RACE DIFFERENCES IN ASSOCIATIONS BETWEEN MICRONUTRIENT INTAKE AND HABITUAL SLEEP VARIABILITY IN ADOLESCENTS

A Thesis in Public Health Sciences
by Carla Daou

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Abstract

Objective: The objective plan of this study was to investigate the relations between micronutrients (Calcium, Magnesium, Zinc, Iron and Copper) and habitual sleep variability (HSV), mean sleep duration (HSD) and insomnia complaint (INS) and whether the associations between mean sleep duration and variability are modified by gender and race.

Methods: We used data from 324 adolescents who participated in the Penn State Child Cohort follow-up examination. Actigraphy was used over seven consecutive nights to estimate nightly sleep duration. The seven-night mean and standard deviation of sleep duration were used to represent HSD and HSV, respectively. Insomnia complaint INS was also assessed in this study. The Youth/Adolescent Questionnaire (YAQ) was used to evaluate the participants’ daily nutrition and food intake behavior. Frequency of consumption of 152 food items were measured and then converted into a series of nutrient indices which was then converted to the amount of different nutrients consumed. 5 micronutrients were assessed: Calcium, Copper, Iron, Magnesium and Zinc. Linear regression models were used to study the association between habitual sleep patterns and micronutrient intake and whether these associations vary between gender and race, whereas logistic regression models were used to evaluate the associations between insomnia complaint and micronutrient intake.

Results: After adjusting for age, race, sex, body mass index (BMI) and caloric intake, a decreased HSD was associated with an increase intake of Copper. For example, for every 1 unit increase in log (Cu), there is a 7.28 minutes decrease in HSD. The association between each of calcium, iron and magnesium and the sleep variability was race dependent. For example, among white people, sleep variability was decreased by almost 6 minutes, as compared to 3 minutes increase among non-white for 1 unit log increase in calcium intake, decreased by 4 minutes among white and increased by 4 minutes among non-white for every 1 log unit increase in iron, and decreased by 6 minutes in white as opposed to 5 minutes increase in non-white for every 1 log unit increase in Magnesium. Sex differences had no effect on the associations between habitual sleep patterns and micronutrient intake. No relationships between micronutrient intake and either of insomnia complaint and sleep variability were observed.

Conclusion: Race modifies the associations between micronutrient intake and habitual sleep variability. There is an increase in HSV and not HSD in white people as compared to an increase in HSV in non-white when consuming calcium, iron and Magnesium. Increase in copper intake decreases sleep duration by about 7 minutes.
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## Abbreviations

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<th>Description</th>
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<tbody>
<tr>
<td>HSD</td>
<td>Habitual Sleep Duration</td>
</tr>
<tr>
<td>HSV</td>
<td>Habitual Sleep Variability</td>
</tr>
<tr>
<td>INS</td>
<td>Insomnia Complaint</td>
</tr>
<tr>
<td>PSCC</td>
<td>Penn State Child Cohort</td>
</tr>
<tr>
<td>PSG</td>
<td>Polysomnographic</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>DFA</td>
<td>Difficulty Falling Asleep</td>
</tr>
<tr>
<td>Y AQ</td>
<td>Youth/Adolescent Questionnaire</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
</tr>
<tr>
<td>Calc</td>
<td>Calcium</td>
</tr>
<tr>
<td>Magn</td>
<td>Magnesium</td>
</tr>
<tr>
<td>Zn</td>
<td>Zinc</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>RDA</td>
<td>Recommended Dietary Allowance</td>
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<tr>
<td>RLS</td>
<td>Restless Leg Syndrome</td>
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</table>
Chapter 1: Introduction

An optimal sleep pattern has important implications for health maintenance and health promotion\(^1\). According to a new study in the Centers for Disease Control and Prevention’s (CDC) Morbidity and Mortality Weekly Report, more than a third of American adults are not getting enough sleep on a regular basis \(^5\).

National US surveys have revealed a decrease of 1.5 to 2 hours in self-reported sleep duration over the last 50 years \(^9\). Many people underestimate the importance of getting the optimal number of hours of sleep per day. Sleep deprivation and sleep impairment can disturb cognitive performance in children \(^2\) and adults \(^3\). Short sleep duration is associated with weight gain and obesity, diabetes, cardiovascular disease, psychiatric illness, and performance deficits. Similarly, long sleep duration is also related to poor physical and mental health \(^4\). And according to the CDC, sleep disorders are now a public health epidemic \(^6\). Therefore, sleep is a public health concern and a potential new risk factor that has to be further studied, especially in children and adolescents \(^10\). Even though publications have shown that sleep duration affects a big number of diseases \(^11,\ 12\), little interest has been given to the factors that affect sleep pattern.

