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The Relationship between Screen Time, Weight Status, and Fatty Liver Disease in U.S. Adolescents, a Cross-Sectional Study Using NHANES, 2017-2018

Becky J. Thomas
thomas.847@wright.edu

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Becky J. Thomas M.D.

Wright State University Boonshoft School of Medicine

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Abstract

Objective: The purpose of this study was to assess if screen time in U.S. adolescents is positively associated with evidence of fatty liver disease (steatosis and/or fibrosis) on FibroScan technology and to test the hypothesis that being overweight or obese mediates this relationship.

Methods: The analysis used cross-sectional data from 12–17-year-old participants (n = 612) in the 2017-2018 National Health and Nutrition Examination Survey (NHANES) to evaluate the association between self-reported average daily screen time and the presence of liver steatosis and/or fibrosis using FibroScan. Adjusted logistic regression analysis was performed to describe the independent association between screen time and the presence of liver disease. Additionally, mediation analysis was conducted by sequentially regressing obesity on screen time and regressing liver disease on screen time and obesity.

Results: Overall, 38.2% of adolescents had evidence of liver disease on FibroScan. A significant effect of daily screen time was seen on liver disease status, t (610) = 2.74, p =.006. Adolescents with evidence of liver steatosis and/or fibrosis spent an average of 38.4 minutes (95% CI, 11.0 - 65.8) per day longer on screens than those who did not have liver disease. Sobel's test (ab = .128, Z=2.053, p=.040) confirmed that overweight/obesity significantly mediates the relationship between screen time and liver disease. After accounting for the mediating effect of overweight/obese status, screen time has a small, but not statistically significant direct effect on fatty liver disease.

Discussion: Average daily screen time in adolescents affects liver steatosis and/or fibrosis indirectly through obesity.

Keywords: Overweight, Obesity, Steatosis, Fibrosis, Fibroscan

The Relationship between Screen Time, Weight Status, and Fatty Liver Disease in U.S. Adolescents, a Cross-Sectional Study Using NHANES, 2017-2018

The prevalence of obesity (BMI 95th percentile and above for age and sex) in adolescents in the United States (U.S.) has been consistently and dramatically increasing from 6.1% in the early 1970s to 21.2% in 2018 (Fryar, Carroll, & Afful, 2020). Increasing adolescent obesity has led to obesity-related cardiovascular and metabolic diseases at earlier ages that affect nearly every organ, including the liver. The prevalence of fatty liver disease is estimated to be 7.6-9.6% in children generally and 34.2% in obese children (Le Garf et al., 2021). Fatty liver disease progresses along a continuum from steatosis (simple fatty liver), non-alcoholic steatohepatitis or NASH (fat with inflammation), liver fibrosis, cirrhosis, and hepatocellular cancer. Previously termed nonalcoholic fatty liver diseases (NAFLD), many researchers and clinicians are using the term metabolic-associated fatty liver diseases (MAFLD) to accurately reflect the etiology of the spectrum of fatty liver abnormalities. It is estimated that 23% of all adolescents with MAFLD have NASH and that 9% of adolescents with NASH have advanced fibrosis or cirrhosis (Le Garf et al., 2021). Beyond obesity, other risk factors for pediatric MAFLD include male sex, Hispanic ethnicity, and increasing age.

With a global prevalence of 3-10%, MAFLD is currently the leading form of chronic liver disease in adolescents (Le Garf et al., 2021). MAFLD is an independent risk factor for type 2 diabetes and cardiovascular disease. Liver disease developed early in life can result in significant morbidity and mortality in adulthood. Along with increasing rates of obesity and rising MAFLD prevalence in adolescents, there is a concerning trend of increasing liver transplant registrations of younger patients with NASH; this reflects a cohort-based 'adipose wave effect' as MAFLD progresses in severity over the life course (Shingina et al., 2019). In the

decades ahead, MAFLD will likely surpass viral etiologies to become the leading cause of end stage liver disease among all age groups.

