



## Physical activity, sedentary, and dietary behaviors associated with indicators of mental health and suicide risk

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### ABSTRACT

We used data from the 2017 national Youth Risk Behavior Survey to examine associations between physical activity, sedentary, and healthy dietary behaviors and indicators of mental health, suicidal thoughts, and suicidal attempts among a representative sample of US high school students. Sex-stratified logistic regression was used to separately model each mental health-related outcome on the health-related behaviors, while controlling for race/ethnicity, grade, and body weight status. Significant associations were found between insufficient physical activity, sedentary, and less healthy dietary behaviors and the mental health-related outcomes. Feeling sad and hopeless was associated with not eating breakfast on all 7 days (past week), drinking soda or pop (female only), not meeting the aerobic physical activity guideline (male only), not playing on at least one sports team, and playing video/computer games or using a computer more than two hours (per day). Suicidal thoughts were associated with not eating breakfast on all 7 days, drinking soda or pop, not meeting the aerobic physical activity guideline, and playing video/computer games or using a computer more than two hours per day. Attempted suicide was associated with not eating breakfast on all 7 days, drinking soda or pop, drinking sports drinks, watching television more than two hours per day, and playing video or computer games or using a computer more than two hours per day (male only). While limiting sedentary behaviors and increasing physical activity and healthy dietary behaviors is not a sole solution for improving mental health among adolescents, it could be another possible strategy used in schools to benefit all students.

### 1. Introduction

In a given year, a total of 13–20% of children and adolescents living in the United States experience a mental health disorder, including behavioral or conduct problems, anxiety, and depression (Perou et al., 2013). Poor mental health can interfere with regular daily activities such as relationships and learning and achieving in school (Burton et al., 2014; Perou et al., 2013; Wood et al., 2012). Further, suicide is the second leading cause of death among adolescents ages 10–19 in the United States (Centers for Disease Control and Prevention (CDC), 2018). Adolescents who attempt or die by suicide often suffer from

feelings of sadness, hopelessness, depression, or other undiagnosed mental health disorders (World Health Organization, 2014; Turecki and Brent 2016; Bilsen, 2018).

Modifiable health risk factors, such as smoking, drinking, and using drugs, have been shown to be associated with poor mental health and suicidal behaviors (Substance Abuse and Mental Health Services Administration, 2017; Dowdy et al., 2013; Lowry et al., 2014). However, less research has explored how physical activity, sedentary, and dietary behaviors are associated with mental health and suicidal behaviors among adolescents. Focusing on these modifiable behaviors could help schools identify other strategies to benefit the health and

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wellbeing of all students, including their mental health outcomes (Centers for Disease Control and Prevention, 2011).

The *Physical Activity Guidelines for Americans*, 2nd edition (Guidelines) recommend adolescents do 60 minutes of moderate-to-vigorous physical activity daily (US Department of Health and Human Services, 2018). As part of their 60 or more minutes of daily physical activity, adolescents should include muscle-strengthening and bone-strengthening physical activity on at least 3 days of the week. However, less than one-third (26.1%) of US high school students are meeting the national recommended minutes of physical activity and just over half (51.1%) are meeting the recommendation for muscle strengthening (Kann et al., 2018). Insufficient physical activity could negatively affect students' physical, social, and psychological well-being (Biddle et al., 2019; Lubans et al., 2016; Broshnan et al., 2004; Brown et al., 2007; Brown et al., 2013). The Guidelines also indicate that moderate to strong evidence shows that physical activity reduces the risk of depression and depressive symptoms (US Department of Health and Human Services, 2018). In a recent study, an association was found between not meeting the physical activity guidelines and increased suicide ideation (Pfledderer et al., 2019). This is also supported by a meta-analysis finding that physical activity is a promising method for reducing suicide ideation (Vancampfort et al., 2018). Furthermore, associations have been found between not participating in physical activity or in team sports and challenges in developing adolescents' social networks, which has been shown to be protective from anxiety or depression (Doré et al., 2016; Smith, 2003), and both of these have been shown to be correlated with suicidal thoughts or attempts (May and Klonsky, 2016).

Sedentary behaviors, which involve low exertion of energy such as behaviors that involve prolonged periods of sitting, also may affect adolescent mental health (Hoare et al., 2014; Tremblay et al., 2011). Studies assessing participation in sedentary behaviors, especially TV and social media screen time, indicate greater risk for poor mental health and suicidal behaviors among adolescents (Rostad et al., 2018). In addition, increased engagement in sedentary behaviors during adolescence is associated with feeling less connected to parents and peers (Richards et al., 2010). As a result, sedentary behaviors may increase feelings of social isolation, which is a risk factor for poor mental health and suicidal behaviors (Bearman and Moody, 2004). More research is needed to determine how and to what extent sedentary behaviors influence mental health both with and independent of physical activity levels.

Similar to physical activity behaviors, most US adolescents do not meet recommendations for healthy eating (Krebs-Smith et al., 2010), which has implications for their physical and mental health (Dietary Guidelines Advisory Committee, 2015; US Department of Health and Human Services and US Department of Agriculture, 2015; O'Neil et al., 2014). Previous research has shown that unhealthy dietary patterns are associated with depression, low mood, and anxiety among adolescents (Hoare et al., 2014; O'Neil et al., 2014; Khalid et al., 2016; Oddy et al., 2018). Inadequate intake of breakfast (Fulkerson et al., 2004; Arbour-Nicitopoulos et al., 2012), and fruit and vegetables (Neumark-Sztainer et al., 1996), are associated with depressive symptoms. Additionally, daily soda consumption has been shown to be associated with feeling sad or hopeless, suicide ideation, and suicide attempts (Solnick and Hemenway, 2014). More research is needed to determine what extent unhealthy dietary behaviors are associated with adolescent mental health.

This study extends the current literature by describing the associations of insufficient physical activity, sedentary, and less healthy dietary behaviors with feelings of sadness or hopelessness, and suicidal thoughts and attempts among US high school students. However, it is not intended to provide any conclusions regarding the direction of the associations but rather to better understand the relationships among these variables that could inform schools of another possible rationale to implement policies and practices that decrease sedentary behaviors

and increase physical activity and healthy dietary behaviors among students. Previous studies have only focused on one health behavior, fewer measures of physical activity and dietary behaviors, and previous national recommendations for health behaviors.

## 2. Methods

### 2.1. Sample and survey administration

The 2017 national Youth Risk Behavior Survey (YRBS) collected cross-sectional data on a wide range of priority health risk behaviors from a nationally representative sample of public and private high school students in grades 9 through 12. The survey used a three-stage probability sampling methodology that has been previously described (Kann et al., 2018; Brener, et al., 2013). A weighting factor was applied to each student record to adjust for the varying probabilities of selection at each stage of sampling, student non-response, and the oversampling of black and Hispanic students. The questionnaire was administered in the classroom during a regular class period by trained data collectors. Responses were recorded directly on computer-scannable questionnaire booklets or answer sheets. Student participation in the survey was anonymous and voluntary, and local procedures were used to obtain parental consent. The school response rate was 75% and the student response rate was 81%, for an overall response rate of 60%, and a sample size of 14,765. The national YRBS has been reviewed and approved by an IRB at the Centers for Disease Control and Prevention (CDC).

