response labels

"excellent," "very good," "good," "fair," and "poor." Responses marked as "excellent," "very good," "good," and "fair" were classified as good physical health, and responses marked as "poor" were not classified as good physical health.

Sleep Duration. At Wave I, sleep duration was determined using the question, "How many hours of sleep do you usually get?" Participants responded in total number of hours. At Wave IV, sleep duration was determined using self-reported bed and wake times.

Biological Data. At Wave IV, participants provided blood samples that were used to determine low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), and triglycerides. To obtain blood samples, investigators pricked participants' middle or ring fingers and collected seven drops of blood using capillary whole blood collection cards. Blood samples were also used to determine individual levels of CRP. In accordance with recommendations from the American Heart Associations, CRP was categorized based on low risk (<1 mg/L), moderate risk (1-3 mg/L), and high risk (>3 mg/L) for of future heart attack or stroke. Data on 1) subclinical sources of infection, 2) subclinical sources of inflammation, and 3) medications that may influence CRP levels were collected to be used as a control variable in the final assessment of CRP outcomes. Variables included cold or flu-like symptoms, fever, night sweats, nausea, vomiting or diarrhea, blood in stool, feces, or urine, gum disease/tooth loss, active infection, acute illness, surgery, active seasonal allergies, and the use of anti-inflammatory medications containing aspirin (e.g., Advil, Aleve, ibuprofen). Blood

pressure was calculated using an average of resting systolic and diastolic blood pressures (mmHG) taken three times for each participant.

Type 2 Diabetes. At Wave IV, participants were asked, "Have you ever been diagnosed with diabetes?" Participants responded "yes" or "no".

Data Analyses

Individual trajectories of digital media use across Waves I-IV were identified using a group-based modeling technique (PROC TRAJ). Rather than accounting for individual variability about the mean population trend, the present study assessed how subcategories of digital media users (e.g., high users, low users, etc.) were affected by digital media use trends.[47,48] Accordingly, distinct participant groups were identified based on similar digital media use trajectories using maximum likelihood estimates. Forward-selection stepwise procedures, including linear, quadratic, and cubic growth curve parameters, were used to determine the best-fit model and number of individual trajectory groups.[47,48] Prior to these analyses, an outlier analysis was used to determine the appropriate cutoff for digital media use hours per week. Given the data was negatively skewed, a cutoff of approximately 3 SD above the mean (i.e., 3 SD above the mean rounded to the nearest whole number) was determined best fit. Accordingly, participants who reported digital media use over 84 hours per week were considered missing. This affected 820 participants (12.11%) of the original sample. No other issues were found regarding normality and homogeneity of variance. Participants with missing digital media use data in Waves I-IV were also excluded from trajectory analyses.

Digital media use trajectory groups were used as predictors of Wave IV cardiometabolic health outcomes (i.e., BMI, WHtR, LDL, HDL, triglycerides, CRP, and blood pressure) using seven separate general linear models (PROC SURVEYREG). Data were checked for normality and homogeneity of variance prior to these analyses. A logistic regression (PROC SURVEYLOGISTIC) was used to assess the predictive relationship between media use trajectory group and type II diabetes diagnosis in Wave IV. Prior to this analysis, data was checked for normality and multicollinearity. Covariates were predetermined based on past literature (Table 1).

Media use trajectory groups were also used as predictors of Wave IV sleep duration. A general linear model (PROC SURVEYREG) was used to assess the predictive relationship between media use trajectory group and total sleep duration in Wave IV. Covariates were predetermined based on past literature (Table 1).

To further assess the effects of digital media use on cardiometabolic health and sleep duration, a cross-sectional analysis of outcomes at Wave IV was conducted to compare the effects of digital media use at different time points across the transition from adolescence into young adulthood.

All analyses were run using Statistical Analysis Software (SAS). Survey weights were used to ensure that data was nationally representative of U.S. Census Bureau population estimates.[49] All missing data were handled using a pattern-mixture model approach (MNAR) using the MISSING and NOMCAR functions.

Table 1. Predetermined Covariates for Cardiometabolic Health Outcomes

Measure	Covariates
Digital Media Use	• Sex • Race • Age (Wave IV) • Income (Wave I) • Rurality (Waves I & IV) • Physical health (Wave IV)
BMI	• Sleep duration (Wave IV) • BMI Percentile (Wave I)
Waist to Height Ratio	• Sleep duration (Wave IV)
Sleep Duration	• BMI (Wave IV)
Blood Pressure	• BMI (Wave IV)
Type 2 Diabetes	• BMI (Wave IV)
Triglycerides	• BMI (Wave IV)
C-Reactive Protein	• BMI (Wave IV) • Subclinical sources of infection (Wave IV) • Anti-inflammatory medications (Wave IV)
HDL Cholesterol	• BMI (Wave IV)
LDL Cholesterol	• BMI (Wave IV)

Results

Participants included 6,767 adolescents (M_{age}=15.53, SD=1.42; 56.86% female, 66.89% White) ages 11-17 at Wave I and ages 24-30 at Wave IV (Table 2).

Table 2. Participant Demographics by Trajectory Group

Group	N	Wave I Age	Race			Sex
		Years	% White	% Black	% Other	% Male
Group 1 “Increase”	675	15.58	70.31	16.70	12.99	39.11
Group 2 “Low”	4964	15.51	60.73	24.88	14.39	57.56
Group 3 “Decrease”	943	15.29	52.72	35.15	12.13	61.51
Group 4 “High”	185	15.31	55.36	31.14	13.5	15.31

Note: “% Other” includes Native Americans, Asian or Pacific Islanders, Hispanic individuals, and individuals who selected “other” when reporting race.

Four digital media use trajectory groups emerged (Figure 1). Group 1, “increase”, included 9.97% of participants and exhibited a steady increase in digital media use across waves, increasing from 20.56 hours per week in Wave I to 49 hours per week in Wave IV. Group 2, “low”, included 73.36% of participants. Participants in Group 2 exhibited the lowest digital media use at all time points compared to other trajectory groups. Group

3, “decrease”, included 13.94% of participants and exhibited a steady decrease in digital media use across waves, decreasing from 44.44 hours per week in Wave I to 17.97 hours per week in Wave IV. Group 4, “high”, included 2.73% of participants. Participants in Group 4 exhibited consistently high levels digital media use, averaging 47.30 hours per week across all waves. See Table 3 for digital media use hours per week by trajectory group and wave.

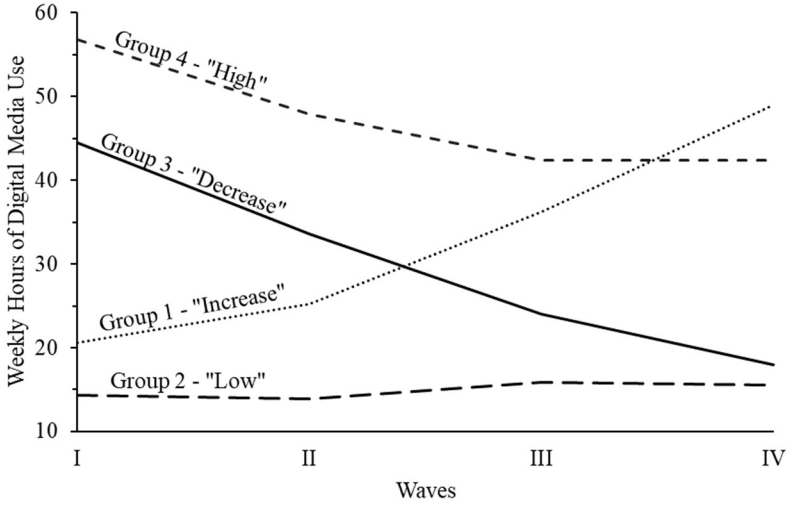

Figure 1. Digital Media Use Trajectories Across Waves I-IV

Table 3. Digital Media Use Hours per Week by Trajectory Group and Wave

Group	**Wave I Hours**	**Wave II Hours**	**Wave III Hours**	**Wave IV Hours**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Group 1 “Increase”	20.56 (11.57)	25.19 (15.04)	36.22 (17.52)	49.00 (16.17)
Group 2 “Low”	14.34 (9.59)	13.84 (10.24)	15.89 (11.08)	15.57 (10.31)
Group 3 “Decrease”	44.44 (13.91)	33.56 (16.19)	24.05 (14.51)	17.97 (10.64)
Group 4 “High”	56.73 (14.45)	47.84 (16.80)	42.38 (16.42)	42.23 (16.68)

Digital media use trajectory group significantly predicted Wave IV BMI such that individuals in Group 2 (M=25.28, SD=4.79) experienced significantly lower BMI at Wave IV than individuals in Group 1 (M=26.65, SD=5.13), Group 3 (M=27.91, SD=4.13), and Group 4 (M=26.65, SD=5.02). A cross-sectional analysis of outcomes at

Wave IV revealed that Wave IV digital media use significantly predicted Wave IV BMI. Specifically, individuals with >30 hours of digital media use per week (i.e., ~4 hours/day) experienced significantly greater BMI compared to individuals with <30 hours of digital media use hours per week. Digital media use trajectory group also significantly predicted Wave IV WHtR. Specifically, individuals in Groups 1 (M=0.59, SD=0.39) and 4 (M=0.59, SD=0.43) experienced significantly greater WHtR at Wave IV compared to individuals in Group 2 (M=0.56, SD=0.15). Wave IV digital media use also significantly predicted Wave IV WHtR such that individuals with >30 hours of digital media use per week experienced increased WHtR compared to individuals with <30 hours of digital media use per week. Finally, Digital media use trajectory group also predicted Wave IV HDL. Individuals in Group 2 (M=5.48, SD=1.86) experienced significantly higher HDL at Wave IV compared to individuals in Group 1 (M=4.89, SD=1.79). Wave IV digital media use did not independently predict Wave IV HDL. Neither digital media use group nor Wave IV digital media use significantly predicted Wave IV LDL, CRP, triglycerides, blood pressure, diabetes diagnosis, or sleep duration. See Tables 4 and 5 for a summary of the analyses and results and follow-up tests for Wave IV cardiometabolic health outcomes, respectively.

