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# Impact of Body Mass Index, Socioeconomic Status, and Bedtime Technology Use on Sleep Duration in Adolescents

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## Abstract

Factors related to adolescents and sleep are understudied. We evaluate the relationship between bedtime technology use (TU), TV in bedroom, weight, and socioeconomic status in seventh graders (N = 3956) enrolled in a school-based wellness intervention. Sleep quantity was dichotomized to insufficient (<8 hours) or sufficient (≥8 hours); high TU before sleep was defined by use "a few nights each week" or "every, or almost every night." Insufficient sleep (38.7%), having TV in bedroom (72.9%), and high TU (83.1%) were commonly reported. The likelihood of sufficient sleep was lower for those with high TU (odds ratio [OR] = 0.529 [0.463-0.605]), obese students (OR = 0.815 [0.700-0.949]), and those with a TV in the bedroom (OR = 0.817 [0.703-0.950]). Also, attending a school with higher percent low socioeconomic status students was also associated with insufficient sleep ($P$ = .026). Interventions to reduce TU may be important for improving sleep quantity, especially for some vulnerable populations.

## Keywords

sleep, adolescents, obesity, technology use

## Introduction

Sufficient sleep has been shown to confer positive health outcomes.[1] Conversely, insufficient sleep has been shown to have negative impacts on physical health and cognitive development in children and adolescents.[2] For example, insufficient sleep is related to increased risk of injuries, hypertension, obesity, diabetes, and depression/self-harm in these populations.[3,4] Furthermore, insufficient sleep has a direct impact on attention, behavior, learning, memory, and emotional regulation.[5,6]

There is a growing body of research illustrating the effects of technology use (TU) before sleep on sleep outcomes. Television (TV) in the bedroom and access to smart devices, such as cellular phones, may directly displace sleep time, disrupt circadian rhythm, and promote continued emotional arousal during bedtime.[7-9] Handheld smart devices have been associated with self-reported insufficient sleep.[10] TU is also a known risk factor for abnormal weight gain[11,12] and has been shown to be associated with beverage and snack consumption behaviors.[13] Insufficient sleep itself may promote the development of obesity.[1,5,14-17]

In this study, we aimed to explore the relationship between self-reported TU before sleep and self-reported sleep duration in a cohort of 3956 seventh graders in eastern North Carolina. Furthermore, we aimed to determine if, and how, weight and socioeconomic status (SES) influence the relationship between TU and the likelihood of reporting sufficient sleep. We hypothesized that (1) high TU, presence of a TV in the bedroom, overweight (OW)/obese (OB) status and low SES would increase the risk of insufficient sleep while (2) neither sex nor race/ethnicity would influence reported sleep duration.

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## Methods

We performed a cross-sectional, secondary analysis of observational data from young adolescents in a school-based wellness program called Motivating Adolescents with Technology to Choose Health (MATCH), which has been described previously.[18]

### Participants and Measures

Participants included seventh-grade students from the MATCH program in the fall of 2017. All seventh-grade students served in mainstream classes in the school received the MATCH curriculum and were eligible to participate in the study. At the start of the school year, all students receive information about study participation and parent consent and participant assent information, including opt-out forms. Participants included all students with both body mass index (BMI) and sleep behavior data recorded and not providing a signed parent or student opt-out form. Measures included (1) height and weight measured at the beginning of the school year; (2) answers to questions from a self-administered "Sleep, Eating, Activity, and Technology" (SEAT) health behavior questionnaire[13]; (3) demographic information including age, sex, and race as documented in school registration records; and (4) school-level participation in the National School Lunch Program (NSLP), the program that subsidizes cost of school meals to qualifying children. The school-level percent of students participating in the NSLP was used as a proxy measure of SES.