### 2.2. Measures

Table 1 identifies the questions and analytic coding for each measure included in the analyses. One indicator of mental health, feeling sad and hopeless, was included in the analyses. Two questions assessed suicidal behaviors.

Four measures of physical activity included daily physical activity, muscle-strengthening activity, physical education, and sports team participation. Two measures of sedentary behaviors focused on screen-time use included television viewing and computer or video game use. Six dietary behaviors included breakfast intake, two questions to determine fruit intake, four questions to determine vegetable intake, intake of soda, intake of sports drink, and water consumption.

Demographic variables included sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and non-Hispanic other), and grade in school (9th–12th). Body weight status was based on body mass index (BMI) calculated from self-reported height and weight. Based on reference data from growth charts produced by CDC, students with BMI  $\geq$  95th percentile for sex and age were considered to have obesity; students with  $85^{\text{th}} \leq$  BMI  $<$  95th percentile were considered to be overweight; students with  $5^{\text{th}} \leq$  BMI  $<$  85th percentile were considered to be normal weight; and students with BMI  $<$  5th percentile were considered to be underweight.

### 2.3. Statistical analysis

All analyses were conducted using SUDAAN (version 11.0.3) to account for the survey's complex sampling design. Analyses were stratified by sex because previous research shows differences for male and female adolescents by mental health-related outcomes and dietary and physical activity behaviors. Statistical interaction testing results did not indicate a need to stratify by race/ethnicity, grade in school, or BMI percentile. Chi-squared tests were used to assess significant ( $p < 0.05$ ) bivariate differences in mental health-related outcomes and physical activity, sedentary, and dietary behaviors by male and female students. Sex-stratified multiple logistic regressions were used to separately model each mental health-related outcome variable on categorical variables for physical activity, sedentary, and dietary behaviors, while

**Table 1**  
Question and Analytic Coding for Included Mental Health and Suicidal Outcomes and Physical Activity, Sedentary, and Dietary Behaviors, 2017 YRBS.<sup>a</sup>

Variable	Question	Analytic Coding
<b>Mental Health and Suicidal Outcomes</b>		
Felt sad and hopeless	During the past 12 months, did you ever feel so sad or hopeless almost every day for two weeks or more in a row that you stopped doing some usual activities?	Yes vs. no
Seriously considered attempting suicide	During the past 12 months, did you ever seriously consider attempting suicide?	Yes vs. no
Attempted suicide	During the past 12 months, how many times did you actually attempt suicide?	≥ 1 attempts vs. 0 attempts
<b>Physical activity behaviors</b>		
Was not physically active for at least 60 min per day on all 7 days <sup>b</sup>	During the past 7 days, on how many days were you physically active for a total of at least 60 min per day? (Add up all the time you spent in any kind of physical activity that increased your heart rate and made you breathe hard some of the time.)	Being physically active for at least 60 min < 7 days (i.e., not meeting the aerobic physical activity guideline) vs. all 7 days (i.e., meeting the aerobic physical activity guideline)
Did not do exercises to strengthen or tone muscles on 3 or more days <sup>b</sup>	During the past 7 days, on how many days did you do exercises to strengthen or tone your muscles, such as push-ups, sit-ups, or weight lifting?	Did exercises to strengthen or tone muscles on < 3 days (i.e., not meeting the muscle strengthening physical activity guideline) vs. ≥ 3 days (i.e., meeting the muscle strengthening physical activity guideline)
Did not attend physical education classes on all 5 days <sup>c</sup>	In an average week when you are in school, on how many days do you go to physical education (PE) classes?	Attended physical education classes < 5 days vs. all 5 days.
Did not play on at least one sports team	During the past 12 months, on how many sports teams did you play? (Count any teams run by your school or community groups.)	Played on none vs. ≥ 1 sports team
<b>Sedentary behaviors</b>		
Watched television more than 2 h per day <sup>d</sup>	On an average school day, how many hours do you watch TV?	More than 2 h per day vs. ≤ 2 h
Played video or computer games or used a computer more than 2 h per day <sup>d</sup>	On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work? (Count time spent on things such as Xbox, PlayStation, an iPad or other tablet, a smartphone, texting, YouTube, Instagram, Facebook, or other social media.)	More than 2 h per day vs. ≤ 2 h
<b>Dietary behaviors</b>		
Did not eat breakfast on all 7 days	During the past 7 days, on how many days did you eat breakfast?	Not all 7 days vs. all 7 days
Ate fruit or drank 100% fruit juice less than one time per day	Based on two questions: <ul style="list-style-type: none"> <li>• During the past 7 days, how many times did you drink 100% fruit juices such as orange juice, apple juice, or grape juice? (Do not count punch, Kool-Aid, sports drinks, or other fruit-flavored drinks.)</li> <li>• During the past 7 days, how many times did you eat fruit? (Do not count fruit juice.)</li> </ul>	Summed both items to determine total fruit intake and was coded as ate fruit or drank 100% fruit juice less than one time per day vs. ≥ 1 times per day
Ate vegetables less than one time per day	Based on four questions: During the past 7 days, how many times did you eat... <ul style="list-style-type: none"> <li>• green salad</li> <li>• potatoes? (Do not count french fries, fried potatoes, or potato chips.)</li> <li>• carrots</li> <li>• other vegetables? (Do not count green salad, potatoes, or carrots.)</li> </ul>	Summed four items to determine total vegetable intake and was coded as ate vegetables less than one time per day vs. ≥ 1 times per day
Drank soda or pop one or more times per day	During the past 7 days, how many times did you drink a can, bottle, or glass of soda or pop, such as Coke, Pepsi, or Sprite? (Do not count diet soda or diet pop.)	Drank a can, bottle, or glass of soda or pop one or more times per day vs. did not drink soda or pop
Drank a sports drink one or more times per day	During the past 7 days, how many times did you drink a can, bottle, or glass of a sports drink such as Gatorade or Powerade? (Do not count low-calorie sports drinks such as Propel or G2.)	Drank a sports drink one or more times per day vs. did not drink a sports drink
Did not drink three or more glasses of plain water per day	During the past 7 days, how many times did you drink a bottle or glass of plain water? (Count tap, bottled, and unflavored sparkling water.)	Drank less than three glasses of water per day vs. ≥ 3 glasses per day

<sup>a</sup> The questions and responses are from the 2017 National Youth Risk Behavior Survey at [https://www.cdc.gov/healthyouth/data/yrbs/pdf/2017/2017\\_yrbs\\_national\\_hs\\_questionnaire.pdf](https://www.cdc.gov/healthyouth/data/yrbs/pdf/2017/2017_yrbs_national_hs_questionnaire.pdf).

<sup>b</sup> Measure aligns with *The Physical Activity Guidelines for Americans, 2nd edition*.

<sup>c</sup> Measure aligns with CDC's school health guidelines.