Table 4. Summary of Analyses and Results for Cardiometabolic Health Outcomes

Trajectory Group Predicting Wave IV Cardiometabolic Health Outcomes	df	F	*p*
General Linear Models			
Wave IV BMI	3	7.43	0.0001*
Wave IV WHtR	3	4.81	<0.01*
Wave IV LDL	3	1.05	0.37
Wave IV HDL	3	4.43	<0.01*
Wave IV Triglycerides	3	0.88	0.45
Wave IV CRP	3	1.57	0.20
Wave IV Blood Pressure	3	0.27	0.85
Wave IV Sleep Duration	3	0.24	0.87
Logistic Regression Models			
Wave IV Type II Diabetes	3	0.31	0.15
Wave IV Digital Media Use Predicting Wave IV Cardiometabolic Health Outcomes	df	F	*p*
General Linear Models			
Wave IV BMI	3	-2.33	<0.05*
Wave IV WHtR	3	-2.33	<0.05*
Wave IV LDL	2	1.45	0.24
Wave IV HDL	2	1.97	0.14
Wave IV Triglycerides	2	0.31	0.74
Wave IV CRP	2	2.95	0.06
Wave IV Blood Pressure	3	0.27	0.85
Wave IV Sleep Duration	3	1.91	0.15
Logistic Regression Models			
Wave IV Type II Diabetes	3	1.76	0.08

*Denotes p-value of <0.05

Table 5. Follow-up Tests for Wave IV Cardiometabolic Health Outcomes

		Adjusted Mean Difference	SE	*p*
Wave IV BMI Group Comparisons				
Group 2	Group 1	1.37	0.52	<0.01*
Group 2	Group 3	2.63	1.05	<0.05*
Group 2	Group 4	1.37	0.45	<0.01*
Group 3	Group 4	1.26	1.22	0.30
Group 3	Group 1	-1.26	1.24	0.31
Group 4	Group 1	-0.01	0.64	0.99
Wave IV WHtR Group Comparisons				
Group 2	Group 1	0.02	0.01	<0.01*
Group 2	Group 3	0.01	0.01	0.30
Group 2	Group 4	0.02	0.01	<0.01*
Group 3	Group 4	-0.01	0.01	0.82
Group 3	Group 1	0.01	0.01	0.50
Group 4	Group 1	0.01	0.01	0.53
Wave IV HDL Group Comparisons				
Group 2	Group 1	-0.59	0.18	<0.01*
Group 2	Group 3	-0.06	0.27	0.83
Group 2	Group 4	-0.28	0.15	0.06
Group 3	Group 4	0.22	0.30	0.45
Group 3	Group 1	-0.53	0.31	0.09
Group 4	Group 1	-0.31	0.21	0.15

*Denotes p-value of <0.05

Discussion

The present study demonstrates the protective effects of longitudinal patterns of low digital media across the transition from adolescence to young adulthood on cardiometabolic health outcomes in young adulthood, including BMI, WHtR, and HDL.

Adolescents in Group 2 "low" experienced significantly lower BMI at Wave IV as compared with individuals in Group 1 "increase," Group 3 "decrease," and Group 4 "high." These results demonstrate a longitudinal relationship between digital media use in adolescence and BMI in young adulthood,[50,51] which is consistent with prior literature on positive associations between increased digital media use and BMI.[51] Wave IV digital media use also predicted Wave IV BMI such that individuals who engaged in more than 30 hours of digital media use per week at Wave IV experienced increased BMI. As individuals in Groups 1 and 4 experienced more than 30 hours of digital media use per week at Wave IV, these results suggest that current digital media use may have a dominant effect on BMI in young adulthood. As individuals in Group 3 did not experience more than 30 hours of digital media use per week at Wave IV yet still experienced greater Wave IV BMI as compared with individuals in Group 2, these results suggest that the pattern of digital media use exhibited by individuals in Group 3 had a significant effect on BMI in young adulthood. One explanation for these results may be decreased physical activity during early adolescence, as individuals in Group 3 exhibited their highest levels of digital media use at Wave I (44.44 hours per week). Of note, the mean age of participants in Group 3 at Wave I was 15.29 years. Physical activity levels

commonly decline around this age,[52] and low levels of physical activity during adolescence have been found to increase probability of OWOB in young adulthood.[53]

It is important to note that WHtR may be a more reliable anthropometric index for central adiposity than BMI, as a recent meta-analysis revealed WHtR to be superior in predicting obesity and cardiometabolic risk.[54] Accordingly, the present study also assessed the effects of digital media use on WHtR. Adolescents in Group 2 "low" experienced significantly reduced WHtR at Wave IV as compared with individuals in Groups 1 "increase" and 4 "high". Digital media use at Wave IV also predicted Wave IV WHtR such that individuals who experienced more than 30 hours digital media use per week experienced increased WHtR. As individuals in Groups 1 and 4 both experienced more than 30 hours of digital media use per week, these results suggest that digital media use during the same time period may have a dominant effect on WHtR in young adulthood. These findings are supported by previous literature demonstrating an association between greater total body fat and increased digital media use.[8] While estimates of harmful levels of digital media use with regard for risk for weight gain have varied (e.g., 2 hours vs 3 hours vs 6 hours),[5-7] this may be due to variations in measurements of digital media use including differences in measurement type (e.g., self-report vs parent report) and type of digital media use measured (e.g., television vs phone vs computer vs video games). Potential causal mechanisms underlying this relationship include poorer food choices, decreased physical activity, and less energy expenditure.[5,9-11]

Finally, adolescents in Group 2 "low" experienced significantly greater HDL at Wave IV as compared with individuals in Group 1 "increase." As digital media use at

Wave IV did not significantly predict Wave IV HDL, these results suggest that the pattern of digital media use exhibited by individuals in Group 1 had a salient effect on HDL. Notably, individuals in Group 1 "increase" exhibited the greatest increase in digital media use hours per week across Waves III-IV. As previously discussed, physical activity levels commonly decline during adolescence, and this pattern persists throughout young adulthood.[52] Thus, increased digital media use during this time period may be associated with a rapid decrease in physical activity, which is a well-established risk factor for low HDL.[9,25] Previous literature highlighting no relationship between increased digital media use and HDL independent of physical activity support these conclusions.[25] Alternatively, these results may be due to the effects of digital media use on diet.[55] Diet quality commonly declines from adolescence into early adulthood,[56] and increased digital media use is associated with poor diet (i.e., increased junk food intake, decreased fruit and vegetable intake).[55] Thus, increased digital media use across Waves III-IV may further contribute to poor diet which is a risk factor for low HDL.[57]

Notably, neither digital media use trajectory groups nor Wave IV digital media use significantly predicted Wave IV LDL, CRP, triglycerides, blood pressure, diabetes diagnosis, or sleep duration. These findings contrast with previous studies that have reported associations with increased digital media use among adolescents and young adults.[9,25,26,31,33] However, previous studies consistently highlight underlying factors which may be more salient in predicting these health outcomes. For example, higher BMI or WHtR may be more important to sleep, LDL, CRP, triglycerides, blood pressure, and diabetes diagnosis.[11,15,58] Another reason for the null results may be due to differences in the measurement of digital media. For example, previous studies have looked at the

effects of various types of digital media (e.g., television vs video games) on cardiometabolic health, whereas the present study adopted a comprehensive assessment of all available types of digital media.

Overall, the results of this study provide evidence for concern, as they highlight the significant effects of digital media use on BMI, WHtR, and HDL. Increased BMI and WHtR may contribute to increased cholesterol and triglycerides, placing adolescents at a further increased risk for OWOB and other cardiometabolic outcomes. Overweight or obesity in adolescence may result in chronic inflammation, high blood pressure, heart disease, certain types of cancer, and higher risk of premature death.[13,14] Further, lower levels of HDL may result in accelerated epigenetic aging, coronary heart or artery disease, and increased risk of stroke.[23,59] These results support a need for interventions aimed at mitigating the negative effects of digital media use on cardiometabolic health. Related, it is critical that adolescents and young adults receive education on the potentially negative consequences of high levels of digital media use.