Heights obtained with a stadiometer and weights obtained with a calibrated scale were measured by trained school staff following a standardized protocol as previously described.[18] BMI was calculated using the measured height and weight values, and weight category was assigned based on age- and sex-specific norms (underweight $<$5th percentile; healthy weight (HW) $\geq$5th but $<$85th percentile; OW $\geq$85th but $<$95th percentile; OB $\geq$95th percentile).[19]

### Study Setting

The MATCH program has been provided for seventh-grade students in increasing numbers of schools in North Carolina since 2006 and in 2020 it is in place in more than 70 schools, reaching more than 8000 youth annually. In 2017, it was provided in 47 schools in 10 counties (Figure 1), mostly in the rural, eastern region of the state where there are high rates of obesity and diabetes.[20] After a school agreed to implement MATCH, teachers were trained to provide lessons within their area of expertise and one teacher served as coordinator for the school. The program provides wellness themed lessons integrated within the standardized curriculum to empower students to make healthy choices in eating and physical activity.[13,18]

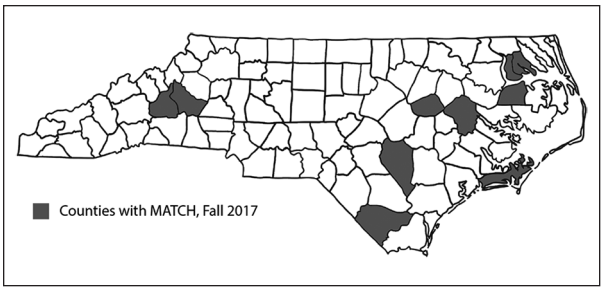


**Figure 1.** Counties in North Carolina with the 47 schools participating in MATCH (Motivating Adolescents with Technology to Choose Health) for this study.

The SEAT questionnaire was designed for use in the MATCH program and included 47 questions that were either selected from validated questionnaires where available or were created for the MATCH program.[21] The questions about sleep and TU from the SEAT questionnaire used for this study, together with their multiple-choice answers, are given below.

*Technology Use.* Question: "In the past 2 weeks, how often do you use a form of technology that has a screen for viewing content, within ONE HOUR BEFORE trying to go to sleep? (Television, computer or laptop, cell phone, video game console such as a Wii, PS3, or Xbox, MP3 player or iPod, or E-book reader)."

Answer choices:

A. Never
B. Rarely
C. A few nights each week
D. Every night or almost every night

For this study, responses were dichotomized, with responses C and D collapsed into a single category defined as "yes" for high TU, while responses A and B were collapsed into a single category defined as "no" for high TU.

*Sleep Duration.* Question: "How many hours do you sleep each night?"

Answer choices:

A. Less than 6 hours
B. Greater than 6 hours but less than 8 hours
C. At least 8 hours but not more than 10 hours
D. 10 hours or more.

For this study, responses were dichotomized, with responses C and D collapsed into a single category defined as "yes" for sufficient sleep (≥ 8 hours) and with responses A and B collapsed into a single category defined as "no" for sufficient sleep (<8 hours).

*TV in Bedroom.* Question: "Do you have a TV in the room where you sleep?"

Answer choices:

A. Yes
B. No

### Analysis

Frequency tables were created to summarize the distributions of categorical variables. Chi-square tests were used to determine the bivariate associations between variables, and Cochran-Armitage tests were used to test for trend in proportions. A multiple logistic regression model was used to investigate the relationship between weight category, high TU, TV in room, and %NSLP and the likelihood of sufficient sleep. Gender and race were not significantly associated with the dependent variable and thus were not included in the logistic regression model. Pearson correlation coefficient was calculated to describe the association between %NSLP and proportion of students who reported less than 6 hours sleep per night at the school level. All analyses were conducted in SAS 9.4 (SAS Institute Inc), and a significance level of .05 was adopted for all statistical tests.

This study was approved by the University Medical Center Institutional Review Board at East Carolina University (07-0741).

**Table 1.** Participant Demographics and Sleep Habits.

| Characteristics | n | % |
|---|---|---|
| Gender (N = 3956) | | |
| Female | 1943 | 49.1 |
| Male | 2013 | 50.9 |
| Race/ethnicity (N = 3956) | | |
| White | 1955 | 49.4 |
| Black | 1060 | 26.8 |
| Other | 941 | 23.8 |
| Weight category (N = 3956) | | |
| Underweight | 91 | 2.3 |
| Healthy weight | 1978 | 50.0 |
| Overweight | 744 | 18.8 |
| Obese | 1143 | 28.9 |
| School-level socioeconomic status[a] (N = 3934) | | |
| <50% in NSLP | 617 | 15.7 |
| 50% to 74% in NSLP | 1604 | 40.8 |
| 75% to 99% in NSLP | 284 | 7.2 |
| 100% in NSLP | 1429 | 36.3 |
| TU before sleep (N = 3956) | | |
| Never | 139 | 3.5 |
| Rarely | 528 | 13.4 |
| A few nights each week | 1103 | 27.9 |
| Every night or most every night | 2186 | 55.3 |
| Sleep duration (N = 3956) | | |
| <6 hours | 349 | 8.8 |
| ≥6 hours but <8 hours | 1182 | 29.9 |
| ≥8 hours but <10 hours | 2044 | 51.7 |
| ≥10 hours | 381 | 9.6 |
| TV in bedroom (N = 3952) | | |
| Yes | 2881 | 72.9 |