Although obesity is strongly associated with MAFLD, it is neither necessary nor sufficient for its development. It is estimated that MAFLD can be found in 8-16% of non-obese children (Brecelj & Orel, 2021). The pathogenesis of MAFLD has been studied in adults more than in adolescents. Liver biopsies show different histological patterns of lipid accumulations in pediatric and adult patients, although the etiological significance of this and its effect on disease progression is unclear. The currently accepted 'multiple hit' hypothesis proposes that genetics, prenatal exposures, and environmental factors may program metabolic and endocrine responses, predisposing to the development of MAFLD. The development of obesity and insulin resistance then contribute to fatty acid accumulation in the liver. The modernization of lifestyle factors, including dietary changes, reduced physical activity, and increased sedentary behaviors may be contributing to the increasing prevalence of both obesity and MAFLD.

Adolescents in the U.S. are spending more time than ever watching television and online videos. A large national study found that teens view an average of seven and a half hours of screen time a day, not including screen use at school or the use of computers for homework (Rideout & Robb, 2019). The COVID-19 pandemic intensified usage of screen-based technology due to stay at home mandates and remote online learning. In the Adolescent Brain Cognitive Development (ABCD) cross-sectional study, average daily screen usage more than doubled during the pandemic in comparison to prepandemic estimates (Nagata et al., 2022). Early studies suggest lifting of mandates may not reduce screen time usage back to prepandemic levels (Werling, Walltza, & Drechsler, 2021). As screening platforms increase, total screen time usage is likely to remain high.

Increasing use of screens is associated with adverse social, mental, and physical health outcomes, including poor self-esteem, depression, and obesity (Barnett et al., 2018). While adolescent screen time has been evaluated in terms of metabolic biomarkers for hyperglycemia, hypercholesterolemia, and hypertension (Hardy et al., 2010), the use of serum biomarkers to screen for MAFLD may underestimate its prevalence in young obese people and overestimate it in the general pediatric population (Le Garf et al., 2021). Although liver biopsy is the gold standard to assess liver steatosis and fibrosis, it is expensive, invasive, has limited sensitivity, and is not practical for follow-up assessments. No study to date has evaluated the association between screen time and the presence of MAFLD using liver imaging modalities. FibroScan uses ultrasound measures of controlled attenuation parameter (CAP) to assess liver steatosis (fat) and ultrasound combined with vibration-controlled transient elastography (TE) to assess liver fibrosis (stiffness) and is a non-invasive, evidence-based method of assessing liver disease in pediatric patients (Chen & Pan, 2022). The purpose of this study was to examine the association of screen time with liver steatosis and/or fibrosis using FibroScan technology in a nationally representative sample of adolescents aged 12 to 17 as mediated by overweight/obesity. It was hypothesized that screen time will positively predict liver steatosis and/or fibrosis using FibroScan technology and that being overweight or obese will mediate this relationship.