<sup>d</sup> The American Academy of Pediatrics recommends placing consistent limits on the time spent using media and the types of media for adolescents and ensuring that media does not take the place of adequate sleep, physical activity, and other behaviors essential to health. The cut point for these variables is based on previous guidance of "2 h or less," which has been used in previous studies.

controlling for race/ethnicity, grade, and body weight status. Results from the multivariable analyses are reported as adjusted prevalence ratios (APRs) with 95% confidence intervals. APRs were considered statistically significant if  $p < 0.05$  or the 95% confidence interval (CI) did not include 1.0.

### 3. Results

#### 3.1. Sample description

The overall sample was 14,765 US high school students with approximately half females (50.7%). A total of 53.5% were non-Hispanic white, 13.4% were non-Hispanic black, 22.8% were Hispanic, and 10.3% were non-Hispanic other. The sample was distributed across the

**Table 2**  
Mental Health and Suicidal Outcomes and Physical Activity, Sedentary, and Dietary Behaviors by Sex Among U.S. High School Students, 2017 YRBS.

Outcomes and Behaviors	Overall (14,765)		Females (n = 7526)		Males (n = 7112)		P Value <sup>a</sup>
	n	%	n	%	n	%	
<b>Mental Health and Suicidal Outcomes</b>							
Felt sad and hopeless <sup>b,c</sup>	4631	31.5	3059	41.1	1519	21.4	< 0.001
Seriously considered attempting suicide <sup>b</sup>	2571	17.2	1684	22.1	848	11.9	< 0.001
Attempted suicide <sup>b</sup>	837	7.4	541	9.3	278	5.1	< 0.001
<b>Physical Activity Behaviors</b>							
Was not physically active for at least 60 min per day on all 7 days (did not meet the aerobic physical activity guideline) <sup>d,e</sup>	10,796	73.8	6131	82.5	4565	64.7	< 0.001
Did not do exercises to strengthen or tone muscles on 3 or more days <sup>d,f</sup>	5389	49.9	3315	59.2	2023	37.9	< 0.001
Did not attend physical education classes on all 5 days	10,361	70.1	5616	74.7	4655	65.3	< 0.001
Did not play on at least one sports team <sup>b,g</sup>	5307	45.7	2950	50.7	2312	40.3	0.001
<b>Sedentary Behaviors</b>							
Watched television more than 2 h per day <sup>h</sup>	3077	20.7	1556	20.6	1498	20.8	0.82
Played video or computer games or used a computer more than 2 h per day <sup>h,i</sup>	5984	43.0	3044	43.1	2890	43.0	0.95
<b>Dietary Behaviors</b>							
Did not eat breakfast on all 7 days <sup>d</sup>	7783	64.7	4226	69.0	3491	60.1	< 0.001
Ate fruit or drink 100% fruit juice less than one time per day <sup>d,j</sup>	5889	39.3	3188	41.9	2656	36.7	< 0.001
Ate vegetables less than one time per day <sup>d,k</sup>	5807	40.6	3023	40.7	2741	40.6	0.90
Drank soda or pop one or more times per day <sup>d,l</sup>	2650	18.7	1124	15.4	1503	22.3	< 0.001
Drank sports drink one or more times per day <sup>d,m</sup>	1401	12.4	491	8.26	900	16.9	< 0.001
Drank less than three glasses of water per day <sup>d,n</sup>	5284	48.7	2743	48.8	2495	48.6	0.80

<sup>a</sup> Chi-square. Difference between females and males.  
<sup>b</sup> During the past 12 months.  
<sup>c</sup> Almost every day for two weeks or more in a row that you stopped doing some usual activities.  
<sup>d</sup> During the past 7 days.  
<sup>e</sup> Adding up time spent in any kind of physical activity that increased their heart rate and made them breathe hard some of the time.  
<sup>f</sup> Such as push-ups, sit-ups, or weight lifting.  
<sup>g</sup> Counting any teams run by their school or community groups, during the 12 months before the survey.  
<sup>h</sup> On an average school day.  
<sup>i</sup> Counting time spent on things such as Xbox, PlayStation, an iPad or other tablet, a smartphone, texting, YouTube, Instagram, Facebook, or other social media.  
<sup>j</sup> This variable included two questions: how many times did you drink 100% fruit juices such as orange juice, apple juice, or grape juice? (Do not count punch, Kool-Aid, sports drinks, or other fruit-flavored drinks) and how many times did you eat fruit? (Do not count fruit juice).  
<sup>k</sup> This variable included four questions: how many times did you eat green salad?, how many times did you eat potatoes? (Do not count French fries, fried potatoes, or potato chips), how many times did you eat carrots?, and how many times did you eat other vegetables? (Do not count green salad, potatoes, or carrots).  
<sup>l</sup> Such as Coke, Pepsi, or Sprite, not counting diet soda or diet pop.  
<sup>m</sup> Such as Gatorade or PowerAde, not counting low-calorie sports drinks such as Propel water or G2.  
<sup>n</sup> Counting tap, bottled, and unflavored sparkling water.

grades in school, 27.3% were in 9th grade, 25.6% in 10th, 23.9% in 11th, and 23.0% in 12th. Most US high students had a normal body weight (66.6%), 15.6% were overweight, 14.8% had obesity, and 3.0% were underweight. The analytic sample varied for each model due to missing data from listwise deletion (see Tables 3 and 4 for analytic sample sizes).

Table 2 provides the prevalence estimates and chi-squared p-values of the mental health and suicide-related outcomes and health-related behaviors stratified by sex. Female students compared with male students had significantly higher prevalence rates for feeling sad or hopeless, suicidal thoughts, and suicide attempts. All outcomes and health behaviors were significantly different for males and females except for two of the dietary behaviors and both sedentary behaviors.

Female students compared with male students had significantly higher prevalence of all the insufficient physical activity behaviors. Female students compared to male students had significantly higher prevalence rates for not eating breakfast and for eating fruit or drinking 100% fruit juice. Whereas male students compared to female students had significantly higher prevalence rates for drinking soda or pop and drinking sports drinks.

### 3.2. Associations of physical activity and sedentary behaviors with mental health and suicidal outcomes

Male students who did not meet the aerobic physical activity guideline were 23% more likely to feel sad and hopeless than those who

did (Table 3). Female and male students who did not play on at least one sports team compared to those who did were 16% and 18%, respectively, more likely to feel sad and hopeless. Female and male students who played video or computer games or used a computer more than two hours per day compared to those who did not were more likely to feel sad and hopeless.

Female and male students who did not meet the aerobic physical activity guideline compared to those who did were 35% and 36%, respectively, more likely to have seriously considered attempting suicide. In addition, female and male students who played video or computer games or used a computer more than two hours per day compared to those who did not were 42% and 58%, respectively, more likely to have seriously considered attempting suicide.

None of the physical activity behaviors were significantly associated with suicide attempts. However, female and male students who watched television more than two hours per day compared to those who did not were 55% and 73%, respectively, more likely to have attempted suicide. Furthermore, male students who played video or computer games or used a computer more than two hours per day compared to those who did not were 56% more likely to have attempted suicide.