This is the first study to our knowledge to assess the longitudinal effects of digital media use across the adolescent transition to young adulthood. Strengths of the study include the diverse, nationally representative sample comprised of individuals from various socioeconomic, racial, and geographical backgrounds. The study design allowed for predictions of pathways linking subcategories of digital media users with sleep and cardiometabolic health outcomes. Blood pressure, WHtR, BMI, CRP, triglycerides, HDL, and LDL were objectively measured. Limitations include self-reported sleep duration and digital media use across waves, as well as the inability to control for time between waves. Additionally, the measurement of digital media use varied across waves and did not

account for digital media use platforms that have been developed over the past decade. However, these results are still useful for informing the effects of adolescent versus young adulthood digital media use.

In summary, this study found significant effects of longitudinal patterns of digital media use on BMI, WHtR, and HDL in young adulthood. Specifically, digital media use greater than 30 hours per week, or ~4 hours per day, was found to predict increased BMI and WHtR. Further, patterns of increased digital media use from adolescence to young adulthood were found to contribute to decreased HDL. Overall, these findings highlight the potentially harmful effects of digital media use on cardiometabolic health and emphasize the importance of interventions aimed at effectively reducing screen time for adolescents and young adults.

REFERENCES

1. Rideout V, Robb MB. The common sense census: Media use by tweens and teens. Common Sense Media.

2. Smith A, Anderson M. Social Media Use in 2018. Pew Research Center.

3. Barack L. Americans now log more screen time than they do sleep.

4. LeBlanc AG, Gunnell KE, Prince SA, Saunders TJ, Barnes JD, Chaput JP. The ubiquity of the screen: An overview of the risks and benefits of screen time in our modern world. *Translational Journal of the ACSM*. 2017;2(17):104-113. doi:10.1249/TJX.0000000000000039

5. Choi H, Kim C, Ko H, Park CG. Relationship between sedentary time and sleep duration among Korean adolescents. *Journal of School Nursing*. 2020;36(6):423-429. doi:10.1177/1059840519842230

6. Bai Y, Chen S, Laurson KR, Kim Y, Saint-Maurice PF, Welk GJ. The associations of youth physical activity and screen time with fatness and fitness: The 2012 NHANES national youth fitness survey. *PLoS Ones*. 2016;11(1):e0148038. doi:10.1371/journal.pone.0148038

7. Khajeheian D, Colabi AM, Ahmad Kharman Shah NB, Bt Wan Mohamed Radzi C, Jenatabadi HS. Effect of social media on child obesity: Application of structural equation modeling with the taguchi method. *International Journal of Environmental Research and Public Health*. 2018;15(7):1343. doi:10.3390/ijerph15071343

8. Wu L, Sun S, He Y, Jiang B. The effect of interventions targeting screen time reduction: A systematic review and meta-analysis. *Medicine (Baltimore)*. 2016;95(27):e4029. doi:10.1097/MD.0000000000004029

9. Alotaibi A, Almuhanna R, Alhassan J, Alqadhib E, Mortada E, Alwhaibi R. The relationship between technology use and physical actviity among typically developing children. *Healthcare*. 2020;8(4):488. doi:10.3390/healthcare8040488

10. Robinson TN, Banda JA, Hale L, et al. Screen media exposure and obesity in children and adolescents. *Pediatrics*. 2017;140(2):S97-S101. doi:10.1542/peds.2016-1758K

11. Cha EM, Hoelscher DM, Ranjit N, et al. Effect of media use on adolescent body weight. *Preventing Chronic Disease*. 2018;15doi:10.5888/pcd15.180206

12. McCrindle BW, Urbina EM, Dennison BA, et al. Drug therapy of high-risk lipid abnormalities in children and adolescents: A scientific statement from the American Heart Association Atherosclerosis, Hypertension, and Obesity in Youth Committee, Council of Cardiovascular Disease in the Young, with the Council on Cardiovascular Nursing. *Circulation*. 2007;115(14)doi:10.1161/CIRCULATIONAHA.107.181946

13. Reinehr T. Long-term effects of adolescent obesity: Time to act. *Nature Review Endocrinology*. 2017;14:183-188. doi:10.1038/nrendo.2017.147

14. Lindenberg L, Danielsoson P, Persson M, Marcus C, Hagman E. Association of childhood obesity with risk of early all-cause and cause-specific mortality: A Swedish prospective cohort study. *PLOS Medicine*. 2020;17(3)doi:10.1371/journal.pmed.1003078

15. Lee DS, Jiang T, Crocker J, Way BM. Social media use and its link to physical health indications. *Cyperbpsychology, Behavior, and Social Networking*. 2022;25(2):87-93. doi:10.1089/cyber.2021.0188

16. Lee DS, Way BM. Social media use and systemic inflammation: The moderating role of self-esteem. *Brain, Behavior, & Immunity - Health*. 2021;16doi:10.1016/j.bbih.2021.100300

17. Paffen E, deMaat MPM. C-reactive protein in atherosclerosis: A casaul factor? *Cardiovascular Research*. 2006;71(1):30-39. doi:10.1016/j.cardiores.2006.03.004

18. Fobian AD, Elliott L, Louie T. A systematic review of sleep, hypertension, and cardiovascular risk in children and adolescents. *Current Hypertension Reports*. 2018;20(5):42. doi:10.1007/s11906-018-0841-7

19. Visser M, Bouter LM, McQuillan GM. Elevated C-reactive protein levels in overweight and obese adults. *JAMA*. 1999;282(22):2131-2135. doi:10.1001/jama.282.22.2131

20. Vanderloo LM, Keown-Stoneman CDG, Sivansan H, et al. Associations of screen time and cardiometabolic risk in school-aged children. *Preventative Medicine Reports*. 2020;20:101183. doi:10.1016/j.pmedr.2020.101183

21. Misra S, Al-Dubai S, Oy Y. Does screen time addect the cardiometabolic risk factors among young adults? presented at: 12th European Nutrition Conference; 2015; Berlin, Germany.

22. Mark AE, Janssen I. Relationship between screen time and metabolic syndrome in adolescents. *Journal of Public Health*. 2008;30(2):153-160. doi:10.1093/pubmed/fdn022

23. Elshourbagy NA, Meyers HV, Abdel-Meguid SS. Cholesterol: The good, the bad, and the ugly - therapeutic targets for the treatment of dyslipidemia. *Medical Principles and Practice*. 2014;23(2):99-111. doi:10.1159/000356856

24. LeBlanc AG, Janssen I. Dose-response relationship between physical activity and dyslipidemia in youth. *Canadian Journal of Cardiology*. 2010;26(6):e201-e205. doi:10.1016/s0828-282x(10)70400-1

25. Mielke GI, Brown WJ, Wehrmeister FC, et al. Associations between self-reported physical activity and screen time with cardiometabolic risk factors in adolescents: Findings from the 1993 Pelotas (Brazil) birth cohort study. *Preventative Medicine*. 2019;119:31-36. doi:10.1016/j.ypmed.2018.12.008

26. Lopes S, Mesquita-Bastos J, Alves AJ, Ribeiro F. Exercise as a tool for hypertension and resistant hypertension management: Current insights. *Integrated Blood Pressure Control*. 2018;11:65-71. doi:10.2137/IBPC.S136028

27. Schmid D, Willet WC, Forman MR, Ding M, Michels KB. TV viewing during childhood and adult type 2 diabetes mellitus. *Scientific Reports*. 2021;11doi:10.1038/s41598-021-83746-4

28. Diseases NIoDaDaK. Risk factors for type 2 diabetes.

29. Owens JA, Weiss MR. Insufficient sleep in adolescents: Causes and Consequences. *Minerva Pediatrics*. 2017;69(4):326-336. doi:10.23736/S0026-4946.17.04914-3

30. Lund L, Solvhoj IN, Danielson D, Anderson S. Electronic media use and sleep in children and adolescents in western countries: A sytematic review. *BMC Public Health*. 2021;21(1)doi:10.1186/s12889-021-11640-9

31. Hale L, Guan S. Screen time and sleep among school-aged children and adolescents: A systematic literature review. *Sleep Medicine Reviews*. 2015;21:50-58. doi:10.1016/j.smrv.2014.07.007

32. Hale L, Kirschen GW, LeBourgeois MK, et al. Youth screen media habits and sleep: Sleep-friendly screen-behavior recommendations for clinicians, educators, and parents. *Child and Adolescent Psychiatric Clinics of North America*. 2018;27(2):229-245. doi:10.1016/j.chc.2017.11.014

33. Fobian AD, Avis K, Schwebel DC. The impact of media use on adolescent sleep efficiency. *Journal of Developmental and Behavioral Pediatrics*. 2016;37(1):9-14. doi:10.1097/DBP.0000000000000239

34. Cain N, Gradisar M. Electronic media use and sleep in school-aged children and adolescents: A review. *Sleep Medicine*. 2010;11(8):735-742. doi:10.1016/j.sleep.2010.02.006

35. Chaput JP, Dutil C. Lack of sleep as a contributor to obesity in adolescents: Impact on eating and activity behaviors. *International Journal of Behavioral Nutrition and Physical Activity*. 2016;13:103. doi:10.1186/s12966-016-0428-0

36. Chen X, Beydoun MA, Wang Y. Is sleep duration associated with childhood obesity? A systematic review and meta-analysis. *Obesity*. 2008;16(2):265-274. doi:10.1038/oby.2007.63