Abbreviations: NSLP, National School Lunch Program; TU, technology use; TV, television.
[a]Socioeconomic status was tabulated on the school level.

## Results

Participant (N = 3956) characteristics are shown in Table 1. About half of participants were female; about half were White, one quarter Black, and one quarter were "other" race; the vast majority attended schools with high percent of students of low SES. Almost half (47.7%) of the students exceeded a HW, with 18.8% categorized as OW and 28.9% as OB (Table 1). The participant demographics of the study group were overall similar to those for students in North Carolina public schools the same year (White 48.4%, Black 25.3%, and participation in NSLP 57.2%).[22,23]

Responses to questions about sleep, TU, and TV in the bedroom are also shown in Table 1. More than a third (38.7%) of participants reported getting insufficient sleep (<8 hours) while more than half (55.3%) reported TU "every night or almost every night." When combined with those reporting TU "a few nights per week," most participants (83.1%) fell into the high TU before sleep category. A majority of participants (72.9%) reported having a TV in the room where they sleep.

There were no significant differences in sufficient sleep by sex or race: male, 62.4%; female, 60.1% ($P = .116$): Black, 59%; White, 61.6%; other, 63.1% ($P = .160$). However, there were differences when comparing sufficient sleep by frequency of TU, weight category, and having a TV in the bedroom. The proportion of participants with sufficient sleep was significantly different across TU categories ($P < .001$). The Cochran-Armitage test indicates that adolescents in higher TU categories were less likely to report sufficient sleep compared with those in lower TU categories ($P < .001$). Only 54.6% of participants in the highest TU category reported sufficient sleep (Figure 2). The proportion of participants with sufficient sleep was significantly different across