### 3.3. Associations of dietary behaviors with mental health and suicidal outcomes

Female and male students who did not eat breakfast on all 7 days were 48% and 59%, respectively, more likely to feel sad and hopeless

**Table 3**  
Association between Physical Activity and Sedentary Behaviors and Felt Sad and Hopeless, Seriously Considered Attempting Suicide, and Attempted Suicide Among U.S. High School Students, 2017 YRBS.

Regression Model	Felt Sad and Hopeless <sup>a</sup>				Seriously Considered Attempting Suicide <sup>a</sup>				Attempted Suicide <sup>a</sup>				
	Female n = 5628 <sup>b</sup>		Male n = 5290 <sup>b</sup>		Female n = 5610 <sup>b</sup>		Male n = 5278 <sup>b</sup>		Female n = 5180 <sup>b</sup>		Male n = 4740 <sup>b</sup>		
Independent Variables	%	APR (95% CI)	%	APR (95% CI)	%	APR (95% CI)	%	APR (95% CI)	%	APR (95% CI)	%	APR (95% CI)	
Was not physically active for at least 60 min per day on all 7 days (did not meet the aerobic physical activity guideline) <sup>c,d</sup>	Yes	41.4	0.98 (0.87–1.10)	23.3	1.23* (1.04–1.45)	23.2	1.35* (1.03–1.77)	13.9	1.36** (1.11–1.66)	9.3	1.00 (0.72–1.38)	5.5	1.16 (0.82–1.64)
	No	40.0	(ref)	17.3	(ref)	17.3	(ref)	8.7	(ref)	9.3	(ref)	4.3	(ref)
Did not do exercises to strengthen or tone muscles on 3 or more days <sup>c,e</sup>	Yes	41.5	0.96 (0.86–1.07)	23.5	0.92 (0.78–1.08)	23.4	0.92 (0.80–1.07)	14.2	0.98 (0.79–1.22)	8.9	0.84 (0.66–1.06)	5.2	0.92 (0.57–1.48)
	No	41.2	(ref)	19.9	(ref)	21.5	(ref)	10.6	(ref)	9.8	(ref)	4.4	(ref)
Did not attend physical education classes on all 5 days	Yes	41.0	1.02 (0.89–1.15)	22.7	1.19 (0.99–1.43)	22.3	1.11 (0.93–1.33)	13.0	1.10 (0.90–1.35)	9.1	1.12 (0.78–1.60)	4.7	0.84 (0.60–1.18)
	No	41.4	(ref)	18.5	(ref)	21.4	(ref)	10.2	(ref)	9.7	(ref)	5.6	(ref)
Did not play on at least one sports team <sup>f,g</sup>	Yes	44.3	1.16* (1.02–1.33)	24.3	1.18* (1.04–1.35)	23.9	1.10 (0.91–1.32)	14.3	1.16 (0.91–1.49)	9.7	1.20 (0.89–1.61)	5.2	1.11 (0.80–1.54)
	No	38.1	(ref)	18.9	(ref)	20.4	(ref)	10.4	(ref)	8.6	(ref)	4.6	(ref)
Watched television more than 2 h per day <sup>h</sup>	Yes	46.2	1.08 (0.97–1.20)	21.0	0.93 (0.75–1.14)	27.2	1.18 (1.00–1.40)	12.1	1.00 (0.74–1.36)	14.7	1.55* (1.19–2.01)	7.5	1.73 <sup>i</sup> (1.07–2.79)
	No	39.6	(ref)	21.1	(ref)	20.7	(ref)	11.8	(ref)	7.8	(ref)	4.1	(ref)
Played video or computer games or used a computer more than 2 h per day <sup>h,j</sup>	Yes	46.4	1.21*** (1.09–1.34)	24.6	1.30*** (1.13–1.50)	27.2	1.42*** (1.25–1.63)	15.0	1.58*** (1.32–1.90)	11.3	1.33 (0.98–1.79)	6.3	1.56* (1.04–2.33)
	No	36.9	(ref)	18.5	(ref)	18.3	(ref)	9.6	(ref)	7.5	(ref)	3.7	(ref)

APR = adjusted prevalence ratio; CI = confidence interval; YRBS = Youth Risk Behavior Survey. Regression models assessing the associations between physical activity and sedentary behaviors (independent variables) and mental health-related behaviors (dependent variables), included all physical activity and sedentary behaviors, plus controlling for race/ethnicity, grade, and body weight status. <sup>a</sup>Model adjusted for race/ethnicity, grade in school, and BMI percentile.

\*p ≤ 0.05; \*\*p ≤ 0.01; \*\*\*p ≤ 0.001.

<sup>b</sup> The weighted analytic sample for this model.

<sup>c</sup> During the past 7 days.

<sup>d</sup> Adding up time spent in any kind of physical activity that increased their heart rate and made them breathe hard some of the time.

<sup>e</sup> Such as push-ups, sit-ups, or weight lifting.

<sup>f</sup> During the past 12 months.

<sup>g</sup> Counting any teams run by their school or community groups, during the 12 months before the survey.

<sup>h</sup> On an average school day.

<sup>i</sup> p = 0.06, but the 95% confidence interval (CI) did not include 1.0 so is still considered statistically significant.

<sup>j</sup> Counting time spent on things such as Xbox, PlayStation, an iPad or other tablet, a smartphone, texting, YouTube, Instagram, Facebook, or other social media.

compared to those who did (Table 4). Female students who drank soda or pop one or more times per day in the last 7 days compared to those who did not were 27% more likely to feel sad and hopeless.

Female and male students who did not eat breakfast on all 7 days compared to those who did were 50% and 76%, respectively, more likely to have seriously considered attempting suicide. In addition, female students who drank soda pop one or more times per day compared to those who did not were 36% more likely to have seriously considered attempting suicide.

Female students who did not eat breakfast on all 7 days compared to those who did were more than 2 times as likely to have attempted suicide. Similarly, male students who did not eat breakfast on all 7 days compared to those who did were almost 2 times more likely to have attempted suicide. Both female and male students who drank soda or pop one or more times per day compared to those who did not were 56% and 70%, respectively, more likely to have attempted suicide. In addition, female and male students who drank a sports drink one or more times per day compared to those who did not were 50% and 57%, respectively, more likely to have attempted suicide.

#### 4. Discussion

Mental health and suicidal behaviors among adolescents are a national concern (The National Advisory Mental Health Council Workgroup on Child and Adolescent Mental Health Intervention Development and Deployment, 2001). As a result, Healthy People 2020 created two objectives to address these behaviors, which include “reduce suicide attempts by adolescents” and “reduce the proportion of adolescents aged 12–17 years who experience major depressive episodes” (Office of Disease Prevention and Health Promotion, 2016). Understanding the modifiable risk factors that affect mental health and suicidal behaviors can inform parents, schools, and communities about the types of activities that promote student health and wellbeing. While this study did not make any conclusions about the direction of the results, it did find different associations between insufficient physical activity, sedentary, and less healthy dietary behaviors and feelings of sadness or hopelessness and suicidal thoughts and attempts. Furthermore, the findings indicated that there are differences for female and male students.