Methods

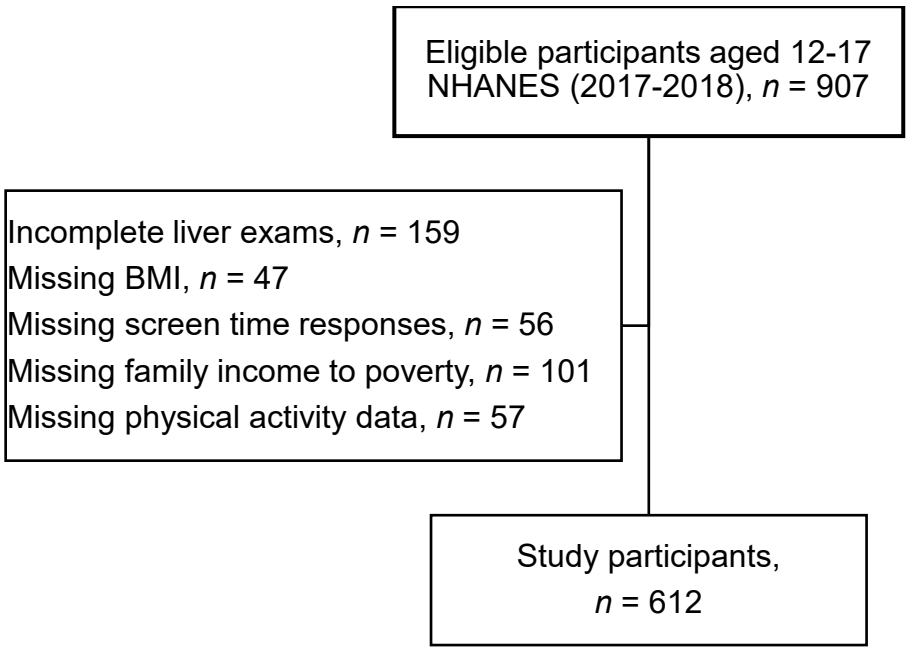
Study Design and Population

This study utilized existing data from the 2017-2018 National Health and Nutrition Examination Survey (NHANES). NHANES is a cross-sectional survey with stratified, multistage, clustered probability sampling design including individuals who are representative of the general, non-institutionalized population, aged two months and older (CDC, 2017-2018).

The eligible population for the current study of the association between the independent variable average daily screen time (continuous) and the dependent variable liver disease (yes/no [referent]) were adolescents 12 to 17 years of age (n = 907). Exclusion criteria were known self-reported history of viral or autoimmune liver disease, serological evidence of Hepatitis B or C, and missing or incomplete data for screen time, BMI, FibroScan exam, or covariates age, race/ethnicity, sex, family income, or physical activity for a final study population (n = 612) (Figure 1). Analysis for mediation by weight category (overweight/obese yes vs. overweight/obese no[referent]) was conducted for the association of screen time with liver disease. Participants were questioned about their history of liver disease, and all denied knowledge of fibrosis, cirrhosis, viral hepatitis, and autoimmune liver disorders. Two participants were aware they have fatty liver disease, which was confirmed on FibroScan examination. No participants were found to have serological evidence of acute or chronic hepatitis B or C.

Figure 1

Selection of Study Participants from Adolescents Aged 12-17, NHANES 2017-2018



Data Collection

NHANES combines in home health interviews with standardized health examinations. Questions of demographic and personal information (age, sex, race/ethnicity, and family income) were asked directly to adolescents aged sixteen and older; a proxy responded for younger adolescents and for older children unable to answer the questions. The family income to poverty ratio (FIPR) was calculated using annual Department of Health and Human Services poverty guidelines. The FIPR was analyzed by quartiles with the highest quartile serving as the referent category. Questions regarding screentime and physical activity were asked in the home for individuals aged 16 and older and in the Mobile Examination Center (MEC) for adolescents aged 12 to 15. All adolescents answered these questions themselves unless they were unable, in which case a proxy was used. For screen time, adolescents were asked two questions about their screen use in the last 30 days, “On average how many hours per day did you sit and watch TV or

videos?" and "On average, how many hours per day did you use a computer or play computer games outside of school? Include PlayStation, Nintendo DS, or other portable video games." These hours were combined to form an average daily screentime variable (continuous). Physical activity was assessed by asking "During the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?" and analyzed as a continuous variable. Physical exam included measurement of weight and height to generate a body mass index (BMI). BMI was then characterized as overweight/obese if it was at the 85th percentile or above for age and sex according to CDC growth charts (National Center for Health Statistics, n.d.).

Liver evaluation was performed using FibroScan® Model 502 V2 Touch by trained NHANES health technicians in the MEC according to manufacturer guidelines. Data from all 12–17-year-olds with completed elastography examination (fasting time at least three hours, minimum 10 complete stiffness measures, and liver stiffness interquartile (IQRe) range/ median stiffness <30%) were analyzed. FibroScan uses transient elastography (TE) to derive median liver fibrosis and controlled attenuation parameter (CAP) to derive median liver steatosis. Cutoffs of 7.3 E/kPa on TE measurement and 233 dB/m on CAP measurement were used to denote the presence of clinically significant fibrosis and steatosis, respectively, in accordance with current literature in pediatric liver disease evaluation (Chen & Pan, 2022). A dichotomous variable Liver Disease (yes/no[referent]), was created for the presence of fibrosis and/or steatosis on FibroScan exam.