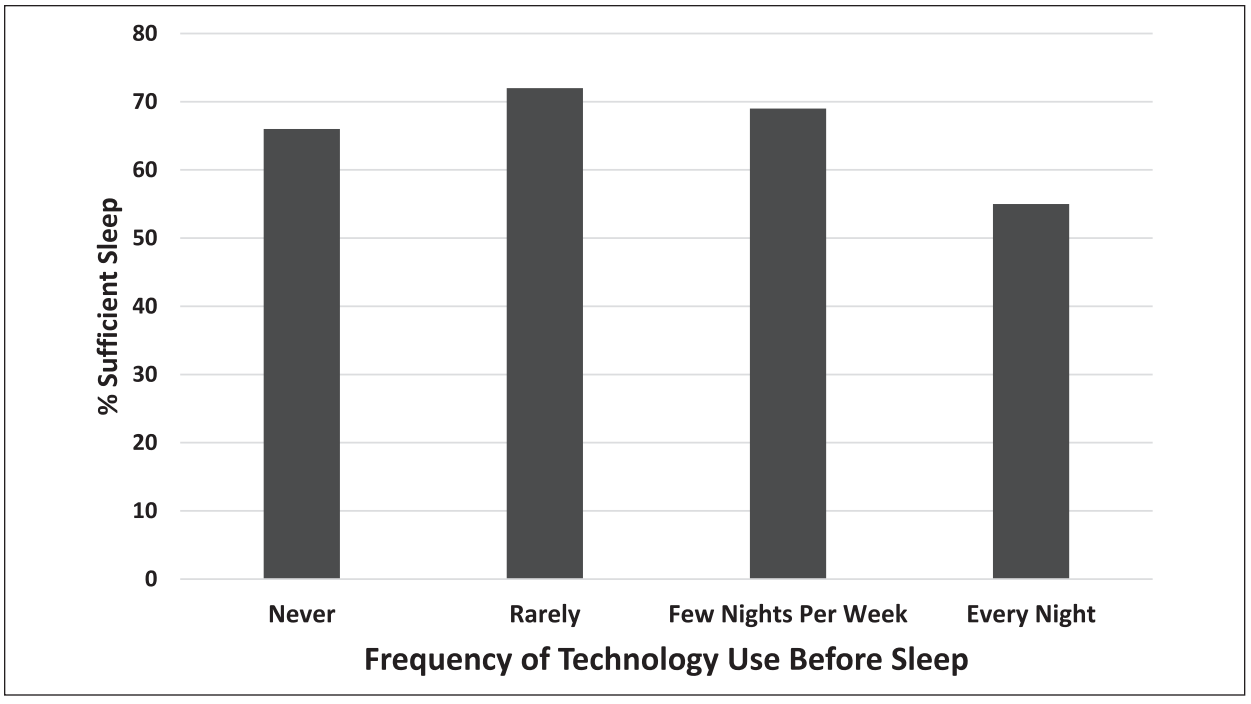


**Figure 2.** Percent of participants reporting sufficient sleep (≥8 hours per night) by self-reported frequency of technology use before sleep ($P < .001$).

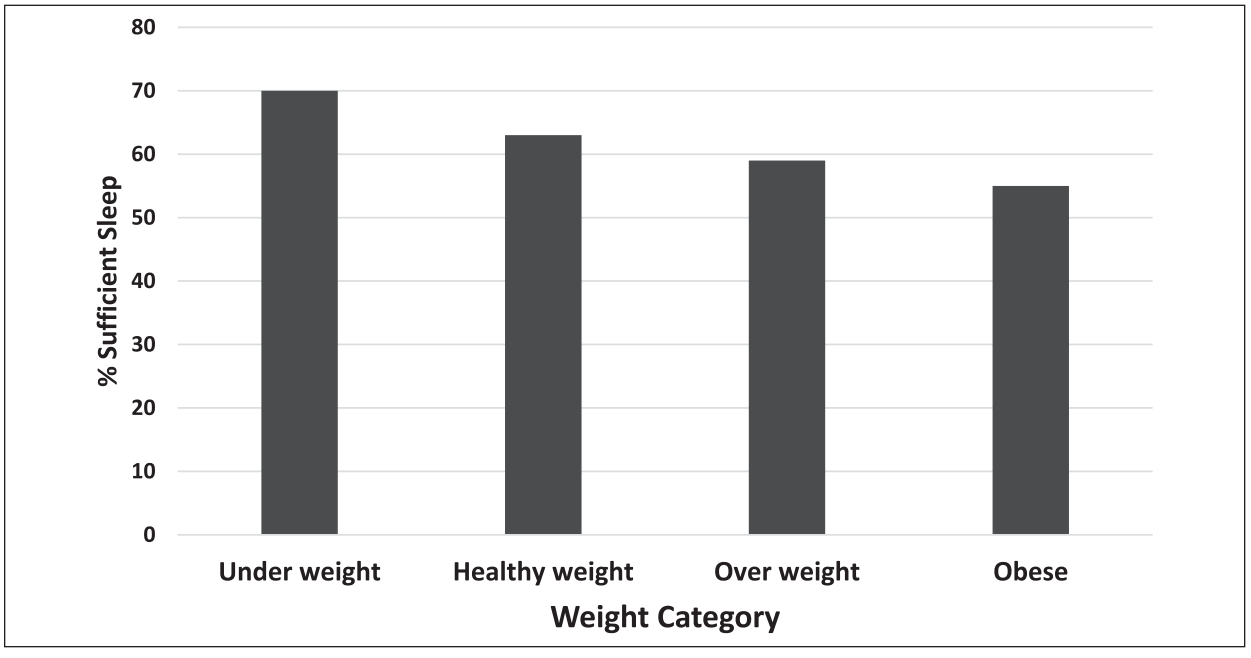


**Figure 3.** Percent of participants reporting sufficient sleep (≥8 hours per night) by weight category ($P < .001$).

weight categories ($P < .001$). The Cochran-Armitage test suggests that individuals in weight categories with higher BMI were less likely to report sufficient sleep than students in weight categories with lower BMI ($P = .0012$; Figure 3). Finally, compared with their counterparts without a TV, a lower percentage of participants with a TV in the bedroom reported sufficient sleep (65.9% vs 59.6%, respectively; $P < .001$).