37. How Much Sleep Do I Need? Center for Disease Control and Prevention.

38. Eaton DK, McKnight-Eily LR, Lowry R, Perry SP, Presley-Cantrell L, Croft JB. Prevalence of insufficient, borderline, and optimal hours of sleep among high school students - United States, 2007. *Journal of Adolescent Health*. 2010;46(4):399-402. doi:10.1016/j.jadohealth.2009.10.011

39. Valdez P, Ramirez C, Garcia A. Delaying and extending sleep during weekends: Sleep recovery or circadian effect? *Chronobiology International*. 1996;13(3):191-198. doi:10.3109/07420529609012652

40. Colrain IM, Baker FC. Changes in sleep as a function of adolescent development. *Neuropsychology Review*. 2011;21:5-21. doi:10.1007/s11065-010-9155-5

41. Gohil A, Hannon TS. Poor sleep and obesity: Concurrent epidemics in adolescent youth. *Frontiers in Endocrinology*. 2018;9doi:10.3389/fendo.2018.00364

42. Harris KM, Halpern CT, Whitsel EA, et al. The National Longitudinal Study of Adolescent to Adult Health (ADD Health). *International Journal of Epidemiology*. 2019;48(5):1415-1425. doi:10.1093/ije/dyz115

43. CDC. About Child and Teen BMI. 2021;

44. CDC. Children's BMI Tool for Schools. https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/tool_for_schools.html

45. Malafaia AB, Nassif P, Lucas R, et al. Is the wasit/height ratio a better parameter than BMI in determining the cardiometabolic risk profile of obese people>. *Brazilian Archies of Digestive Surgery*. 2022;34(3)doi:10.1590/0102-672020210003E1610

46. Martin-Calvo N, Moreno-Galarraga L, Martinez-Gonzalez MA. Association between body mass index, waist-to-height ratio and adiposity in children: A systematic review and meta-analysis. *Nutrients*. 2016;8(8):512. doi:10.3390/nu8080512

47. Nagin DS. Group-based trajectory modeling: An overview. *Annals of Nutrition and Metabolish*. 2014;65:205-210. doi:10.1159/000360229

48. Nagin DS, Jones, B.L., Passos, V.L., Tremblay, R.E. Group-based multi trajectory modeling. *Statistical Methods in Medical Research*. 2016;0(0):1-9. doi:10.1177/0962280216673085

49. Chen P, Harris KM. *Guidelines for Analyzing Add Health Data*. 2020.

50. Boone JE, Gordon-Larsen, P., Adair, L.S., Popkin, B.M. Screen time and physical activity during adolescence: Longitudinal effects on obesity in young adulthood. *International Journal of Behavioral Nutrition and Physical Activity*. 2007;4:26. doi:10.1186/1479-5868-4-26

51. Mitchell JA, Rodriguez, D., Schmitz, K.H., Audrain-McGovern, J. Greater screen time is associated with adolescent obesity: A longitudinal study of the BMI distribution from ages 14 to 18. *Obesity*. 2013;21(3):572-575. doi:10.1002/oby.20157

52. Corder K, Winpenny, E., Love, R., Brown, H.E., White, M., van Sluijs, E. Change in physical activity from adolescence to early adulthood: A systematic review and meta-analysis of longitudinal cohort studies. *British Journal of Sports Medicine*. 2017;53(8)

53. Guddal MH, Stensland, S.O., Smastuen, M.C., Johnsen, M.B., Heuch, I., Zwart, J.A., Storheim, K. Obesity in young adulthood: The role of physical activity level, musculoskeletal pain, and psychological distress in adolescents (The HUNT-Study). *International Journal of Environmental Research and Public Health*. 2020;17(12):4603. doi:10.3390/ijerph17124603

54. Yoo EG. Waist-to-height ratio as a screening tool for obesity and cardiometabolic risk. *Korean Journal of Pediatrics*. 2016;59(11):425-432. doi:10.3345/KJP.2016.59.11.425

55. Mumena WA, Alnezari, A.I., Safar, H.I., Alharbi, N.S., Alahmadi, R.B., Qadhi, R.I., Faqeeh, S.F., Kutbi, H.A. Media use, dietary intake, and diety quality of adolescents in Saudi Arabia. *Pediatric Reseach*. 2023;(94):789-795. doi:10.1038/s41390-023-02505-5

56. Winpenny EM, van Slujis, E.M.F., White, M., Klepp, K.I., Wold, B., Lien, N. Changes in diet through adolescence and early adulthood: Longitudinal trajectories and association with key life transitions. *International Journal of Behavioral Nutrition and Physical Activity*. 2018;15:86. doi:10.1186/s12966-018-0719-8

57. Funtikova AN, Navarro, E., Bawaked, R.A., Fito, M., Schroder, H. Impact of diet on cardiometabolic health in children and adolescents. *Nutrition Journal*. 2015;14(118)doi:10.1186/s12937-015-0107-z

58. Sehn AP, Gaya, A.R., Dias, A.F., Brand, C., Mota, J., Pfeiffer, K.A., Sayavera, J.B., Renner, J.D., Reuter, C.P. Relationship between sleep duration and TV time with cardiometabolic risk in adolescents. *Environmental Health and Preventative Medicine*. 2020;25(42)doi:10.1186/s12199-020-00880-7

59. Pletcher MJ, Bibbins-Domingo, K., Liu, K., Sidney, S., Lin, F., Vittinghoff, E., Hulley, S.B. Non-optimal lipids commonly present in young adults and coronary calcium later in life. *Annals of Internal Medicine*. 2010;153(3):137-146. doi:10.1059/0003-4819-153-3-201008030-00004

LONGITUDINAL EFFECTS OF ADOLESCENT DIGITAL MEDIA USE ON MENTAL HEALTH

CAROLINE WATSON, AARON FOBIAN, CHRISTOPHER HENRICH, DUSTIN LONG

In preparation for *Annals of Behavioral Medicine*

Format adapted for thesis

LONGITUDINAL EFFECTS OF ADOLESCENT DIGITAL MEDIA USE ON MENTAL HEALTH

Adolescence is a critical period for developing healthy habits, including those related to digital media use.[1,2] Accordingly, the American Academy of Pediatrics recommends that adolescents spend no more than 2 hours per day on digital media.[1] However, in 2019, American adolescents spent 7 hours and 33 minutes per day on digital media, which is a 42-minute increase since 2015.[3,4] As digital media use among adolescents has increased, there has been a sharp decline in adolescent mental health. Large scale screening studies on the mental health of adolescents since 2010 show drastic increases in anxiety and depressive symptoms, major depressive episodes, suicidal ideation, and suicide attempts.[5] There is concern that such decline in mental health may be associated with increased digital media use.[5,6] However, research on the associations between digital media use and mental health outcomes among adolescents, including depression and anxiety disorders, depressive symptomology, suicidality, and cognitive health, has found conflicting results.[7]

Anxiety disorders are the most prevalent mental health disorders among adolescents.[8] Adolescent anxiety poses several long-term health risks, including poor mental health and adverse physical health conditions in adulthood.[9-11] Increased evidence suggests that digital media use may contribute to adolescent anxiety. For example, digital media use may reduce the frequency of adolescents' face-to-face interactions with peers,

which may result in decreased feelings of closeness. Considering the importance of meaningful peer relationships in adolescence, decreased feelings of closeness may exacerbate adolescent anxiety.[7] However, cross-sectional and longitudinal research on the relationship between digital media use and anxiety has found conflicting results.[11,12] One study of 2,525 adolescents found that adolescents who spent less than four hours per day on digital media were less likely to experience symptoms of anxiety disorders (i.e., generalized anxiety disorder, social phobia, and panic disorder) 12 months later than adolescents who spent more than four hours per day on digital media.[13] Conversely, a 2016 study that followed adolescents for 11 years found no relationship between digital media use and anxiety. However, this study only examined television and computer games in their measure of digital media use.[14]

The relationship between digital media use and depression is also unclear. Several studies have demonstrated positive correlations between digital media use and depression and depressive symptoms.[15] One longitudinal study found that each additional hour spent viewing a screen during adolescence was associated with a 1.58 times greater risk for depression in young adulthood.[16] In a study of 14- to 17-year-olds, adolescents who used digital media more than 7 hours a day were more than two times more likely to be diagnosed with depression.[7] The sedentary nature of digital media use may explain this relationship, as sedentary behaviors are consistently associated with increased risk for depression and depressive symptomology.[17] Conversely, a substantial amount of cross-sectional research suggests little or no relationship between digital media use and depression.[18,19] In a recent literature review, only 45% of studies included found associations between digital media use and depressive symptoms.[14]

The relationship between digital media use and suicide attempts and suicidal ideation (i.e., thoughts of or plans to commit suicide) among adolescents is especially concerning.[5,6] Since 2010, emergency hospital visits for suicide attempts and suicidal ideation among adolescents have nearly doubled. Among 10-12-year-old girls, self-poisoning rates have quadrupled, hospital admissions for self-harm have tripled, and suicide rates have doubled.[5] Increased digital media use is often blamed for this marked increase.[6] A recent literature review found consistent evidence linking time spent using digital media to suicidal ideation among adolescents in Western countries.[20] This relationship may be due to depression, as adolescents who are more depressed are at increased risk for suicidal ideation and suicide attempts and often spend more time on digital media.[6] Cyberbullying via digital media may also play a role in this relationship, as victims of cyberbullying are two times more likely to attempt suicide.[21] The media contagion effect—the idea that exposure to suicide through media can increase individual risk for suicidal ideation and suicide attempts—may also contribute to the relationship between digital media use and suicide.[21-23] Research consistently reports associations between media reports of suicide and increased suicide rates.[23] One study found that 15- to 19-year-olds exposed to a death by suicide in their county were two to four times more likely to commit suicide.[22]

Recent research has also considered the effects of digital media use on cognitive ability. In a cross-sectional study of 11,875 adolescents, adolescents who exceeded 7 hours of digital media use per day were 40% less likely to achieve higher grades in school.[12] Similarly, a recent systematic review found consistent evidence relating increased digital media use to slowed learning and acquisition.[24] Conversely, a systematic

review and meta-analysis of 58 cross-sectional studies found no association between digital media use and academic performance across studies.[25] However, most studies have focused on academic performance and learning ability as measures of cognitive ability, rather than assessing specific aspects of cognitive functioning such as working memory and short-term memory.