Statistical Procedures

Univariate analysis. Descriptive statistics for continuous variables (screen time (hours/day), physical activity (days/week) and age (years)) included measures of centrality (mean) and dispersion (standard deviation) and graphical displays (histograms). Frequency

distributions were examined for categorical variables (liver disease, weight status, sex, race/ethnicity, and FIPR quartiles).

Bivariate analysis. Across two liver disease status groups, associations were tested by Student's two-sample t-test for continuous variables (screen time, physical activity, and age) and chi-square test for categorical variables (liver disease, weight status, sex, race/ethnicity, and FIPR quartiles).

Multivariable analysis. Adjusted logistic regression analysis was performed to describe the independent association between screen time and liver status. A series of logistic regression analyses were carried out to test the hypothesis that overweight/obesity status mediates the relationship between screen time and liver disease. One model regressed liver disease on screen time. Another model regressed obesity on screen time. A third model regressed liver disease on screen time and obesity. Adjustments were made for age, sex, race/ethnicity, FIPR quartiles, and physical activity for all regressions. The indirect effect of daily screen time on liver disease through overweight/obesity status was determined by the product of coefficients method (a*b). Sobel's test was used to determine whether overweight/obesity mediates the association between daily screen time and the presence of liver steatosis and/or fibrosis in adolescents. All tests were two-sided and conducted at the $\alpha = 0.05$ level of significance. Analyses were performed using Statistical Package for the Social Sciences (SPSS) IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp.

Results

Overall, 234 (38%) adolescents had evidence of liver disease (steatosis and/or fibrosis) on FibroScan (Table 1).

Table 1

*Results of FibroScan Testing for Liver Disease - Fibrosis and Steatosis, Participants Aged 12-17 Years, NHANES 2017-2018**

	Fibrosis present ***n* (% of total)**	**Fibrosis absent** ***n* (% of total)**	**Total** ***n* (% of total)**
Steatosis present ***n* (% of total)**	25 (4.1)	200 (32.7)	225 (36.8)
Steatosis absent ***n* (% of total)**	9 (1.5)	378 (61.8)	387 (63.2)
Total ***n* (% of total)**	34 (5.6)	578 (94.4)	612 (100)

*Cutoffs of 7.3 E/kPa on TE measurement and 233 dB/m on CAP measurement were used to denote the presence of clinically significant fibrosis and steatosis, respectively (Chen & Pan, 2022).

In the sample population, the average age of adolescents was 14.7 years (*SD* = 1.7) (Table 2). The mean screen time for all participants was 5.8 hours per day (*SD* = 2.8). A sizeable proportion of adolescents in the study were overweight or obese (43%). Overall, there was a fairly equal distribution between male (48%) and female (52%) participants. Non-Hispanic Whites (34%) comprised the largest racial/ethnic group, followed by Hispanic (24%) and non-Hispanic Black (22%).

Table 2

Characteristics of NHANES 2017-2018 Cross-Sectional Study Participants Aged 12-17 Years, Overall, and by Liver Disease (Steatosis and/or Fibrosis) on FibroScan Imaging