As the relationship between insufficient sleep, weight gain and obesity has been previously observed in several studies \(^13-14-15\), there was an increasing attention given to potential links between dietary intake, nutrition and sleep \(^16\). Several studies have covered the association between macronutrients and sleep problems \(^8,\ 16\) and have found that an increase in consumption of fat and carbohydrates was associated with increased sleep variability but not related to sleep duration \(^8\). However, little has been studied about micronutrients as compared to macronutrients intake and its effect on sleep.
deprivation and sleep problems. There are a few epidemiological studies and clinical trials that have provided evidence to support the association between micronutrient intakes and sleep patterns. For example, randomized controlled trials in infants found longer night-time and total sleep duration in those receiving supplemental zinc or iron compared with the placebo group [17]. To date, nevertheless, no study has analytically studied the current literature on the relationship between micronutrients and sleep in a developmental perspective for sleep patterns [16]. Not only the association between micronutrients and sleep isn’t critically reviewed but also gender and race differences in the relation between micronutrients and sleep pattern haven’t been covered in the literature. It has been found that sleep is associated with body mass index and other body composition variables and this relationship has been found to be stronger in women than men [8] but race differences and relationships in terms of micronutrients were not studied. Therefore, we carried out this study to investigate the association between objectively measured habitual sleep duration (HSD), habitual sleep variability (HSV), insomnia complaint (INS) and consumption of five different micronutrients: Calcium, Copper, Magnesium, Iron and Zinc and to study whether this association varies between gender (female vs. male) and race (black vs. white) in a population-based sample of healthy adolescents.
Chapter 2: Methods

Population

We used the data collected from 421 adolescents who completed the follow-up examination of the Penn State Child Cohort (PSCC) study. Recruitment methods and examination procedures for the PSCC baseline study have been published elsewhere \(^{7-8}\). The initial number of participants was a total of 700 children with ages ranging between 6–12 years and who participated in the baseline examination directed in 2002–2006 \(^8\). Among the 700 subjects, there were 421 subjects who returned and completed the follow-up examination during 2010–2013, yielding a response rate of 60%. The reason the number of subjects has decreased over years was because of a loss to follow-up which was caused by subjects moving out of the central Pennsylvania area. However, the demographic characteristics between the participants who joined the follow-up examination and those who did not were very similar. The participants were examined at the Clinical Research Center in the Pennsylvania State University College of Medicine. After undergoing a whole-body dual-energy X-ray absorptiometry scan, a detailed physical examination and questionnaire-based data collection protocol were performed. An actigraph tri-axis accelerometer monitor was used to measure the sleep duration. The participants stayed overnight in a sleep laboratory to complete a standardized polysomnographic (PSG) recording. After collecting morning blood, saliva, and urine samples, the participants were allowed to proceed with their daily routine with the actigraphy and a set of questionnaires about their habitual behaviors, including food consumption. The study protocol was approved by the Penn State University College of
Medicine Institutional Review Board. Written informed consent was obtained from participants and their parents or legal guardians if younger than 18 years [8].

**Sleep Variables**

In this study, we were interested in studying three different sleep variables: Habitual Sleep Duration (HSD), Habitual Sleep Variability (HSV) which were computed to assess the participants’ habitual sleep patterns and Insomnia Complaint (INS). To measure the sleep duration, an actigraphy was worn on the wrist of a non-dominant hand during bedtime for eight consecutive nights over the period of the study, and a sleep diary was used to record the “bedtime” and “out of bedtime” on a nightly basis. The data received by the actigraphy were then sent to a designated computer for analysis. After removing artifacts, the actual sleep duration was obtained using ActLife 6 software (Actigraph LLC, Pensacola, FL, USA) [8]. The sleep data for the first night were omitted from the calculation, as these were measured under a 9-h sleep protocol in a laboratory environment. The average of sleep duration across seven nights in the free-living environment was used to represent HSD. The intra-subject standard deviation (SD) of the seven-night sleep duration was used to represent HSV. Participants with less than five (<5) nights, that is, <70% of seven nights, of sleep data were excluded from the analysis [8].