Overall, the causal mechanisms underlying the relationship between digital media use and mental health remain unclear. As increased digital media use is associated with poorer mental health, longitudinal studies that will allow insight into predictive pathways linking digital media use with mental health are needed. It is further important to identify factors in adolescence that may contribute to digital media use, including parental support, face-to-face interactions with peers, family connectedness, and self-esteem.

Digital media use may be influenced by parenting behaviors.[26] Previous literature reports that children of more involved parents spend less time on digital media, and adolescents who spend more time on digital media report poorer parental attachment.[27,28] Within the family system, digital media use has been associated with poorer family relationships and less time spent together as a family.[28] Similarly, digital media use has been associated with poor attachment to peers, possibly due to increased time spent on digital media and decreased time spent face-to-face with peers.[7,28] Research has yet to identify the direction of these relationships and how parental support, face-to-face interactions with peers, and family connectedness may contribute to digital media use.

To address these gaps in the literature, the present study seeks to assess how trajectories of digital media use across the adolescent transition to adulthood predict mental health outcomes in young adulthood, including short-term memory, working

memory, diagnoses of depression and anxiety disorders, depressive symptomology, and suicidality. The present study further seeks to assess how parental support, face-to-face interactions with peers, family connectedness, and self-esteem in adolescence predict digital media use across the transition from adolescence into young adulthood. Overall, the present study will provide a clearer understanding of the long-term effects of digital media use and identify factors in adolescence that predict digital media use.

Methods

The present study retrieved data from the National Longitudinal Study of Adolescent Health (Add Health) database. The Add Health database is a nationally representative sample that recruited participants from 80 high schools across the United States. Data collection involved in-home and in-school questionnaires administered to participants as they transitioned from adolescence into young adulthood. The present study focuses on digital media use questions asked in Waves I-IV as predictors of mental health outcomes in Wave IV.

Participants

The present study includes the sample of participants who responded to digital media use questions asked in Waves I-IV. To maintain the goal of following participants across the transition from adolescence into young adulthood, participants older than 17 years of age at Wave I were excluded from analyses. Participants were ages 11-17 at Wave I (1994) and ages 24-30 at Wave IV (2008-2009). Participants who were pregnant at Wave IV were also excluded from analyses.

Measures

Demographics. At Wave I, adolescents provided self-reports of sex, date of birth, and race, and parents provided self-reports of total household income before taxes.

Digital Media Use. In Waves I-III, participants were asked, "How many hours a week do you play video or computer games?", "How many hours a week do you watch television?", and "How many hours a week do you watch videos?" At Wave IV, participants were asked "How many hours a week do you play video or computer games?", "In the past seven days, how many hours did you spend using the internet, for example, accessing your email or using the web?", and "In the past 7 days, how many hours did you watch television or videos, including VHS, DVDs, or music videos?" Responses were recorded in total hours and summed to construct a single measure of digital media use per week at each wave.

Pregnancy Status. At Wave IV, participants provided self-reports of pregnancy status by responding "yes/no" to the question, "Are you pregnant now?" Participants who reported current pregnancy status at Wave IV were excluded from the study.

Rurality. At Wave I, interviewers were asked to describe the immediate area or street where the respondent lived, including "rural," "suburban," "urban (residential only)," "3 or more commercial properties (mostly retail)," "3 or more commercial properties (mostly wholesale or industrial)," and "other." At Wave IV, interviewers were

again asked to describe the immediate area or street where the respondent lived, including "rural farm," "rural town," "suburban," "urban (residential only)," "3 or more commercial properties (mostly retail)," "3 or more commercial properties (mostly wholesale or industrial)," and "other."

Depression. Depression diagnosis at Wave IV was determined using the question, "Have you ever been diagnosed with depression?" with a "yes/no" response.

Depressive Symptomology. At Wave IV, depressive symptomology was determined using a series of questions. Participants were asked how often the following statements were true in the past week: "You felt depressed," "You enjoyed life," "You felt sad," "You felt that people disliked you," "You felt that you could not shake off the blues, even with help from your family and your friends," "You felt that you were too tired to do things," "You felt you were just as good as other people," "You had trouble keeping your mind on what you were doing," "You were bothered by things that don't usually bother you." Responses were recorded using a 4-point Likert scale with response labels "never to rarely," "sometimes", "a lot of the time", and "most of the time or all of the time." Responses marked as "sometimes", "a lot of the time", and "most of the time or all of the time" were classified as depressive symptomology, and responses marked as "never to rarely" were classified as no depressive symptomology. From this information, a total depressive symptomology score was calculated by summing the total number of items classified as depressive symptomology for a final score ranging from 0-9.

Anxiety. At Wave IV, anxiety diagnosis was determined using the question, "Has a doctor, nurse, or other health care provider ever told you that you have or had anxiety or panic disorder?" Participants provided a "yes/no" response.

Suicidal Ideation and Suicide Attempts. At Wave IV, participants were asked, "During the past 12 months, did you ever seriously think about committing suicide?" and "During the past 12 months, how many times did you attempt suicide?" Response values were recorded individually as suicidal ideation and suicide attempts, respectively.

Cognitive Health. At Wave IV, participants completed two cognitive tasks assessing working memory and short-term memory. In the working memory task, participants were read a set of numbers and asked to repeat the numbers in reverse order. Each number set included two number sequences of the same length, and the length of numbers in the sequence increased by one number with each set. The task ended when the participant failed to accurately repeat both trials of the same length or accurately completed all seven sets. One point was awarded for each number set accurately completed and summed to construct a single measure of working memory at Wave IV.

In the short-term memory task, participants were read 15 words and asked to recall as many words as they could remember. The task ended when the participant failed to recall any more words or after 90 seconds. One point was awarded for each word accurately recalled and summed to construct a single measure of short-term memory at Wave IV.

Self-Esteem. At Wave I, self-esteem was determined using a series of questions. Participants were asked how much they agreed or disagreed with the following statements: "You feel like you are doing just about everything right," "You feel loved and wanted," "You feel socially accepted," "You have lots of good qualities," "You have lots to be proud of," and "You like yourself just the way you are." Responses were recorded using a 5-point Likert scale with response labels "strongly agree," "agree," "neither agree nor disagree," "disagree," and "strongly disagree." Responses marked as "strongly agree" and "agree" were classified as presence of self-esteem, and responses marked as "neither agree nor disagree," "disagree," and "strongly disagree" were not classified as presence of self-esteem. A total self-esteem score was calculated by summing the total number of items classified as presence of self-esteem for a final score ranging from 0-6.

Parental Support. At Wave I, participants responded to a series of questions regarding their in-house (biological, step, adoptive, or foster) mother and/or father. Participants with both an in-house mother and father provided responses on their mother and father, and participants with one in-house mother or father provided responses only on their in-house mother or father. Participants were asked, "How close do you feel to your (biological, step, adoptive, or foster) mother/father?" and "How much do you think your (biological, step, adoptive, or foster) mother/father cares about you?" Responses were recorded on a 5-point Likert scale with response labels "not at all," "a little," "some," "quite a bit," and "very much". Participants were also asked how much they agreed or disagreed with the following statements: "Most of the time your mother/father

is warm and loving toward you," "You are satisfied with the way your mother/father and you communicate," and "Overall, you are satisfied with your relationship with your mother/father". Responses were recorded using a 5-point Likert scale with response labels "strongly agree," "agree," "neither agree nor disagree," "disagree," and "strongly disagree." Responses marked as "a little," "some," "quite a bit," "very much," "strongly agree," or "agree" were classified as parental support, and responses marked as "not at all", "neither agree nor disagree", "disagree," and "strongly disagree" were not classified as parental support. In cases where both mother and father data were available, responses classified as parental support were summed for the mother and father individually, then averaged to construct a single measure of parental support at Wave I for a final score ranging from 0-5. In cases where only mother or father data were available, responses classified as parental support for the mother or father were summed to construct a single measure of parental support at Wave I for a final score ranging from 0-5. Thus, data that were missing for legitimate reasons (e.g., single parent) were not excluded to retain maximum sample size.