**Table 4**  
Association between Dietary Behaviors and Felt Sad and Hopeless, Seriously Considered Attempting Suicide, and Attempted Suicide Among U.S. High School Students, 2017 YRBS.

Regression Model		Felt Sad and Hopeless <sup>a</sup>				Seriously Considered Attempting Suicide <sup>a</sup>				Attempted Suicide <sup>a</sup>			
		Female n = 5632 <sup>b</sup>		Male n = 5320 <sup>b</sup>		Female n = 5618 <sup>b</sup>		Male n = 5308 <sup>b</sup>		Female n = 5191 <sup>b</sup>		Male n = 4755 <sup>b</sup>	
Independent Variables		%	APR (95% CI)	%	APR (95% CI)	%	APR (95% CI)	%	APR (95% CI)	%	APR (95% CI)	%	APR (95% CI)
Did not eat breakfast on all 7 days <sup>c</sup>	Yes	46.2	1.48*** (1.33–1.64)	24.9	1.59*** (1.26–2.00)	24.8	1.50*** (1.35–1.67)	14.7	1.76*** (1.36–2.29)	11.0	2.11*** (1.52–2.93)	6.2	1.98** (1.23–3.19)
	No	30.1	1.0 (ref)	15.4	1.0 (ref)	16.3	1.0 (ref)	7.6	1.0 (ref)	5.3	1.0 (ref)	3.0	1.0 (ref)
Ate fruit or drink 100% fruit juice less than one time per day <sup>c,d</sup>	Yes	41.0	0.95 (0.88–1.03)	22.5	1.07 (0.93–1.24)	22.6	1.01 (0.88–1.16)	13.3	1.15 (0.97–1.36)	8.3	0.83 (0.64–1.07)	5.3	1.13 (0.84–1.52)
	No	41.1	1.0 (ref)	20.7	1.0 (ref)	21.9	1.0 (ref)	11.1	1.0 (ref)	10.0	1.0 (ref)	4.8	1.0 (ref)
Ate vegetables less than one time per day <sup>c,e</sup>	Yes	42.2	1.02 (0.93–1.12)	20.2	0.88 (0.75–1.03)	22.2	1.00 (0.87–1.16)	11.0	0.82 (0.665–1.01)	9.2	0.97 (0.82–1.16)	4.4	0.72 (0.46–1.13)
	No	40.2	1.0 (ref)	21.8	1.0 (ref)	22.1	1.0 (ref)	12.4	1.0 (ref)	9.3	1.0 (ref)	4.8	1.0 (ref)
Drank soda or pop one or more times per day <sup>c,f</sup>	Yes	51.3	1.27*** (1.16–1.38)	25.2	1.17 (0.96–1.43)	28.5	1.36*** (1.18–1.56)	14.7	1.20 (0.92–1.56)	15.0	1.56** (1.22–2.00)	8.0	1.70* (1.12–2.58)
	No	39.2	1.0 (ref)	20.2	1.0 (ref)	20.9	1.0 (ref)	11.2	1.0 (ref)	8.3	1.0 (ref)	4.1	1.0 (ref)
Drank a sports drink one or more times per day <sup>c,g</sup>	Yes	51.1	1.09 (0.93–1.27)	20.8	0.91 (0.70–1.18)	26.1	1.00 (0.82–1.21)	12.4	0.97 (0.73–1.30)	17.7	1.50 <sup>h</sup> (1.01–2.23)	8.6	1.57* (1.17–2.12)
	No	40.3	1.0 (ref)	21.1	1.0 (ref)	21.8	1.0 (ref)	11.7	1.0 (ref)	8.5	1.0 (ref)	3.9	1.0 (ref)
Drank less than three glasses of water per day <sup>c,i</sup>	Yes	41.6	0.96 (0.87–1.06)	21.8	1.01 (0.86–1.17)	22.1	0.90 (0.77–1.05)	13.1	1.14 (0.93–1.41)	9.2	0.86 (0.69–1.07)	5.2	1.23 (0.89–1.71)
	No	41.1	1.0 (ref)	20.6	1.0 (ref)	23.1	1.0 (ref)	10.7	1.0 (ref)	9.4	1.0 (ref)	4.1	1.0 (ref)

APR = adjusted prevalence ratio; CI = confidence interval; YRBS = Youth Risk Behavior Survey.

Regression models assessing the associations between dietary behaviors (independent variables) and mental health-related behaviors (dependent variables), included all dietary behaviors, plus controlling for race/ethnicity, grade, and body weight status.

\*p ≤ 0.05; \*\*p ≤ 0.01; \*\*\*p ≤ 0.001.

<sup>a</sup> Model adjusted for race/ethnicity, grade in school, and BMI percentile.

<sup>b</sup> The weighted analytic sample for this model.

<sup>c</sup> During the past 7 days.

<sup>d</sup> This variable included two questions: how many times did you drink 100% fruit juices such as orange juice, apple juice, or grape juice? (do not count punch, Kool-Aid, sports drinks, or other fruit-flavored drinks) and how many times did you eat fruit? (do not count fruit juice).

<sup>e</sup> This variable included four questions: how many times did you eat green salad?, how many times did you eat potatoes? (do not count french fries, fried potatoes, or potato chips), how many times did you eat carrots?, and how many times did you eat other vegetables? (do not count green salad, potatoes, or carrots).

<sup>f</sup> Such as Coke, Pepsi, or Sprite, not counting diet soda or diet pop.

<sup>g</sup> Such as Gatorade or PowerAde, not counting low-calorie sports drinks such as Propel water or G2.

<sup>h</sup> p = 0.07, but the 95% confidence interval (CI) did not include 1.0 so is still considered statistically significant.

<sup>i</sup> Counting tap, bottled, and unflavored sparkling water.

#### 4.1. Physical activity and sedentary behaviors

Previous research has found associations between adolescents who participated in daily physical activity and considering attempting suicide (Brosnahan et al., 2004; Brown et al., 2007). The current study found a similar inverse association, showing that male and female students who were *not* physically active for at least 60 min daily were more likely to seriously consider attempting suicide. Although previous studies have shown a significant association between physical activity and attempted suicide (Brown et al., 2007; Sibold et al., 2015), the current study did not find this association. Studies that have found this association examined vigorous activity among adolescents on various number of days of doing physical activity (Brown et al., 2007; Sibold et al., 2015), while this study examined self-reported moderate and vigorous physical activity combined and on all 7 days, which aligns with national guidance. In addition, the only sex difference found for physical activity was that male students who did not meet the aerobic physical activity guideline were more likely to feel sad and hopeless. This finding might be explained by the support males get from family, friends, and school environments to be more physically active, which in turn might have a stronger influence on their self-efficacy and level of enjoyment (Wenthe et al., 2009), and ultimately, their overall feelings

and emotions.