Insomnia Complaint (INS) was recorded by “yes” or “no” based on two questions that were asked in a self-reported version of the Pediatric Sleep Questionnaire: “do you have difficulty falling asleep” (DFA) or “do you have difficulty staying asleep?”
Micronutrients Variables

In order to get data about micronutrients intake, a self-administered Youth/Adolescent Questionnaire (YAQ) was first used to evaluate the participants’ average nutrition and food intake behavior over one year period prior to the examination. A total of 152 food items were considered and the participants were requested to report the frequency of consumption of those items over one year prior to the study. Those frequencies were examined and then converted into a series of nutrient indices representing the daily nutrition intake of the participants [8]. This information has been sent to Harvard and converted to amount of different nutrients (both macro-nutrients and micro-nutrients) consumed. In this study, we used the data of five different micronutrients intake, and these include: Calcium, Copper, Iron, Magnesium and Zinc.

Other Co-variables

The demographic information of the participants’ such as age, race and gender, was collected using a self-administered questionnaire. As for the Body Mass Index (BMI), the heights and weights of the subjects were measured to calculate their (BMI) percentile which was then adjusted for age and gender based on the formula and data from the 2000 Centers for Disease Control and Prevention CDC) growth charts [8].

As for the calories intake, and as previously mentioned, a self-administered Youth/Adolescent Questionnaire (YAQ) was used to evaluate the participants’ daily nutrition and food intake behavior. The frequencies of the consumption of the 152 food items were analyzed and converted into a series of nutrient indices representing the daily nutrition intake which in return generated the caloric intake results.
**Statistical Analyses**

As previously mentioned, the initial number of participants was 700, and due to a loss to follow-up, 421 participants participated in the follow-up examination. Among those 421 subjects, 94 individuals were then excluded from the analysis due to insufficient nights of sleep data. Hence, the sample size used for this paper is 327. We used linear regression models to study the association between habitual sleep patterns and micronutrient intake. Logistic regression models, on the other hand, were used to evaluate the association between insomnia complaint and micronutrient intake. HSD and HSV were included both in the same model to control for each other. Major demographic confounding factors such as age, sex, race, BMI percentile and caloric intake were also adjusted for in the models used. And since the distribution of the independent variables, the micro-nutrients, are different, we used log transformations for the micronutrients variables to bring the distributions towards the normal and express the results in terms of one standard deviation increase of log transformed micro-nutrients.

Interaction terms between the log-micronutrients and race/gender were created and then inserted in the model to study whether the effect of these micro-nutrients on the dependent variables varies between white vs. black or male vs. female.
Chapter 3: Results

Demographic characteristics of the sample

The demographic results of the study population are summarized in Table 1. The mean (SD) age of this sample of adolescents was 16.93 (2.24) years. Of the subjects, 48% were male and 78.4% were white. The mean (SD) of the daily caloric intake was 1744 (727.5) kcal and that of the Blood Pressure was 66.6 (9.05). The mean BMI percentile for the sample was 65.35 (28.39).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=327)</th>
<th>Male (n=170)</th>
<th>Female (n=157)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>16.71 (2.26)</td>
<td>16.50 (2.27)</td>
<td>16.93 (2.22)</td>
</tr>
<tr>
<td>Race (% white)</td>
<td>78.59</td>
<td>81.17</td>
<td>75.79</td>
</tr>
<tr>
<td>BMI percentile</td>
<td>66.07 (28.21)</td>
<td>63.88 (30.11)</td>
<td>68.44 (25.88)</td>
</tr>
<tr>
<td>Calories (Kcal)</td>
<td>1770.85 (706.83)</td>
<td>1867.91 (786.94)</td>
<td>1665.76 (593.13)</td>
</tr>
<tr>
<td>Sex (% male)</td>
<td>51.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log_Calc</td>
<td>6.724 (0.552)</td>
<td>6.75 (0.588)</td>
<td>6.69 (0.509)</td>
</tr>
<tr>
<td>Log_Cu</td>
<td>0.302 (0.68)</td>
<td>0.303 (0.704)</td>
<td>0.301 (0.656)</td>
</tr>
<tr>
<td>Log_Iron</td>
<td>2.627 (0.599)</td>
<td>2.623 (0.618)</td>
<td>2.63 (0.579)</td>
</tr>
<tr>
<td>Log_Magn</td>
<td>5.36 (0.441)</td>
<td>5.386 (0.468)</td>
<td>5.339 (0.409)</td>
</tr>
<tr>
<td>Log_Zn</td>
<td>2.43 (0.585)</td>
<td>2.445 (0.594)</td>
<td>2.419 (0.576)</td>
</tr>
<tr>
<td>HSD</td>
<td>419.94 (49.88)</td>
<td>411.88 (45.82)</td>
<td>428.66 (52.71)</td>
</tr>
<tr>
<td>HSV</td>
<td>70.65 (36.11)</td>
<td>68.06 (33.48)</td>
<td>73.45 (38.67)</td>
</tr>
<tr>
<td>INS (%)</td>
<td>36.39</td>
<td>27.64</td>
<td>45.85</td>
</tr>
</tbody>
</table>