Characteristic	Overall *N* = 612	Liver Disease *N* = 234 (38.2%)	No Liver Disease *N* = 378 (61.8%)	*p*-value*
Screen time (hours/day) mean ± SD	5.75 ± 2.82	6.15 ± 2.78	5.51 ± 2.82	.006*
Physical activity (days/week) mean ± SD	3.79 ± 2.24	3.71 ± 2.25	3.83 ± 2.24	.507
Weight status, *n* (%)				<.001*
Overweight/obese	263 (42.97)	165 (70.51)	98 (25.93)	
Not overweight/obese	349 (57.03)	69 (29.49)	280 (74.07)	
Gender, *n* (%)				.018*
Male	295 (48.20)	127 (54.27)	168 (44.44)	
Female	317 (51.80)	107(45.73)	210 (55.56)	
Age (years at screening) mean ± SD	14.72 ± 1.66	14.84 ± 1.54	14.65 ± 1.73	.150
Race/ethnicity, *n* (%)				.160
Non-Hispanic White (ref)	205 (33.50)	65 (27.78)	140 (37.04)	
Non-Hispanic Black	134 (21.90)	53 (22.65)	81 (21.43)	
Hispanic	147 (24.02)	64 (27.35)	83 (21.96)	
Non-Hispanic Asian	63 (10.29)	24 (10.26)	39 (10.32)	
Other	63 (10.29)	28 (11.97)	35 (9.26)	
Family income to poverty ratio (FIPR) quartiles, *n* (%)				.012*
≤ 1.02	161 (26.31)	78 (33.33)	83 (21.96)	
>1.02 and < 1.82	156 (25.49)	59 (25.21)	97 (25.66)	
1.82 to < 3.33	148 (24.18)	51 (21.79)	97 (25.66)	
≥ 3.33 (ref)	147 (24.02)	46 (19.66)	101 (26.72)	

p-values for comparison between Liver Disease and No Liver Disease were conducted by *t*-test (continuous) or Chi-square test (categorical)
**p*-value significant at α=0.05

Significant differences between adolescents with and without liver disease were seen for screen time, weight status, gender, and FIPR quartiles. There was a significant effect of daily screen time on liver disease status, t (610) = 2.74, p = .006, with adolescents who had evidence of liver steatosis and/or fibrosis spending an average of 38.4 minutes (95% CI, 11.0 - 65.8) per day longer on screens outside of school than those who did not have liver disease on FibroScan. There was a significant difference in liver disease by weight status, (χ^2 (1, N = 612) = 117.24, p < .001); 63% of those with overweight/obesity had liver disease compared with 20% of those who

were not overweight/obese. Participants with liver disease differed by sex, (χ^2 (1, N = 612) = 5.59, p = .018) with 43% of males having liver disease, compared with 34% of females. The frequency of participants with liver disease was significantly different by FIPR quartile (χ^2 (3, N = 612) = 11.02, p = .012). No significant differences were seen on bivariate analysis between those with and without liver disease on imaging by days of physical activity per week.

In multivariable logistic regression (Table 3), after adjusting for age, sex, race, and FIPR, the odds of liver steatosis and/or fibrosis on liver imagining were 8% higher for each additional hour of daily screen time (aOR = 1.080; 95% CI = 1.015, 1.150; p = 0.016). Significant associations with liver disease were also seen with male sex, Hispanic ethnicity (compared to non-Hispanic White race), and the lowest FIPR quartile (compared to the highest FIPR quartile). Physical activity was not significant when adjusted for in the regression of liver disease on screen time.

Table 3

Total Multivariable Logistic Regression for Liver Disease (Steatosis and/or Fibrosis) by Average Daily Screen Time, NHANES 2017-2018 Participants Aged 12-17 Years, (N = 612)