In addition, the current study did not find a significant association between sports participation and suicidal behaviors as other studies have shown (Brown et al., 2007; Gunn and Lester, 2014; Southerland et al., 2016). However, there was a significant association for both male and female students that showed not playing on a sports team increased their likelihood of feeling sad and hopeless, which supports the social benefits of playing on a sports team and demonstrates a possible protective effect. The 2019 release of the *National Youth Sports Strategy* also underscores the physical activity, psychosocial, and academic achievement benefits of sports team participation (U.S. Department of Health and Human Services, 2019). Although physical education attendance was not significantly associated with mental health outcomes, it is the cornerstone for Comprehensive School Physical Activity Programs, which serves as a national framework for physical education and physical activity in schools (CDC, 2019). However, only 4% of schools nationwide require daily physical education for all students K-12 (CDC, 2015), suggesting opportunities exist for improving adolescents' attendance in physical education and ultimately increasing daily physical activity.

Adolescents who engage in the recommended levels of daily physical activity can still be at risk for high levels of sedentary behaviors at

other times during the day, subsequently leading to increased risk for undesirable health outcomes (Tremblay et al., 2011). Previous studies have found associations between adolescent sedentary behaviors and poor mental health outcomes, including depression, though some findings have been mixed (Benson et al., 2013; Suchert et al., 2015). In this study, playing video games or using the computer for more than two hours per day was significantly associated with greater likelihood of feeling sad and hopeless and seriously considering suicide. Prolonged periods of engaging in sedentary activities can increase social isolation and feelings of loneliness, which are associated with suicidal thoughts and behaviors (Bearman and Moody, 2004). The observed sex differences for the associations between video game and computer usage and suicide attempts highlight the importance of considering other factors such as social media engagement and video game content. Further exploring the types of video games and websites accessed on computers and the ways in which adolescents engage in video gaming and other media might inform differences between female and male adolescents and differential effects on their mental health (Desai et al., 2010).

#### 4.2. Dietary behaviors

Similar to findings from previous research, the current study found associations between skipping breakfast and increased risk of mental health related outcomes among males and females. Individuals who feel sad and hopeless or experience other mental health issues may be more likely to skip meals because of low appetite or as a dieting strategy. Alternatively, skipping breakfast could lead to lower calorie intake which may contribute to depressed mood (Fulkerson et al., 2004). Further, natural shifts in sleep patterns among adolescents might also lead to breakfast skipping (Crowley et al., 2007). Efforts to support healthy eating behaviors are needed at multiple levels (US Department of Health and Human Services and US Department of Agriculture, 2015). For example, schools can support healthy eating behaviors, including regular consumption of breakfast by participating in the federal school meal programs (e.g., School Breakfast Program), and offering second chance breakfast during morning break at school.

This study also found associations between consuming soda one or more times per day and all three mental health and suicidal outcomes among females. Interestingly, after adjusting for covariates, among males, consuming soda was only associated with having attempted suicide. It is not clear why these differences between female and male students exist. Other research has shown associations between soda intake and similar mental health related outcomes in adolescents but did not stratify results by sex (Solnick and Hemenway, 2014). Research has also shown associations between caffeine consumption and depressive symptoms in both male and female adolescents (Fulkerson et al., 2004). This study was not able to distinguish between caffeinated and non-caffeinated sodas. The American Academy of Pediatrics states that caffeine use among all children should be discouraged (Committee on Nutrition and the Council on Sports Medicine and Fitness, 2011). Although the Smart Snacks in School nutrition standards allow high schools to sell low calorie caffeinated beverages (e.g., diet soda), school districts can establish nutrition standards that specifically address the sale of caffeinated beverages.

One finding that warrants further research is the association between consuming sports drinks one or more times per day and having attempted suicide among females and males. Sports drinks typically contain added sugar and electrolytes, but do not contain caffeine (Committee on Nutrition and the Council on Sports Medicine and Fitness, 2011). However, it is possible that YRBS participants are including energy drinks, which contain added caffeine and other stimulants, when asked about sports drink consumption. These two types of beverages are often confused (Committee on Nutrition and the Council on Sports Medicine and Fitness, 2011), and could affect the results of the analysis.

#### 4.3. Limitations

A few key limitations should be noted. The cross-sectional data used in these analyses do not allow for conclusions regarding the direction of the modeled associations. Specifically, the correlations in this current study do not show causation. While adolescents who have insufficient physical activity and engage in sedentary and less healthy dietary behaviors may experience poor mental health and suicidal thoughts and behaviors, it is also true that adolescents with poor mental health and suicidal thoughts and behaviors might be less likely to engage in healthy behaviors. Depression also could lead to the social withdrawal, lessened activity, and impact on eating behaviors. However, previous evidence has shown support for a causal association from sedentary behavior to depression (Choi et al., 2019). Longitudinal studies are needed to identify potential cause-and-effect associations between modifiable health risk behaviors and mental health and suicidal behaviors.

While many of the statistically significant effects were small in magnitude, the associations were consistent with previous findings. Additional variables that explain personal (e.g., self-efficacy) and contextual (e.g., peer and parent support) factors of health behaviors might yield greater effects and may be considered in future research. In addition, data came from a single survey so associations could represent a shared response bias. Further, the results are based on student self-report responses to self-administered questionnaires, raising the possibility of reporting error or social-desirability bias, and single-item assessments of suicide attempts seem to be problematic (Hom et al., 2016 and 2019). However, YRBS questionnaire items generally demonstrate good test-retest reliability (Brener et al., 2013). CDC also reviewed existing empiric literature to assess cognitive and situational factors that might affect the validity of adolescent self-reporting of behaviors (Brener et al., 2013). Family socioeconomic status was not available but could potentially be a confounder. Results also could be biased by using listwise deletion and not including adolescents who are out of school who may be at higher risk of poor mental health outcomes.

Finally, a greater precision of measurement could be used to assess physical activity, dietary behaviors, sedentary behaviors, and medical record information documenting mental health and suicidal behaviors or more comprehensive scales for these behaviors. Given these limitations, the data should be interpreted cautiously. However, the results of this study reveal potentially important associations between modifiable health risk behaviors and mental health and suicidal behaviors.

#### 5. Conclusion

Promoting physical activity and healthy eating and limiting sedentary behaviors may be useful school and community interventions that reinforce protective factors, which can be beneficial to the mental health of all adolescents. School health teams can lead these efforts to ensure policies and practices are in place to promote physical activity and healthy dietary behaviors while limiting sedentary behaviors (CDC, 2011). These policies and practices can be addressed within the Whole School, Whole Community, Whole Child Model, which demonstrates the interconnectedness of multiple health behaviors and promotes collaboration among a variety of partners such as mental health professionals, school leaders, school nurses, physical and health educators, and parents to promote the health and well-being of all students including students with disabilities (ASCD and CDC, 2014). Equipping students with the knowledge, skills, and opportunities to practice being physically active, eating healthy, and avoid being sedentary could help them better manage stress, anxiety, depression, or other mental health disorders they are experiencing, which in turn will improve the students' well-being and school experience.

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The authors have no conflict of interest to declare.

## Disclaimer

The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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None.