Table 1: Descriptive characteristics of the study population
**Association between habitual sleep patterns, INS and micronutrient intake**

The associations between habitual sleep patterns and micronutrient intake are presented in Table 2 below. As shown in the table, HSV was decreased with an increased intake of each of the following micronutrients: calcium, copper, iron, magnesium and zinc. However, none of these associations were statistically significant. For example, 1 unit of log (Calc) intake increase is associated with 3.93 minutes decrease in sleep variability. On the other hand, HSD was decreased with an increase intake of all of the micronutrients except for calcium where HSD was increased with an increase in log (Calc) intake; 1 unit of log (Calc) increase is associated with 0.37 minutes increase in HSD. All of the associations were not statistically significant except for the relationship between log (Cu) and HSD: For every 1 unit increase in log (Cu), there is a 7.28 minutes decrease in HSD with a p value of 0.0179 (<0.05).
Table 2: Regression coefficients, SE and P values for associations between habitual sleep patterns and micronutrient intake.

<table>
<thead>
<tr>
<th>Micronutrient Variable</th>
<th>Habitual sleep pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HSV</td>
</tr>
<tr>
<td>Log (Calc)</td>
<td>-3.93 (2.97)</td>
</tr>
<tr>
<td>Log (Cu)</td>
<td>-2.93 (2.24)</td>
</tr>
<tr>
<td>Log (Iron)</td>
<td>-1.88 (2.36)</td>
</tr>
<tr>
<td>Log (Magn)</td>
<td>-3.03 (3.93)</td>
</tr>
<tr>
<td>Log (Zn)</td>
<td>-3.10 (2.36)</td>
</tr>
</tbody>
</table>

Table 3 shows the associations between INS and micronutrients intake in terms of odds ratios and 95% confidence intervals. All the associations were not statistically significant as the confidence intervals of all the relationships included the null value 1. The odds of having insomnia complaint were decreased for 1 log unit increase in all of the micronutrients except for Zinc that did not really have an effect on INS as OR was almost 1. For example, for 1 log unit increase in calcium intake, the odds of having insomnia complaint was decreased by about 17%.
Association between interaction terms of sex with log micronutrients and habitual sleep pattern

We tested the interactions between sex and each of the micronutrients in their relationships with HSD and HSV. None of the interaction terms were statistically significant at $p < 0.10$ level.

Association between interaction terms of race with log micronutrients and habitual sleep pattern

In addition to studying the potential effect modification effect by sex, we also tested the interactions between race and each of the micronutrients in their relationships with HSD and HSV. None of the interaction terms were statistically significant at $p < 0.10$ level for HSD.

<table>
<thead>
<tr>
<th>Micronutrient Variable</th>
<th>INS</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log (Calc)</td>
<td></td>
<td>0.834</td>
<td>0.608-1.144</td>
</tr>
<tr>
<td>Log (Cu)</td>
<td></td>
<td>0.891</td>
<td>0.698-1.139</td>
</tr>
<tr>
<td>Log (Iron)</td>
<td></td>
<td>0.989</td>
<td>0.765-1.279</td>
</tr>
<tr>
<td>Log (Magn)</td>
<td></td>
<td>0.751</td>
<td>0.501-1.126</td>
</tr>
<tr>
<td>Log (Zn)</td>
<td></td>
<td>1.033</td>
<td>0.799-1.335</td>
</tr>
</tbody>
</table>

Table 3: OR and 95% for the associations between INS and log micronutrient intake.
However, the interaction terms between race and calcium (p<0.05), iron (p=0.06), magnesium (p=0.02), and zinc (p=0.08) were statistically significant. Only race and copper interaction was not statistically significant (p=0.14).