Family Connectedness. At Wave I, participants were asked, "How much do you feel that people in your family understand you?", "How much do you feel that you and your family have fun together?", and "How much do you feel that your family pays attention to you?". Responses were recorded on a 5-point Likert scale with response labels "not at all," "very little", "somewhat", "quite a bit," and "very much". Responses marked as "very little," "somewhat," "quite a bit," and "very much" were classified as family closeness, and responses marked as "not at all" were not classified as family

closeness. Responses classified as family closeness were summed to construct a single measure of family closeness for participants at Wave IV for a final score ranging from 0-3.

Data Analyses

PROC TRAJ—a group-based modeling technique—was used to identify distinct trajectories of digital media use across Waves I-IV. Using maximum likelihood estimates to create distinct participant groups, the present study assessed how varying levels of digital media use affected subcategories of digital media users. Using a forward-selection approach, stepwise procedures were used to determine number of trajectory groups and the best-fit model, including linear, quadratic, and cubic growth curve parameters.[29,30] Prior to these analyses, an outlier analysis was conducted and determined approximately 3 SD above the mean (i.e., 84 hours/week) as the appropriate cutoff for digital media use hours/week. Thus, participants who reported more than 84 hours of digital media use per week were considered missing. This affected 820 participants (12.11%) of the original sample. No other issues were found regarding normality and homogeneity of variance. Participants missing digital media use data in Waves I-IV were also excluded from analyses. Survey weights were utilized to ensure data was nationally representative, and missing data were handled using the MISSING and NOMCAR functions.

Digital media use trajectory groups were used as predictors of Wave IV mental health outcomes including diagnoses of anxiety and depression, depressive symptomology, suicidal ideation, suicide attempts. Three separate general linear models (PROC SURVEYREG) were used to assess the predictive relationship between media

use trajectory groups and depressive symptomology, working memory, and short-term memory. Prior to these analyses, assumptions of normality and homogeneity of variance were assessed. Four separate logistic regressions (PROC SURVEYLOGISTIC) were used to assess the predictive relationship between media use trajectory group and anxiety diagnosis, depression diagnosis, suicidal ideation, and suicide attempts. Covariates were pre-determined based on prior literature (Table 1). Prior to these analyses, data were checked for normality and multicollinearity. Further, a cross-sectional analysis of outcomes at Wave IV was used to assess the longitudinal effects of digital media use at various time points across the transition from adolescence into young adulthood.

Table 1. Predetermined Covariates for Mental Health Outcomes

Measure	**Covariates**
Digital Media Use	• Sex • Race • Age (Wave IV) • Income (Wave I) • Rurality (Waves I & IV)
Suicidal Ideation	• Depression Diagnosis (Wave IV) • Depressive Symptomology (Wave I) • Depressive Symptomology (Wave IV)
Suicide Attempts	• Depression Diagnosis (Wave IV) • Depressive Symptomology (Wave I) • Depressive Symptomology (Wave IV)

Four separate logistic regressions (PROC LOGISTIC) were used to assess the predictive relationship between parental support, family connectedness, face-to-face interactions with peers, and self-esteem with digital media use trajectory group. Prior to these analyses, data were checked for normality and multicollinearity. Covariates were predetermined based on past literature (Table 1).

Results

The final sample included 6,767 participants (M_{age}=15.53, SD=1.42; 56.86% female, 66.89% White) ages 11-17 at Wave I and ages 24-30 at Wave IV.

Four digital media use trajectory groups emerged (Figure 1). Group 2, “low” included the majority of participants (73.36%). Participants in Group 2 exhibited the lowest digital media use across Waves I-IV, averaging between 14.91 hours per week across Waves. Participants in Group 1, “increase” (9.97%), exhibited a steady increase in digital media use across Waves I-IV, whereas individuals in Group 3, “decrease” (13.94%), exhibited a steady decrease in digital media use across Waves I-IV. Group 4, “high”, included the least number of participants (2.73%), and exhibited high levels of digital media use across Waves I-IV.

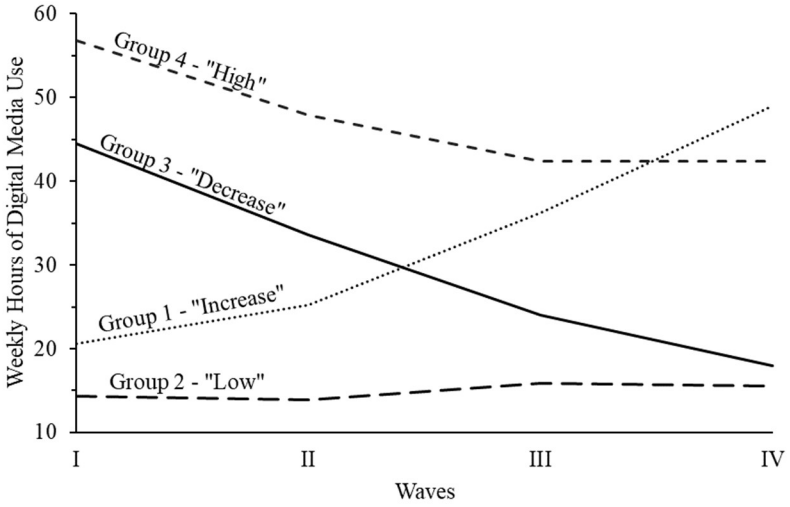

Figure 1. Digital Media Use Trajectories Across Waves I-IV

Digital media use trajectory group significantly predicted Wave IV short-term memory such that individuals in Group 4 (M=6.28, SD=4.01) experienced decreased short-term memory at Wave IV compared to individuals in Group 2 (M=6.86, SD=2.94). Wave IV digital media use did not independently predict Wave IV short-term memory. Digital

media use trajectory group also significantly predicted suicide attempts such that individuals in Groups 3 odds of a suicide attempt in the past 12 months was 1.07% greater (95% CI [0.01, 0.29]) than the odds individuals in Group 2. Individuals in Group 4 odds of a suicide attempt in the past 12 months were 1.10% greater (95% CI [0.01, 0.35]) than the odds of individuals in Group 2. Wave IV digital media use did not independently predict Wave IV suicide attempts. Neither digital media use trajectory group nor Wave IV digital media use significantly predict Wave IV depressive symptomology, working memory, depression diagnosis, anxiety diagnosis, or suicidal ideation. Wave IV parental support, family connectedness, face-to-face interactions with peers, and self-esteem did not predict digital media use trajectory group membership.

Table 2. Summary of Analyses and Results for Mental Health Outcomes

Trajectory Group Predicting Wave IV Mental Health Outcomes	df	F	p
General Linear Models			
Wave IV Depressive Symptomology	3	1.62	0.19
Wave IV Working Memory	3	0.30	0.82
Wave IV Short-Term Memory	3	8.02	<0.001*
Logistic Regression Models			
Wave IV Anxiety Diagnosis	3	0.43	0.73
Wave IV Depression Diagnosis	3	1.78	0.15
Wave IV Suicidal Ideation	3	0.63	0.59
Wave IV Suicide Attempt	3	283.30	<0.001*
Wave I Variables Predicting Trajectory Group Membership	df	F	p
General Linear Models			
Wave I Parental Support	3	1.61	0.19
Wave I Family Connectedness	3	1.70	0.17
Wave I Face-to-Face Interactions with Peers	3	2.04	0.11
Wave I Self Esteem	3	1.57	0.22
Wave IV Digital Media Use Predicting Wave IV Mental Health Outcomes	df	F	*p*
General Linear Models			
Wave IV Depressive Symptomology	2	0.60	0.55
Wave IV Working Memory	2	0.93	0.40
Wave IV Short-Term Memory	2	0.22	0.80
Logistic Regression Models			
Wave IV Anxiety Diagnosis			
Wave IV Depression Diagnosis	2	-0.30	0.76
Wave IV Suicidal Ideation	2	-0.58	0.56
Wave IV Suicide Attempts	2	1.22	0.12

*Denotes p-value of <0.05

Table 3. Follow-up Tests for Wave IV Mental Health Outcomes

Wave IV Short-Term Memory Group Comparisons		Adjusted Mean Difference	SE	*p*
Group 2	Group 1	-0.27	0.14	0.07
Group 2	Group 3	-0.27	0.19	0.17
Group 2	Group 4	-0.58	0.13	<0.001*
Group 3	Group 4	0.31	0.24	0.19
Group 3	Group 1	0.00	0.22	1.00
Group 4	Group 1	0.31	0.19	0.11
Wave IV Suicide Attempts Group Comparisons		OR	95% CI	*P*
Group 2	Group 1	0.12	0.09, 0.52	0.31
Group 2	Group 3	1.10	1.02, 1.34	<0.01*
Group 2	Group 4	1.07	1.01, 1.42	<0.01*

*Denotes p-value of <0.05

Discussion

This study assessed the effects of digital media use patterns across the transition from adolescence to young adulthood on mental health outcomes in young adulthood. Results of the present study highlight relationships between longitudinal digital media use and short-term memory and suicide attempts.