## CRedit authorship contribution statement

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## References

- Arbour-Nicitopoulos, K.P., Faulkner, G.E., Irving, H.M., 2012. Multiple health-risk behaviour and psychological distress in adolescence. *J. Can. Acad. Child Adolesc. Psychiatry* 21, 171–178.
- ASCD, Centers for Disease Control and Prevention. 2014. Whole School, Whole Child, Whole Community: A Collaborative Approach to Learning and Health. Alexandria, VA: ASCD. Available from <http://www.ascd.org/ASCD/pdf/siteASCD/publications/wholechild/wssc-a-collaborative-approach.pdf>.
- Bearman, P.S., Moody, J., 2004. Suicide and friendships among American adolescents. *Am. J. Public Health* 94 (1), 89–95.
- Benson, L.P., Williams, R.J., Novick, M.B., 2013. Pediatric obesity and depression: a cross-sectional analysis of absolute BMI as it relates to children's depression index scores in obese 7-to 17-year-old children. *Clin. Pediatr.* 52 (1), 24–29.
- Biddle, S.J.H., Ciacconi, S., Thomas, G., Vergeer, I., 2019. Physical activity and mental health in children and adolescents: an updated review of reviews and an analysis of causality. *Psychol. Sport Exerc.* 42, 146–155.
- Bilsen, J., 2018. Suicide and youth: risk factors. *Front. Psychiatry* 9, 540–545.
- Brener, N.D., Kann, L., Shanklin, S., et al., 2013. Methodology of the youth risk behavior surveillance system—2013. *MMWR Recomm. Rep.* 62 (1), 1–20.
- Brosnahan, J., Steffen, L.M., Lytle, L., Patterson, J., Boostrom, A., 2004. The relation between physical activity and mental health among Hispanic and non-Hispanic white adolescents. *Arch. Pediatr. Adolesc. Med.* 158, 818–823.
- Brown, D., Galuska, D., Zhang, J., Eaton, D., Fulton, J., Lowry, R., Maynard, L.M., 2007. Physical activity, sport participation, and suicidal behavior: U.S. high school students. *Med. Sci. Sports Exerc.* 39 (12), 2248–2257.
- Brown, H.E., Pearson, N., Braithwaite, R.E., Brown, W.J., Biddle, S.J.H., 2013. Physical activity interventions and depression in children and adolescents: a systematic review and meta-analysis. *Sports Med.* 43, 195–206.
- Burton, C.M., Marshal, M.P., Chisolm, D.J., 2014. School absenteeism and mental health among sexual minority youth and heterosexual youth. *J. Sch. Psychol.* 52 (1), 37–47.
- Committee on Nutrition and the Council on Sports Medicine and Fitness, 2011. Sports drinks and energy drinks for children and adolescents: are they appropriate? *Pediatrics* 127 (6), 1182–1189.
- Centers for Disease Control and Prevention, 2011. School health guidelines to promote healthy eating and physical activity. *MMWR* 60 (5), 1–80.
- Centers for Disease Control and Prevention. 2015. Results from the School Health Policies and Practices Study 2014. Atlanta, GA: Centers for Disease Control and Prevention, US Dept of Health and Human Services. Available from [https://www.cdc.gov/healthyschools/data/shpps/pdf/shpps-508-final\\_101315.pdf](https://www.cdc.gov/healthyschools/data/shpps/pdf/shpps-508-final_101315.pdf).
- Centers for Disease Control and Prevention, 2018. Web-based injury statistics query and reporting system (WISQARS). Available from <https://www.cdc.gov/injury/wisqars/index.html>.
- Centers for Disease Control and Prevention. 2019. Increasing physical education and physical activity: a framework for schools. Atlanta, GA: Centers for Disease Control and Prevention, US Dept of Health and Human Services. Available from [https://www.cdc.gov/healthyschools/physicalactivity/pdf/2019\\_04\\_25\\_PE-PA-Framework\\_508tagged.pdf](https://www.cdc.gov/healthyschools/physicalactivity/pdf/2019_04_25_PE-PA-Framework_508tagged.pdf).
- Choi, K.W., Chen, C.Y., Stein, M.B., Klimentidis, Y.C., Wang, M.J., Koenen, K.C., Smoller, J.W., 2019. Assessment of bidirectional relationships between physical activity and depression among adults: a 2-sample mendelian randomization study. *JAMA Psychiatry*. 76 (4), 399–408.
- Crowley, S.J., Acebo, C., Carskadon, M.A., 2007. Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep Med.* 8, 602–612.
- Desai, R.A., Krishnan-Sarin, S., Cavallo, D., Potenza, M.N., 2010. Video-gaming among high school students: health correlates, gender differences, and problematic gaming. *Pediatrics* 126 (6), e1414–e1424.
- Dietary Guidelines Advisory Committee. 2015. Scientific Report of the 2015 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary Health and Human Services and the Secretary of Agriculture. Washington, DC: US Department of Health and Human Services. Available from <https://www.dietaryguidelines.gov/sites/default/files/2019-05/Scientific-Report-of-the-2015-Dietary-Guidelines-Advisory-Committee.pdf>.
- Doré, I., O'Loughlin, J.L., Beauchamp, G., Martineau, M., Fournier, L., 2016. Volume and social context of physical activity in association with mental health, anxiety and depression among youth. *Prev. Med.* 91, 344–350.
- Dowdy, E., Furlong, M.J., Sharkey, J.D., 2013. Using surveillance of mental health to increase understanding of youth involvement in high-risk behaviors: a value-added analysis. *J. Emot. Behav. Disord.* 21 (1), 33–44.
- Fulkerson, J.A., Sherwood, N.E., Perry, C.L., Neumark-Sztainer, D., Story, M., 2004. Depressive symptoms and adolescent eating and health behaviors: a multifaceted view in a population-based sample. *Prev. Med.* 38 (6), 865–875.
- Gunn III, J.F., Lester, D., 2014. Sports participation and suicidal behaviour: does sport type matter? *Int. J. Sport Exerc. Psychol.* 12 (4), 333–338.
- Hoare, E., Skouteris, H., Fuller-Tyszkiewicz, M., et al., 2014. Associations between obesogenic risk factors and depression among adolescents: a systematic review. *Obes. Rev.* 15 (1), 40–51.
- Hom, M.A., Stanley, I.H., Duffy, M.E., Rogers, M.L., Hanson, J.E., Gutierrez, P.M., Joiner, T.E., 2019. Investigating the reliability of suicide attempt history reporting across five measures: a study of US military service members at risk of suicide. *J. Clin. Psychol.* 75, 1332–1349.
- Hom, M.A., Joiner, T.E., Bernert, R.A., 2016. Limitations of a single-item assessment of suicide attempt history: implications for standardized suicide risk assessment. *Psychol. Assess.* 28, 1026–1030.
- Khalid, S., Williams, C.M., Reynolds, S.A., 2016. Is there an association between diet and depression in children and adolescents? A systematic review. *Br. J. Nutr.* 116 (12), 2097–2108.
- Kann, L., McManus, T., Harris, W.A., et al., 2018. Youth risk behavior surveillance – United States, 2017. *MMWR Surveill. Summ.* 67 (8), 1–479.
- Krebs-Smith, S.M., Guenther, P.M., Subar, A.F., et al., 2010. Americans do not meet federal dietary recommendations. *J. Nutr.* 140, 1832–1838.
- Lowry, R., Crosby, A.E., Brener, N.D., Kann, L., 2014. Suicidal thoughts and attempts among U.S. high school students: trends and associated health-risk behaviors, 1991–2011. *J. Adolesc. Health* 54, 100–108.
- Lubans, D., Richards, J., Hillman, C., et al., 2016. Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. *Pediatrics* 138 (3), e20161642.
- May, A.M., Klonsky, E.D., 2016. What distinguishes suicide attempters from suicide ideators? A meta-analysis of potential factors. *Clin. Psychol.* 23 (1), 5–20.
- The National Advisory Mental Health Council Workgroup on Child and Adolescent Mental Health Intervention Development and Deployment. 2001. Blueprint for Change: Research on Child and Adolescent Mental Health. Washington, D.C. Available from <https://www.nimh.nih.gov/about/advisory-boards-and-groups/namhc/reports/blueprint-for-change-research-on-child-and-adolescent-mental-health.shtml>.
- Neumark-Sztainer, D., Story, M., Resnick, M.D., Blum, R.W., 1996. Correlates of inadequate fruit and vegetable consumption among adolescents. *Prev. Med.* 25 (5), 497–505.
- Oddy, W.H., Allen, K.L., Trapp, G.S.A., Ambrosini, G.L., Black, L.J., Huang, R.C., Rzehak, P., Runions, K.C., Pan, F., Beilin, L.J., Mori, T.A., 2018. Dietary patterns, body mass index and inflammation: pathways to depression and mental health problems in adolescents. *Brain Behav. Immun.* 69, 428–439.
- Office of Disease Prevention and Health Promotion. 2016. Mental health and mental disorders. In *Healthy People 2020*. Available from <https://www.healthypeople.gov/2020/topics-objectives/topic/mental-health-and-mental-disorders/objectives>.
- O'Neil, A., Quirk, S.E., Housden, S., Brennan, S.L., Williams, L.J., Pasco, J.A., Berk, M., Jacka, F.N., 2014. Relationship between diet and mental health in children and adolescents: a systematic review. *Am. J. Public Health* 104 (10), e31–e42.
- Perou, R., Bitsko, R.H., Blumberg, S.J., Pastor, P., Ghandour, R.M., Gfroerer, J.C., Hedden, S.L., Crosby, A.E., Visser, S.N., Schieve, L.A., et al., 2013. Mental health surveillance among children — United States, 2005–2011. *MMWR*. 62 (02), 1–35.
- Pfledderer, C.D., Burns, R.D., Brusseau, T.A., 2019. School environment, physical activity, and sleep as predictors of suicidal ideation in adolescents: evidence from a national survey. *J. Adolesc.* 74, 83–90.
- Wenthe, P.J., Janz, K.F., Levy, S.M., 2009. Gender similarities and differences in factors associated with adolescent moderate-vigorous physical activity. *Pediatr. Exerc. Sci.* 21 (3), 291–304.
- Richards, R., McGee, R., Williams, S.M., Welch, D., Hancox, R.J., 2010. Adolescent screen time and attachment to parents and peers. *Arch. Pediatr. Adolesc. Med.* 164 (3), 258–262.
- Rostad, W.L., Basile, K.C., Clayton, H.B., 2018. Association among television and computer/video game use, victimization, and suicide risk among U.S. high school students. *J. Interpers. Violence*, 1–24.
- Sibold, J., Edwards, E., Murray-Close, D., Hudziak, J.J., 2015. Physical activity, sadness,