**Table 2.** Multiple Logistic Regression Model for the Effects of TV in Room, Weight Category, Technology Use, and School-Level NSLP Percentage on the Likelihood of Sufficient Sleep (≥8 hours).

| Factors | Odds ratio | 95% Confidence interval | *P* |
|---|---|---|---|
| TV in room | | | |
| TV in room versus no TV | 0.817 | 0.703-0.950 | .0085* |
| Weight category | | | |
| Obesity versus healthy weight | 0.815 | 0.700-0.949 | .0249* |
| Overweight versus healthy weight | 0.847 | 0.710-1.009 | .1049 |
| Underweight versus healthy weight | 1.281 | 0.805-2.039 | .1145 |
| TU | | | |
| High TU versus low TU | 0.529 | 0.463-0.605 | <.001* |
| School NSLP percentage, marker of SES | 0.997 | 0.994-1.000 | .0260* |

Abbreviations: NSLP, National School Lunch program; TV, television; TU, technology use; SES, socioeconomic status.
*Statistically significant at .05 significance level.

A multiple logistic regression analysis showed that OB weight status, TV in the bedroom, and high TU all decreased the likelihood of reporting sufficient sleep (Table 2). In particular, the odds of sufficient sleep for participants with high TU was only about one half of the odds for participants with low TU (odds ratio [OR] = 0.529, 95% confidence interval [CI] = 0.463-0.605). Of note, the combined factors of obesity and high TU are associated with an even lower likelihood of sufficient sleep (OR = 0.431, 95% CI = 0.352-0.529). Logistic regression analysis also demonstrated that as the %NSLP increased at the school attended by a participant, the likelihood of sufficient sleep decreased ($P = .026$). In those reporting insufficient sleep, 37.7% are from 100% NSLP schools (contributes 36.3% of study population) and 39.8% from 75% to 99% NSLP schools (contributes 7.2% of study population). Hence, 77.5% of the students reporting insufficient sleep are from the 2 lowest SES categories of schools, which represent only 43.5% of the study population. At the school level, the proportion of students who reported less than 6 hours of sleep per night was also calculated for each school, and analyses revealed that schools with higher %NSLP tended to have a higher proportion of students who reported less than 6 hours sleep per night ($r = 0.3520$, $P = .0177$, N = 45 schools).

## Discussion

According to the consensus document published by the American Academy of Sleep Medicine (AASM) in conjunction with the American Academy of Pediatrics (AAP),[7] a minimum of 9 hours of sleep per night is recommended for children in the 6- to 12-year-old age group and a minimum of 8 hours is recommended for 13- to 18-year-old adolescents. However, recent large population studies show that only about 40% of adolescents in the United States are getting the recommended amount of sleep per night.[24,25] In fact, among 24 800 students aged between 9 and 12 years included in the 2013-2015 Youth Risk Behavioral Surveillance System study, 71.4% reported less than 8 hours of sleep on an average school night.[24] In contrast, we found that among a diverse sample of nearly 4000 seventh graders in eastern North Carolina only 38.7% reported less than 8 hours of sleep per night. While the lower percentage reporting insufficient sleep in our study may represent true differences in sleep duration between study populations, we also speculate that differences in the survey questions (hours of sleep on "average school night" in Youth Risk Behavioral Surveillance System vs "how many hours do you sleep each night" in the SEAT questionnaire) may elicit different responses that depend on the inclusion of non–school night sleep duration in this study. Inclusion of potentially longer sleep duration from weekend nights in our study will tend to underestimate the reporting of insufficient sleep on weekdays. Perhaps of greater concern, the national data represent a 58% increase in those sleeping <7 hours per night since 1991.[25] Consistent with these finding, we also found that about 9% of our participants report less than 6 hours of sleep nightly and that those reporting very short sleep duration are more likely to come from low SES schools. This troubling trend in the decline of sleep among adolescents is likely multifactorial.[26]

Heavy use of screen devices (≥5 hours daily), increased TV viewing prior to initiation of sleep, and the presence of media devices in the bedroom have previously been shown to be associated with shorter duration and/or poorer quality sleep.[7,8,10,24,25,27-29] We also found that the presence of a TV in the bedroom and high TU before sleep were associated with lower likelihood of sufficient sleep. Consistent with previous studies demonstrating that among children aged 10 years and older the use of portable electronic devices had a stronger deleterious effect on sleep duration

than use of nonportable devices,[25,27] we found that high TU had a lower likelihood of being associated with sufficient sleep than reporting the presence of a TV in the bedroom.