Adolescents in Group 4 “high” experienced significantly decreased short-term memory at Wave IV as compared with individuals in Group 2 “low”. Of note, adolescents in Group 4 exhibited an average of 47.30 hours of digital media use per week across waves which was much higher than that of other groups. However, Wave IV digital media use did not independently predict short-term memory in young adulthood. Taken together, these results suggest that a pattern of high levels of digital media across adolescence may have a compounding effect on short-term memory in young adulthood. While the underlying mechanisms in this relationship are unclear, cross-sectional research posits that negative affect may mediate this relationship.[31] A recent study found that increased digital media use was associated with decreased negative affect and subsequent short-term memory

failures.[32] While the present study did not find a longitudinal relationship between digital media use and negative affect, this may be due to the effects of other, more salient variables present in this relationship (e.g., sleep, physical health). These results may also be explained by preliminary research demonstrating a relationship between consistently high levels of digital media use—like those exhibited by individuals in Group 4—and anatomical changes in brain cortex grey matter. It is posited that constant, fast access to information via the internet may alter the brain's need to store facts and knowledge not otherwise gained by personal experiences.[24] Overall, these results support prior literature on associations between increased digital media use and decreased short-term memory.[24,31,32] These results also support the need for 1) further research on other aspects of cognitive ability which may be negatively affected by increased digital media use, and 2) further research on anatomical changes due to digital media use.

Adolescents in Groups 3 "decrease" and 4 "high" were at increased odds of a suicide attempt in the past 12 months at Wave IV as compared with individuals in Group 2 "low". Notably, adolescents in Groups 3 and 4 exhibited the greatest digital media use per week at Waves I and II. Specifically, adolescents in Groups 3 and 4 exhibited 44.44 and 56.73 hours per week at Wave I and 33.56 and 47.84 hours per week at Wave II, respectively. For comparison, adolescents in Group 2 exhibited 14.34 and 13.84 hours per week at Waves I and II, respectively. These results suggest that increased levels of digital media use in adolescence and young adulthood may have a salient effect on suicide attempts in young adulthood. Cyberbullying may play a role in this relationship, as individuals with increased digital media use are more susceptible to cyberbullying,[21] and a meta-analysis of 11 longitudinal studies found that peer victimization in adolescence

consistently predicted suicidal behaviors in young adulthood.[33] Peer victimization in adolescence may also affect later drug use, self-esteem, and interpersonal relationships, which may contribute to susceptibility to suicide attempts.[34,35]

Digital media use trajectory group and Wave IV digital media use did not predict Wave IV depressive symptomology, depression diagnosis, anxiety diagnosis, working memory, or suicidal ideation. While these findings contradict previous cross-sectional literature, this may be due to more salient underlying factors. For example, the positive relationship between sedentary behaviors (e.g., digital media use) and risk for depression is well-documented in research. Increased sedentary behaviors are also consistently associated with increased risk for obesity and poor sleep, which may play a more salient role in the relationship between digital media use and depression.

The present study further assessed factors in adolescence which may contribute to digital media use patterns across waves. Specifically, the present study examined parental support, family connectedness, face-to-face interactions with peers, and self-esteem as predictors of trajectory group membership. While none of these variables significantly predicted trajectory group membership, this may be due to measurement fallibility. Data for those aforementioned variables was obtained via self-report on a 5-point Likert scale. Self-report Likert scales have been associated with response bias,[36] and require caution when being interpreted. Future research should re-assess the measurement of these variables and their relationship with digital media use in adolescence. Future research is also needed to assess other variables that may affect digital media use trends.

This study has several implications. The results are concerning given the significant findings between longitudinal patterns of digital media use and suicide attempts and short-

term memory in young adulthood. As suicide attempts among adolescents have nearly doubled since 2010,[5] interventions aimed at reducing and mitigating the effects of digital media use on suicide attempts are critical. For example, teachers, pediatricians, and related personnel may formally educate parents and adolescents on the potentially harmful effects of digital media use. Parents may also consider implementing time limits for daily digital media use. Regarding short-term memory, future research is needed to assess underlying mechanisms. In the meantime, schools that are reliant on technology in the classroom may consider ways to decrease screen-time in the classroom. Further, the results of the present study highlight the need for additional research to clarify mechanisms which may underly the relationship between digital media use and depression and anxiety diagnoses, depressive symptomology, working memory, and suicidal ideation.

Strengths of this study include the nationally representative sample and study design which allowed for predictions of pathways linking patterns of digital media use in adolescence with mental health outcomes in young adulthood. Limitations include self-reported digital media use across waves and the inability to control for time between waves. Notably, data collection for the present study began in 1994 and concluded in 2009. Technological advancements in the past decade have produced new forms of digital media use not accounted for in the present study. While this is a limitation of the present study, the results are still useful for informing the effects of digital media use during early adolescence versus young adulthood. Likewise, our significant findings warrant additional research as digital media use has increased exponentially in recent years.

In summary, the present study found that patterns of digital media use in adolescence had a significant effect on suicide attempts and short-term memory in young

adulthood. These results highlight the importance of interventions aimed at educating families and adolescents of the risks of high rates of digital media use and at reducing screen time throughout adolescence. Non-significant findings highlight the need for additional research aimed at clarifying these relationships, as well as identifying factors in early adolescence which may contribute to digital media use trajectories.

REFERENCES

1. Hill D, Ameenuddin N, Chassiakos YR, et al. Media use in school-aged children and adolescents. *The American Academy of Pedatrics*. 2016;138(5):e20162592. doi:10.1542/peds.2016-2592

2. Twenge JM, Martin GN, Spitzberg BH. Trends in U.S. adolescents' media use, 1976-2016: The rise of digital media, the decline of TV, and the (near) demise of print. *Psychology of Popular Media Culture*. 2018;8(4):329-345. doi:10.1037/PPM0000203

3. Rideout V, Robb MB. The common sense census: Media use by tweens and teens. Common Sense Media.

4. Rideout V, Inc. VC. The common sense census: Media use by tweens and teens. Common Sense Media.

5. Twenge JM. Increases in depression, self-harm, and suicide among U.S. adolescents after 2012 and links to technology use: Possible mechanisms. *Pyschiatric Research and Clinical Practice*. 2020;2(1):19-25. doi:10.1176/appi.prcp.20190015

6. Coyne SM, Hurst JL, Dyer WJ, et al. Suicide risk in emergying adulthood: Associations with screen time over 10 years. *Journal of Youth and Adolescence*. 2021;50:2324-2238. doi:10.1007/s109640-020-01389-6

7. Twenge JM, Campbell WK. Associations between screen time and lower psychological well-being among children and adolescents: Evidence from a population based study. *Preventative Medicine Reports*. 2018;12:271-283. doi:10.1016/j.pmedr.2018.10.003

8. Organization WH. Adolescent mental health.

9. Bardone AM, Moffitt TE, Caspi A, Dickson N, Stanton WR, Silva PA. Adult physical health outcomes of adolescent girls with conduct disorder, depression, and anxiety. *Journal of the American Academy of Child and Adolescent Psychiatry*. 1998;37(6):594-601. doi:10.1097/00004853-199806000-00009

10. Scott KM. Depression, anxiety and incident cardiometabolic diseases. *Current Opinion in Psychiatry*. 2014;27(4):289-293. doi:10.1097/YCO.0000000000000067

11. Oswald TK, Rumbold AR, Kedzoir SGE, Moore VM. Psychological impacts of "screen time" and "green time" for children and adolescents: A systematic scoping review. *PLOS One*. 2020;15(9):e0237725. doi:10.1371/journal.pone.0237725

12. Paulich KN, Ross JM, Lessem JM, Hewitt JK. Screen time and early adolescent mental health, academic, and social outcomes in 9- and 10-year old children: Utlizing the adolescent brain cognitive development (ABCD) study. *PLOS One*. 2021;16(9):e0256591. doi:10.1371/journal.pone.0256591

13. Zink J, Belcher BR, Kechter A, Stone MD, Leventhal AM. Reciprocal associations between screen time and emotional disorder symptoms during adolescence. *Preventative Medicine Reports*. 2019;13:281-288. doi:10.1016/j.pmedr.2019.01.014

14. Tang S, Werner-Seifler A, Torok M, Mackinnon AJ, Chirtensen H. The relationship between screen time and mental health in young people: A systematic review of longitudinal studies. *Clinical Psychology Review*. 2021;86doi:10.1016/j.cpr.2021.102021

15. Boers E, Afzali MH, Newton N. Association of screen time and depression in adolescence. *JAMA Pediatrics*. 2019;173(9):853-859. doi:10.1001/jamapediatrics.2019.1759

16. Grontved A, Singhammer J, Froberg K, et al. A prospective study of screen time in adolescence and depression symptoms in young adulthood. *Preventative Medicine*. 2015;81:108-113. doi:10.1016/j.ypmed.2015.08.009

17. Khouja JN, Munafo MR, Tilling K, et al. Is screen time associated with anxiety or depression in young people? Results from a UK birth cohort. *BMC Public Health*. 2019;19(1):82. doi:10.1186/s12889-018-6321-9