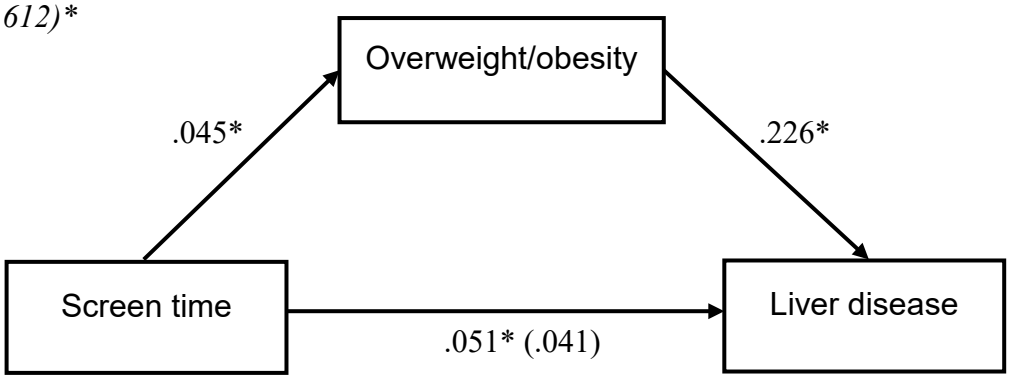
Variable	Unstandardized Coefficient	Adjusted Odds Ratio (95% CI[a])	*p*-value
Screen time (hours/day)	.077	1.080 (1.015-1.150)	.016*
Physical activity (days/week)	-.009	.991 (.917-1.071)	.812
Sex			
Male	.446	1.562 (1.102-2.215)	.012*
Female (referent)	-	-	-
Age (years at screening)	.022	1.023 (.919-1.137)	.680
Race			
Non-Hispanic White (ref)	-	-	-
Non-Hispanic Black	.275	1.317 (.824-2.105)	.250
Hispanic	.533	1.704 (1.082-2.684)	.022*
Non-Hispanic Asian	.331	1.392 (.758-2.558)	.287
Other	.516	1.675 (.923-3.038)	.090
Family income to poverty ratio (FIPR) quartiles			
≤ 1.02	.728	2.070 (1.274-3.363)	.003*
>1.02 and < 1.82	.308	1.360 (.827-2.239)	.226
1.82 to < 3.33	.068	1.070 (.646-1.774)	.792
≥ 3.33 (ref)	-	-	-

Note. Covariates include gender, age, race, and family income to poverty ratio, and physical activity by quartiles.
[a]CI is confidence interval
**p*-value significant at α=0.05

Sobel's test (unstandardized ab = .128, Z=2.053, p = .040) confirmed that overweight/obesity significantly mediates the relationship between screen time and liver disease (Figure 2). Screen time positively affect overweight/obese status (β=.045, z=4.287, p = .038) and overweight/obese status, in turn is positively associated with liver disease (β=.226, z=101.492, p < .001) (Table 4). Physical activity was not significant when adjusted for in the regression of overweight/obesity status on screen time. After accounting for the mediating effect of overweight/obese status, screen time has a small, not statistically significant direct effect, on liver disease (β=.041, z=3.037, p = .081). Overweight/obese status accounted for 19.6% of the total effect (Table 5).

Figure 2

*Mediation Pathway of the Relationship between Screen time and Liver Disease (Steatosis and/or Fibrosis) as Mediated by Overweight/obesity in Adolescents Aged 12-17, NHANES 2017-2018, (N = 612)**



Note. Standardized regression coefficients for the relationship between screen time and liver disease (steatosis and/or fibrosis) as mediated by overweight/obesity. The direct effect between screen time and liver disease, controlling for overweight/obesity, is in parentheses.
Adjustments were made for age, sex, race/ethnicity, and family income to poverty ratio quartile, and physical activity for all regressions.
*p-value significant at α=0.05

Table 4

Mediation Path Estimates for the Relationship between Screen time and Liver Disease (Steatosis and/or Fibrosis) as Mediated by Overweight/obesity, (N = 612).

Relationship	Unstandardized β	Standardized β	aOR (95% CI)	*p*
Screen time (a) → Overweight/obesity	.065	.045	1.067 (1.003-1.134)	.038*
Overweight/obesity (b) → Liver Disease	1.968	.226	7.156 (4.880-10.494)	<.001*
Screen time (c') → Liver Disease (Direct)	.062	.041	1.064 (.992-1.097)	.081
Screen time (c) → Liver Disease (Total)	.077	.051	1.080 (1.015-1.150)	.016*

Adjustments were made for age, sex, race/ethnicity, and family income to poverty ratio quartile, and physical activity for all regressions.
[a]CI is 95% confidence interval
*p-value significant at α=0.05

Table 5

Mediation Path Effects for the Relationship between Screen time and Liver Disease (Steatosis and/or Fibrosis) as Mediated by Overweight/obesity, (N = 612).