There is a well-established relationship between insufficient sleep and OW and OB weight status.[14-16] OB populations may have higher incidence of comorbidities promoting insufficient sleep, such as higher incidences of sleep apnea,[30] while insufficient sleep, per se, promotes the development of obesity[1,6,14-17] and can render interventions aimed at decreasing obesity less effective.[31] Furthermore, OB children are less likely to experience "catch up" sleep on the weekends, perhaps predisposing them to further adverse metabolic outcomes.[17] We also found that OW/OB children were less likely to report adequate sleep than their healthy weight counterparts. A significant novel finding of our study is the particularly low likelihood of sufficient sleep in OB participants also reporting high TU. The negative relationship between obesity and sleep further highlighted by our findings is especially worrisome given that the current prevalence of obesity in US adolescents is 20.6%[20] with more than 9% of 12- to 15-year-old African American and Hispanic youth having class 2 obesity (BMI $\geq$120% of the 95th percentile).[32] Our findings, in the context of national trends, illuminates the importance of studying and implementing interventions aimed at reducing both childhood obesity and disruption of sleep by high TU.

Although our study did not have individual level SES data, our school-level observations support prior findings that as SES decreases, so does the likelihood of sufficient sleep.[33-35] There is evidence that poor sleep outcomes in these populations may in turn have an effect on cognitive performance outcomes.[36] Given the relative paucity of research examining the relationship between SES and sleep, more studies in this area are warranted.

Strengths of this study include the large sample size of almost 4000 adolescents representing approximately 4% of seventh graders across North Carolina in the 2017-2018 school year with demographics similar to children enrolled in North Carolina public schools. Participants were from rural areas with known health disparities, and directly measured heights and weights were used to determine weight status. This study is limited by the cross-sectional design so conclusions cannot be drawn about causality, data are drawn from one region of the southeast United States and results may not be generalizable, and behavior data were self-reported; however, several studies demonstrate that children can accurately report on their own health data.[37,38] Also, SES information was not available on an individual level and the duration of sleep question did not differentiate between weekday and weekend sleep. Hence, depending on how the participant interpreted the question, longer sleep duration on weekends—known as weekend recovery or catch up sleep—may be either unreported or underreported. However, recent research shows that weekend recovery sleep does not prevent metabolic dysregulation associated with insufficient sleep[39] and that longer duration of catch-up sleep in adolescents is actually associated with poor performance on objective attention tasks.[40] Hence, unreported or underreporting catch up sleep is not a significant limitation since catch up sleep may have little or no salutary effects. Finally, use of sleep duration as the sole measure of sleep sufficiency neither captures all elements of sleep hygiene nor addresses individual variation in sleep needs.

## Conclusion

Many children in eastern North Carolina do not regularly achieve sufficient sleep. Of interest, in this largely poor, rural region of North Carolina, attending a school with higher percentage of lower SES students may be associated with insufficient sleep. However, factors mediating the relationship between SES and sleep need to be elucidated. Both BMI and high TU before bedtime exhibited a dose-dependent negative relationship with sleep sufficiency. Because TU is a modifiable behavior, studies to evaluate the effects of reducing TU before bedtime on sleep duration are warranted. Given research that families report not being counseled regarding the proper amount of screen time for their child,[41] and the increasingly pervasive use of portable electronic devices by children of all ages, reducing TU before bedtime may be an area for stronger anticipatory guidance especially as relates to TU effects on sleep duration and quality.

### Authors' Note

All individuals who contributed significantly to this work are included as authors. Preliminary work from this study was presented as an oral presentation by Dr Stine at the 2019 Pediatric Academic Societies meeting in Baltimore, MD.

### Author Contributions

FS: Contributed to conception and design; contributed to interpretation; drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

DNC: Contributed to conception and design; contributed to interpretation; drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

XF: Contributed to conception and design; contributed to analysis; drafted manuscript; critically revised manuscript; gave

final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.
KRD: Contributed to conception and design; contributed to acquisition and interpretation; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.
SL: Contributed to conception and design; contributed to acquisition and interpretation; drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

## Declaration of Conflicting Interests

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