- and suicidality in bullied US adolescents. *J. Am. Acad. Child Adolesc. Psychiatry* 54 (10), 808–815.
- Smith, A.L., 2003. Peer relationships in physical activity contexts: a road less traveled in youth sport and exercise psychology research. *Psychol. Sport Exerc.* 4 (1), 25–39.
- Solnick, S.J., Hemenway, D., 2014. Soft drinks, aggression and suicidal behaviour in US high school students. *Int. J. Inj. Contr. Saf. Promot.* 21 (3), 266–273.
- Southerland, J.L., Zheng, S., Dula, M., Cao, Y., Slawson, D.L., 2016. Relationship between physical activity and suicidal behaviors among 65,182 middle school students. *J. Phys. Act. Health.* 13 (8), 809–815.
- Substance Abuse and Mental Health Services Administration. 2017. Key substance use and mental health indicators in the United States: Results from the 2016 National Survey on Drug Use and Health (HHS Publication No. SMA 17-5044, NSDUH Series H-52). Available from <https://www.samhsa.gov/data>.
- Suchert, V., Hanewinkel, R., Isensee, B., 2015. Sedentary behavior and indicators of mental health in school-aged children and adolescents: a systematic review. *Prev. Medicine.* 76, 48–57.
- Tremblay, M.S., LeBlanc, A.G., Kho, M.E., et al., 2011. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *Int. J. Behav. Nutr. Phys. Act.* 8 (1), 98.
- Turecki, G., Brent, D., 2016. Suicide and suicidal behaviour. *Lancet* 387, 1227–1239.
- US Department of Health and Human Services and US Department of Agriculture. 2015. 2015–2020 Dietary Guidelines for Americans. 8th Edition. Available at <http://health.gov/dietaryguidelines/2015/guidelines/External>.
- US Department of Health and Human Services. 2018. Physical activity guidelines for Americans, 2nd edition. Washington, DC, US Department of Health and Human Services. Available at [https://health.gov/paguidelines/second-edition/pdf/Physical\\_Activity\\_Guidelines\\_2nd\\_edition.pdf](https://health.gov/paguidelines/second-edition/pdf/Physical_Activity_Guidelines_2nd_edition.pdf).
- US Department of Health and Human Services. 2019. National youth sports strategy. Washington, DC, US Department of Health and Human Services. Available at [https://health.gov/paguidelines/youth-sports-strategy/pdf/National\\_Youth\\_Sports\\_Strategy.pdf](https://health.gov/paguidelines/youth-sports-strategy/pdf/National_Youth_Sports_Strategy.pdf).
- Vancampfort, D., Hallgren, M., Firth, J., Rosenbaum, S., Schuch, F.B., Mugisha, J., Probst, M., Van Damme, T., Carvalho, A.F., Stubbs, B., 2018. Physical activity and suicidal ideation: a systematic review and meta-analysis. *J. Affect.* 225, 438–448.
- World Health Organization. 2014. WHO Preventing Suicide: A Global Imperative. Geneva, Switzerland, World Health Organization. Available at: [http://www.who.int/mental\\_health/suicide-prevention/world\\_report\\_2014/en/](http://www.who.int/mental_health/suicide-prevention/world_report_2014/en/).
- Wood, J.J., Lynne-Landsman, S.D., Langer, D.A., Wood, P.A., Clark, S.L., Eddy, J.M., Ialongo, N., 2012. School attendance problems and youth psychopathology: structural cross-lagged regression models in three longitudinal data sets. *Child Dev.* 83 (1), 351–366.