Effect	Standardized estimate	Mediation (%)
Indirect (ab)	.010	19.6
Direct (c')	.041	
Total (ab+c')	.051	

Discussion

It was hypothesized that screen time would positively predict liver steatosis and fibrosis identified on FibroScan technology. While screen time did not have a significant direct effect on the presence of liver disease, the average daily screen time in adolescents had an indirect effect through BMI on imaging apparent liver disease. Overweight or obese status accounted for 19.6% of the total effect between screen time and imaging apparent liver disease. Other studies have demonstrated that blood biomarkers, such as alanine aminotransferase (ALT) are not sensitive for the detection of steatosis and fibrosis in adolescents (Ciardullo, Monti, & Perseghin, 2021). This is the first known study to evaluate the association between screen time and the presence of MAFLD using liver imaging modalities.

Although other studies demonstrated prospectively that adolescents who are more physically active are less likely to have liver adiposity on ultrasound (Anderson et al., 2016), the present cross-sectional analysis did not reveal a significant difference in mean days per week with 60 minutes or more of moderate to vigorous activity by liver disease status. This difference in findings may reflect an information bias due to the self-reported exercise status in the present study, whereas an accelerometer was used to measure physical activity in Anderson et al. (2016). Other studies have shown that physical activity and screen time are both are independent predictors of obesity (O'Brien, Issartel, & Belton, 2018). Sedentary screen usage and physical

activity are not mutually exclusive and not necessarily functional opposites. Stemming the tide of obesity and liver disease in adolescents may involve interventions directed at both decreasing sedentary screen usage and increasing physical activity.

Insulin resistance is closely tied to the prevalence of overweight/obesity. Studies have shown that increased screen time is associated with elevated insulin resistance in adolescents (Hardy et al., 2010). Insulin resistance is furthermore associated with the incidence and progression of fatty liver disorders (Manco, 2017). While the presence of obesity mediates the relationship between increased screen time and liver disease, insulin sensitivity may be another mediating factor along this pathway. Additionally, increased sedentary activity has been associated with decreased activity of muscle lipoprotein lipase (LPL) which regulates blood lipid concentration and carbohydrate metabolism (Park, Moon, Kim, Kong, & Oh, 2020). The present study did not evaluate metabolic factors associated with obesity and fatty liver disease; however further studies could evaluate the role of metabolic factors in the appearance of fatty liver diseases on imaging in adolescents with high screen usage.

Limitations of this study include the following: 1) The study did not assess food consumption or sleep patterns associated with screen use which may impact the observed relationship between screen time and fatty liver disease. 2) Information bias could occur from under-reporting of screen usage. Additionally, it is likely that screen usage is underestimated in the study since the screen time questions excluded use during the school day. 3) Participants were asked about their screen usage in the prior 30 days, which may not reflect usual or long-term screen usage. 4) Although multiple variables were controlled for in the analysis, it is possible that others exist that may confound the results. 5) Since this was a cross-sectional study, a temporal relationship between screen time and liver disease cannot be determined.

The strengths of this study include the utilization of data from a nationally representative sample of adolescents. Selection bias is unlikely as NHANES uses rigorous sampling methods. The study results are generalizable to adolescents in the U.S., but potentially not to other countries where cultural factors may influence screen usage, other obesity risk factors such as diet and physical activity, and the prevalence of fatty liver disease.

Conclusion

Increasing screen time is associated with liver steatosis and fibrosis in U.S. adolescents. This relationship is significantly mediated by overweight/obese status. Fatty liver disease is increasing in prevalence in teens in the U.S., mirroring the increases in screen time and overweight/obesity. This is concerning because fatty liver diseases progress in severity over time and the morbidity and mortality associated with chronic liver diseases is expected to increase as cohorts of adolescents age into adulthood. Non-invasive FibroScan testing may see wider application in adolescents to diagnosis liver disease and monitor progression. Longitudinal studies could assess the effect of screen time on metabolic risk factors which impact liver disease in adolescents. Currently, there are no evidence-based medical interventions for fatty liver disease in adolescents. Treatment is focused on encouraging a healthy diet and increased physical activity. Reduction of screen time is another lifestyle target to decrease MAFLD by reducing the prevalence of obesity.

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