We calculated race-specific associations between these 4 micronutrients intake and HSV, and presented that results in Table 4 below.

<table>
<thead>
<tr>
<th>Variable</th>
<th></th>
<th>B (SE)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calcium</strong></td>
<td>White</td>
<td>-5.79 (3.07)</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Non-white</td>
<td>3.03 (4.48)</td>
<td>0.49</td>
</tr>
<tr>
<td><strong>Iron</strong></td>
<td>White</td>
<td>-4.18 (2.51)</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>Non-white</td>
<td>3.93 (3.97)</td>
<td>0.32</td>
</tr>
<tr>
<td><strong>Magnesium</strong></td>
<td>White</td>
<td>-5.77 (3.97)</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>Non-White</td>
<td>4.73 (5.04)</td>
<td>0.34</td>
</tr>
<tr>
<td><strong>Zinc</strong></td>
<td>White</td>
<td>-4.98 (2.51)</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Non-white</td>
<td>2.40 (3.94)</td>
<td>0.54</td>
</tr>
</tbody>
</table>

*Table 4:* Race specific relationships between micronutrients intakes and HSV.
Chapter 4: Discussion

Micronutrient intake (Copper level) and sleep duration

Previous cross-sectional studies have reported that sleep duration is associated with altered micronutrient levels\(^{[19-24]}\). While the main effect of each micronutrient on sleep patterns has been reported in research, such sleep effect may differ depending on the level of another micronutrient, suggesting an interaction among micro-nutrients\(^{[16]}\). A study conducted in 2016 in children has found that sleep duration is negatively associated with Copper intake\(^{[16]}\). Other studies have showed mixed effects on sleep duration in prior research. For example, in a cross-sectional study investigating the relationship between sleep hours and zinc and copper levels, sleep duration decreased with increased level of serum Copper\(^{[22]}\). Whereas, a study conducted in Eastern Finland investigating the association between sleep duration and serum Zinc and Copper showed highest average levels of serum Copper in the group with the longest sleep duration\(^{[19]}\). Zn:Cu in serum and hair also significantly predicted sleep duration in women, with longer sleep duration associated with a medium tertile of Zn:Cu in serum\(^{[22]}\). Even though the mean age in those two populations\(^{[19, 22]}\) is different than the one in this paper, but the results found in those studies were not linked to age differences. However, sleep duration in those papers was self-reported which may have biased the results, unlike in this paper where HSD was measured using actigraphy. Adding to that, in each one of the studies, only one gender has been studied as compared to this study, where both males and females were covered.
Even though micronutrient levels could be a regulating factor to improve sleep duration, but they may not always show a linear relation with sleep, because longest sleep duration was found in the middle tertile level of Zn and Cu in women and not in the highest tertile \cite{22}. This finding, along with proof that both short- and long-sleep duration have been found to increase mortality \cite{63}, designates that optimal versus low or high micronutrient levels are essential for healthy sleep.

**Micronutrient intake and Sleep variability**

Adolescence is often accompanied by developmental changes in sleep patterns, including a noticeable tendency for later bedtimes, insufficient sleep, long sleep-onset latency, and large night-to-night variability in sleep schedules \cite{68, 69, 70}. It has been documented in a previous study that habitual sleep variability is linked to energy intake and nutritional consumption of fats and carbohydrates, as well as with more snack consumption especially after dinner \cite{8}. But to our knowledge, there hasn’t been previously a study that has investigated a relationship between habitual sleep variability and micronutrients intake. This is the first study to examine the association between the sleep variability and the micronutrient intake behavior in a US adolescent population. HSV was found to be decreased with an increased intake of each of the micronutrients studied. However, none of these associations were statistically significant.

**Micronutrient and Insomnia Complaint.**

Several studies have examined the association between INS and micronutrients intake, specifically Calcium \cite{25} and have found that a greater difficulty falling asleep is linked to less Calcium intake, which is consistent with the results of the current study. Magnesium
was also examined and a double-blind randomized clinical trial has found that supplementation of Magnesium has resulted in a decrease in insomnia severity index \[26\]. Consistent with the results of the current study, the odds of having INS was decreased with the intake of all of the micronutrients except for Zinc where no association has been observed. However, these results were not statistically significant.