18. Gohil A, Hannon TS. Poor sleep and obesity: Concurrent epidemics in adolescent youth. *Frontiers in Endocrinology*. 2018;9doi:10.3389/fendo.2018.00364

19. Harris KM, Halpern CT, Whitsel EA, et al. The National Longitudinal Study of Adolescent to Adult Health (ADD Health). *International Journal of Epidemiology*. 2019;48(5):1415-1425. doi:10.1093/ije/dyz115

20. Memon AM, Sharma SG, Mohite SS, Jain S. The role of online social networking on deliberate self-harm and suicidality in adolescents: A systematized review of literation. *Indian Journal of Psychiatry*. 2018;60(4):384-392. doi:10.4103/psychiatry/indianjpsychiatry_414_17

21. Luxton DD, June JD, Fairall JM. Social media and suicide: A public health perspective. *American Journal of Public Health*. 2012;102(2):S195-S200. doi:10.2105/ajph.2011.300608

22. Gould M, Jamieson P, Romer D. Media contagion and suicide among the young. *American Behavioral Scientist*. 2003;46(9):1269-1284. doi:10.1177/0002764202250670

23. Phillips D. The influence of suggestion on suicide: Substantive and theorectical implications of the werther effect. *American Sociological Review*. 1974;39(3):340-354. doi:10.2307/2094294

24. Neophytou E, Manwell LA, Eikelboom R. Effects of excessive screen time on neurodevelopment, learning, memory, mental health, and neurodegeneration: A scoping review. *International Journal of Mental Health and Addiction*. 2021;19:724-744. doi:10.1007/s11469-019-00182-2

25. Adelantado-Penau M, Moliner-Urdiales D, Cavero-Redondo I, Beltran-Valls MR, Martinez-Vizcaino V, Alvarez-Bueno C. Associations between screen media use and academic performance among children and adolescents: A systematic review and meta-analysis. *JAMA Pediatrics*. 2019;173(11):1058-1067. doi:10.1001/jamapediatrics.2019.3176

26. Arundell L, Parker K, TImperio A, Salmon J, Veitch J. Home-based screen time behaviors amongst youth and their parents: Family typologies and their modifiable correlates. *BMC Public Health*. 2020;20:1492. doi:10.1186/s12889-020-09581

27. Veldhuis L, van Grieken A, Renders CM, HiraSing RA, Raat H. Parenting style, the home environment, and screen time of 5-year old children: The 'Be active, eat right' study. *PLOS One*. 2014;9(2):e88486. doi:10.1371/journal.pone.0088486

28. Richards R, McGee R, Williams SM. Adolescent screen time and attachment to parents and peers. *Archives of Pediatrics and Adolescent Medicine*. 2010;164(3):258-262. doi:10.1001/archpediatrics.2009.280

29. Nagin DS. Group-based trajectory modeling: An overview. *Annals of Nutrition and Metabolish*. 2014;65:205-210. doi:10.1159/000360229

30. Nagin DS, Jones, B.L., Passos, V.L., Tremblay, R.E. Group-based multi trajectory modeling. *Statistical Methods in Medical Research*. 2016;0(0):1-9. doi:10.1177/0962280216673085

31. Sharifian N, Zahodne, L.B. Daily associations between social media use and memory failures: The mediating role of negative affect. *Journal of General Psychology*. 2021;148(8):67-83. doi:10.1080/00221309.2020.1743228

32. Dagher M, Farchakn, Y., Barbar, S., Haddad, C., Akel, M., Hallit, S., Obeid, S. Association between problematic social media use and memory performance in a sample of Lebanese adults: The mediating effect of anxiety, depression, stress, and insomnia. *Head and Face Medicine*. 2021;17(6)doi:10.1186/s13005-021-00260-8

33. Van Geel M, Goemans, A., Zwaanswijk, W., Vedder, P. Does peer victimization predict future suicidal ideation? A meta-analysis on longitudinal studies. *Aggression and Violent Behavior*. 2022;64:101577. doi:10.1016/j.avb.2021.101577

34. Earnshaw VA, Elliott, M.N., Reisner, S.L., Mrug, S., Windle, M., Emery, S.T., Peskin, M.F., Schuster, M.A. Peer victimization, depressive symptoms, and substance use: A longitudinal analysis. *Pediatrics*. 2017;139(6):e20163426. doi:10.1542/peds.2016-3426

35. Wolke D, Lereya, S.T. Long-term effects of bullying. *Archives of Disease in Childhood*. 2015;9(100):879-885. doi:10.1136/archdischild-2014-306667

36. Jebb AT, Ng, V., Tay, L. A review of key Likert Scale development advances: 1995-2019. *Frontiers Pyschology*. 2021;12:637547.

CONCLUSION

In summary, both studies found that low patterns of digital media use across the transition from adolescence to young adulthood had a significant protective effect on physical and mental health outcomes in young adulthood. Specifically, individuals with low patterns of digital media use experienced greater HDL and short-term memory and decreased odds of suicide attempts in the past 12 months in young adulthood. Further, digital media use greater than 4 hours per day in young adulthood predicted increased BMI and WHtR. Overall, these results highlight the need for clinicians and educators to inform adolescents and young adults of the negative consequences associated with high rates of digital media use. Interventions aimed at effectively reducing screen time for both adolescents and young adults are critical and may require unique attention from both parents and schools. Finally, these results further highlight the need for additional research aimed at clarifying the relationship between digital media use and other physical and mental health outcomes, as well as factors in early adolescence that may contribute to longitudinal patterns of digital media use.

REFERENCES

1. Rideout V, Inc. VC. The common sense census: Media use by tweens and teens. Common Sense Media.

2. Rideout V, Robb MB. The common sense census: Media use by tweens and teens. Common Sense Media.

3. Choi H, Kim C, Ko H, Park CG. Relationship between sedentary time and sleep duration among Korean adolescents. Journal of School Nursing. 2020;36(6):423-429. doi:10.1177/1059840519842230

4. Visser M, Bouter LM, McQuillan GM. Elevated C-reactive protein levels in overweight and obese adults. JAMA. 1999;282(22):2131-2135. doi:10.1001/jama.282.22.2131

5. Vanderloo LM, Keown-Stoneman CDG, Sivansan H, et al. Associations of screen time and cardiometabolic risk in school-aged children. Preventative Medicine Reports. 2020;20:101183. doi:10.1016/j.pmedr.2020.101183

6. Misra S, Al-Dubai S, Oy Y. Does screen time addect the cardiometabolic risk factors among young adults? presented at: 12th European Nutrition Conference; 2015; Berlin, Germany.

7. Fobian AD, Avis K, Schwebel DC. The impact of media use on adolescent sleep efficiency. Journal of Developmental and Behavioral Pediatrics. 2016;37(1):9-14. doi:10.1097/DBP.0000000000000239

8. Cain N, Gradisar M. Electronic media use and sleep in school-aged children and adolescents: A review. Sleep Medicine. 2010;11(8):735-742. doi:10.1016/j.sleep.2010.02.006

9. Gohil A, Hannon TS. Poor sleep and obesity: Concurrent epidemics in adolescent youth. Frontiers in Endocrinology. 2018;9doi:10.3389/fendo.2018.00364

10. Reinehr T. Long-term effects of adolescent obesity: Time to act. Nature Review Endocrinology. 2017;14:183-188. doi:10.1038/nrendo.2017.147

11. Dagher M, Farchakn, Y., Barbar, S., Haddad, C., Akel, M., Hallit, S., Obeid, S. Association between problematic social media use and memory performance in a sample of Lebanese adults: The mediating effect of anxiety, depression, stress, and insomnia. Head and Face Medicine. 2021;17(6)doi:10.1186/s13005-021-00260-8

12. Khouja JN, Munafo MR, Tilling K, et al. Is screen time associated with anxiety or depression in young people? Results from a UK birth cohort. BMC Public Health. 2019;19(1):82. doi:10.1186/s12889-018-6321-9

13. Coyne SM, Hurst JL, Dyer WJ, et al. Suicide risk in emergying adulthood: Associations with screen time over 10 years. Journal of Youth and Adolescence. 2021;50:2324-2238. doi:10.1007/s109640-020-01389-6

14. Gould M, Jamieson P, Romer D. Media contagion and suicide among the young. American Behavioral Scientist. 2003;46(9):1269-1284. doi:10.1177/0002764202250670

15. Luxton DD, June JD, Fairall JM. Social media and suicide: A public health perspective. American Journal of Public Health. 2012;102(2):S195-S200. doi:10.2105/ajph.2011.300608

16. Phillips D. The influence of suggestion on suicide: Substantive and theoretical implications of the werther effect. American Sociological Review. 1974;39(3):340-354. doi:10.2307/2094294

17. Twenge JM. Increases in depression, self-harm, and suicide among U.S. adolescents after 2012 and links to technology use: Possible mechanisms. Pyschiatric Research and Clinical Practice. 2020;2(1):19-25. doi:10.1176/appi.prcp.20190015

18. Paulich KN, Ross JM, Lessem JM, Hewitt JK. Screen time and early adolescent mental health, academic, and social outcomes in 9- and 10-year old children: Utilizing

the adolescent Brain cognitive development (ABCD) study. PLOS One. 2021;16(9):e0256591. doi:10.1371/journal.pone.0256591