**Sex differences in association between sleep patterns and micronutrients intake**

Previous studies have examined gender differences in association between sleep and body mass index (BMI), percentage body fat and waist circumference \[27\] but there hasn’t been research done in relationship to micronutrients intake. It was found that BMI and waist circumference are inversely associated with sleep duration in females whereas in males, the associations were in the same direction and of similar magnitude, but were not statistically significant \[27\]. Likewise, sleep duration was found to be linked to BMI in women and not men in a study conducted in a sample of Southern France \[31\]. Another study conducted in adolescents \[33\], has found that longer sleep duration was weakly associated with lower BMI and risk of overweight among male adolescents only. On the other hand, other studies, in an elderly Spanish cohort \[28\], the Quebec Family Study \[29\] or a primary U.S. sample \[30\], have found that gender had no effect on the relationship between sleep and BMI.

These associations need to be further studied and examined to have a better idea about the mechanisms behind those discordant findings. But to our knowledge, there hasn’t been studies examining whether gender affects or modifies the relationship between sleep variability and sleep duration and micronutrients intake. In this current study, no
statistical significant results have been found, but further research is needed to fill in this gap in literature.

**Race differences in association between sleep patterns and micronutrients intake**

It was found in this current study that the relationship between HSV and micronutrients, specifically, Calcium, Iron, Magnesium and Zinc differs between white and non-white. For example, for 1 unit increase in calcium, HSV decreases by 5.8 minutes in white, but increases by 3.0 minutes in non-white. This implies that increased calcium intake is associated with better sleep quality in white as compared to non-white. It is worth reviewing the link between cultural racial differences and food consumption to have a potential clearer idea and rational behind the findings of this study. Ganji V has found in a study conducted in 1 – 10 years old U.S. children that black males had intakes of less than or equal to 67% of the recommended dietary allowance (RDA) of calcium micronutrient and black tend to be at higher risk for calcium, iron and zinc deficiency [42].

Adding to this, James F. Balch, M.D., author of Prescription for Nutritional Healing, writes: "A lack of the nutrients calcium and magnesium will cause you to wake up after a few hours and not be able to return to sleep [43]." And according to the European Neurology Journal, sleep quality would not be improved even if calcium intake increased, if initially, the person was deficient in calcium. What’s required at first is to restore the levels of calcium back to normal, and then after normalization of calcium status which could be achieved by meeting the RDA of calcium daily, then an increase in calcium intake might improve the quality of sleep [65, 65, 66]. And this is consistent with other studies that have argued that calcium is needed to help the brain use tryptophan, an amino acid used to make serotonin and melatonin which are neurotransmitters that slow down
nerve transmissions, relax the brain and body and encourage deep sleep \cite{44-45}. This explains the results of this study; since calcium stimulates sleep and black tend to be at greater risk of calcium deficiency \cite{42} and do consume less dairy products (calcium sources) than white \cite{46} and less than the RDA for calcium \cite{42}, this clarifies then the finding of white people sleeping better than black for every unit increase in calcium. Very similar rational is also applicable to iron intake; black people tend to be at greater risk for iron deficiency \cite{42}, and anemia was 3.3 fold more common in black than white \cite{47}. And from a biological physiological perspective, iron is also linked to less quality of sleep. A study conducted in 104 patients with iron deficiency anemia and 80 healthy individuals found that patients had less sleep quality score than healthy participants \cite{48}. Peirano et al. \cite{49} reported that iron deficiency anemia is associated with long-lasting alterations in the temporal organization of sleep patterns and that the changes in the neurotransmitter metabolism due to iron deficiency, psychological status or a possible restless leg syndrome (RLS) affected sleep negatively. Moreover, iron has a complex effect on dopaminergic function. It is a cofactor for tyrosine hydroxylase and is integral to D2 receptor function \cite{50}. Neuro-modulation by the dopamine system plays an important role in sleep regulation, including the modulation of rapid eye movement sleep quality, quantity, and timing \cite{51-52} and when iron is deficient, this whole process is altered, which as a result, affects sleep quality negatively \cite{50, 51, 52}. Those findings are consistent with the results of this study as black people, and being at higher risk of iron deficiency, tend to have higher sleep variability than white people.

Moving on to Magnesium intake, studies have shown that Black tend to have poorer nutrient profiles and dietary behaviors and patterns as compared to white and that those
differences were often defined as diets high in fat, particularly saturated fat; low in fruits, vegetables, and whole grains; and high in salt \[^{53}\]. It is also instructive to mention a few examples about racial differences in food consumption. For example, according to the Behavioral Risk Factor Surveillance Survey, only 21.3\% of African Americans consume fruits and vegetables more than five times per day, which is the lowest of any U.S. racial or ethnic group \[^{54}\]. And according to results from NHANES III (1999–2002), blacks were 43\% less likely than whites to meet USDA fruit and vegetable guidelines \[^{55}\]. And given the fact that magnesium is mainly found in vegetables, fruits, beans, and dairy products and taking into account that black people tend to consume less dairy products than white \[^{46}\], black people then tend to consume and have lower magnesium levels intake. From a chemical point of view, magnesium aids in falling and staying asleep by activating the parasympathetic nervous system which is responsible for making the person calm and relaxed \[^{56}\]. It regulates the hormone melatonin, which guides sleep-wake cycles in the body by binding the gamma-aminobutyric receptors which quiets own the nervous system resulting in preparing the body to sleep \[^{57-59}\]. It was also found that being deficient in Magnesium interferes with sleep and insomnia \[^{60}\]. So even if black increase their intake of magnesium per day, their sleep quality is going to have a higher variability than white as increase in magnesium intake for someone who is already deficient in Mg would not improve the sleep quality. However, meeting the RDA of Mg and restoring the blood levels of Mg to normal first is needed in order to have a better quality of sleep when increasing the intake of Mg afterwards \[^{56, 57, 59}\]. This supports the results of this current study that showed that white tend to have a better variability in sleep as compared to black for every one unit increase in magnesium.
Additionally, little evidence is available in regard to the relationship between zinc status and sleep quality in adolescents. Given the rapid brain growth and susceptibility to sleep impairment throughout adolescence \cite{70}, suboptimal zinc status could weaken intrinsic sleep regulation and sleep quality, and in turn affect adolescent health in general. And given that black people, including children and adolescents, are deficient in zinc given their diets that are low in fruits and vegetables as well as whole grains \cite{71}, it would make sense that their sleep quality would not improve for every unit increase in zinc.

On the other hand, racial differences in food consumption aren’t only linked to dietary factors, but also to socioeconomic statuses \cite{53, 61, 62}, parent education \cite{53} and other factors that were not accounted for in this current study.

One of the major strengths of this study is that the habitual sleep pattern was obtained using objectively measured sleep duration over seven consecutive nights which helped us, in addition to studying sleep duration, investigating the impact of night-to-night variability in HSD. Most of the previous studies in the literature have used subjective reported sleep duration which could have biased results previously. In addition, among the studies that have used objectively measured sleep duration, a lot of them were based on average sleep duration over a short period of time unlike in this study, where we were able to investigate the intake of micronutrients over a longer period of time. Furthermore, a third strength in this study is that the association between micronutrient intake and habitual sleep pattern was conducted in a free-living environment as opposed to other studies where participants were requested to follow specific sleep protocols \cite{35-37}. A fourth strength is a strong validation for the study since participants with less than five nights of sleep were excluded from the study.
There are also some limitations of the study that should be noted. Selection bias was present since the response rate was 60% for our follow-up examination. Nevertheless, there were no differences in the demographic characteristics between the participants and those lost to follow-up. Moreover, there could be recall bias in food intake which in return affects the nutrient intake conversions. However, the YAQ used in this study has been proven to be a valid tool in assessing dietary and nutritional information in adolescents according to other studies [38-39]. In addition, the small sample size and the fact that the non-white group also included Hispanics and Asians restrict the ability of generalizing the results. Lastly, there is a possibility that the associations between the interaction terms of race and micronutrient intake on HSV were confounded by unmeasured other covariates such as sociocultural factors, socio-economic status and neighborhood settings. For example, a study has showed that neighborhood disadvantage mediates a portion of race differences in waking after sleep onset, an important indicator of sleep efficiency [40]. Another study has also found that racial differences in calcium intake are confounded by differences in socioeconomic status [41-53] and parent education [53].
Chapter 5: Conclusion

In summary, we found that for every one unit increase in copper intake, there’s a 7 minutes decrease in HSD. Race does modify the association between the intake of calcium, iron, magnesium and zinc micronutrients and sleep variability. For every one unit increase in those micronutrients, HSV in white people tend to be decreased as opposed to a higher HSV in non-white, i.e. white people have a better quality of sleep than non-white for every one unit increase in each of calcium, iron, magnesium and zinc micronutrients. Further research is needed to confirm these relationships and to better understand the mechanisms behind them.
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