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# The Relationship Between Diet Quality, Micronutrient Content and Sleep Indices in Children Ages 9-11

Nicholas Joseph Marino
*Syracuse University*

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# Abstract

Physiological factors such as metabolism, circadian rhythms, and hormone production play an important role in sleep quality. The physiology of sleep is significantly modified by externally mediated factors, such as socioeconomic status and the quality of nutrition. Sleep actigraphy records from a sub-sample of school-age participants in the Syracuse Lead Study (n=125) were used to evaluate the impact of diet on sleep quality and efficiency. Sleep duration, efficiency, latency, and fragmentation were extracted from actigraphy records over 5 consecutive weekdays. Healthy Eating Index 2015 (HEI-2015) scores and component sub-scores were calculated from two 24-hour recalls per participant collected through the Automated Self-Administered 24-hour Dietary Assessment Tool (ASA 24) and completed within one week of actigraphy on a consecutive Friday and Saturday for each participant.

As to be expected, sleep efficiency and fragmentation showed strong associations with sleep duration. No significant correlations in sleep parameters were observed with total HEI score. The HEI sub-scores for saturated fat ($r = 0.200$, $p = 0.026$) and sodium ($r = 0.191$, $p = 0.033$) had a positive relationship with sleep efficiency. Additionally, total fat was positively correlated with fragmentation ($r = 0.233$, $p = 0.009$) and total activity ($r = 0.191$, $p = 0.032$). Greater energy intake (kcals) appeared alongside increased fragmentation ($r = 0.179$, $p = 0.046$). SES had a significant effect on duration ($r = 0.1814$ $p = 0.040$), efficiency ($r = 0.208$, $p = 0.020$), fragmentation ($r = -0.253$, $p = 0.004$) and total activity ($r = -0.200$, $p = 0.026$).

Nutrient analysis from dietary recalls found total fat ($r = -0.153$, $p = 0.044$) and sodium ($r = -0.177$, $p = 0.024$) showed an inverse relationship with sleep efficiency, while total fat ($r = 0.232$, $p = 0.005$). and magnesium ($r = 0.190$, $p = 0.017$) were positively correlated with

fragmentation. There were also differences between race, with Black participants found be living at a lower SES (r = -0.208, p = 0.010). White participants in the study, however, experienced greater sleep fragmentation (p = 0.030), lower HEI total scores (p = 0.007) and higher saturated fat intake (p = 0.003).

Hierarchical linear regression was used to determine if these variables explained a statistically significant amount of variance in sleep efficiency and fragmentation after accounting for the fixed factors of socioeconomic status (SES), age, race, gender, and body mass index. The fixed factors accounted for 7.7% of the variability in sleep efficiency, with dietary factors controlling an additional 5.7%; the overall contribution to sleep efficiency was not statistically significant [R2=0.134, F (12,112) =1.45, p=0.154). Fixed factors accounted for 12.9% of the total variation in sleep fragmentation, with diet contributing to an additional 9.8%. The overall model contribution to sleep fragmentation is statistically significant [R2=0.226, F (12, 112) =2.73, p=0.003]. Overall, diet contributed to sleep less than race and SES, with saturated fat being the most significant dietary component.

# The Relationship Between Diet Quality, Micronutrient Content and Sleep Indices in Children Ages 9-11

by
Nicholas J Marino
B.A., Nazareth College of Rochester, 2013

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# Introduction

Sleep is a vital biological process, tightly linked with cognitive function and metabolism (Grandner 2019). Numerous studies have demonstrated its importance for all age groups (Bruce et al. 2017; Matricciani et al. 2019; Neikrug, A. B., & Ancoli-Israel 2010). Likewise, the impact of diet on human health has been rigorously studied and documented in the scientific literature. Independently, both sleep and diet have an influence on outcomes of chronic diseases, such as cardiovascular disease, diabetes and obesity (Oakes et al. 2015; St-Onge, Mikic et al. 2016; Daniels et al. 2018; Ogilvie & Patel 2018). Yet how sleep and diet may interact with one another is still very much an emerging field of research.

More recent studies have found that energy intake and macronutrient distribution modify sleep duration and quality (St-Onge, Roberts et al. 2016; Lindseth 2016; Grandner 2014); these studies place an emphasis on carbohydrates and fat. Although appearing less frequently, there is a discussion of micronutrients in the current literature as well. Of the most prominent are melatonin, magnesium, calcium and zinc. However telling this research has been, much of it has focused on healthy adults while neglecting to include studies on underserved populations.

For a more nuanced understanding of how diet can impact sleep, social determinants must be taken into consideration. Issues such as food insecurity and family dynamics are both potential mediators of sleep that children and young adults of a lower socio-economic status (SES) face (Becerra 2020; Philbrook 2020). Other studies have examined the link between sleep duration and SES, finding that adolescents with lower SES are falling below the recommended level of sleep needed daily (Lukic 2019; Seo 2017). To better understand how diet may play a role in the relationship of sleep, SES, and health outcomes, this study compared the diet of school-aged children (n=125) living in low SES neighborhoods in the Syracuse area with sleep patterns from actigraphy data.

# Background Literature

## Sleep Quality and Disease

A growing body of literature suggests that how we sleep is directly related to a variety of disease outcomes. In adolescents and young adults, sleep quality is considered a strong predictor of BMI (Fatima et al. 2016). As sleep duration and sleep quality decrease, BMI and risk for obesity increase (Gonnissen et al. 2013). This inverse relationship highlights the global trend of obesity and widespread lack of reported sleep duration (Malik et al. 2013; Knutson et al. 2017). Elsewhere in the literature, sleep disturbance has been linked to numerous diseases, such as Alzheimer’s (Mander et al. 2016), cardio-metabolic disease (Cappuccio et al. 2017) and chronic kidney disease (Maung et 2016). With much of this research, the question of bidirectionality exists. Not knowing which problem stems from the other makes potential intervention difficult. It is important, then, to understand what role a modifiable external factor such as diet could play in the overall process.

## Macronutrients and Sleep

Both human and animal studies have found that high-energy diets rich in refined carbohydrates and saturated fats negatively impact sleep duration and quality (Grandner et al. 2010; St-Onge, Mikic et al. 2016; Panagiotou et al. 2018). While many of these studies have employed adult participants, recent research has drawn the same conclusion from young children and adolescents (Coronado et al. 2019; Córdova et al. 2018), making macronutrients a key area of interest when examining this relationship. In a randomized crossover trial of young adults, high intake of carbohydrates trended alongside short sleep duration (Lindseth et al. 2016). The same study noted a positive correlation between sleep quality and high-fat intake. Another cross-sectional study of Korean adults with dyslipidemia also found short sleep duration to be associated with high carbohydrate consumption (Doo et al. 2016). An echo of similar findings can also be found in a study in which teenage Saudi girls sleeping less than 5 hours per night consumed a higher proportion of carbohydrates than those sleeping 7 or more hours per night (Al-Disi et al 2010). Other research has focused more specifically on type and timing of carbohydrate intake, observing that reduced morning and midday sugar consumption led to healthier sleep duration in a large cohort of young European children (Hunsberger et al. 2015). Furthermore, carbohydrate absorption may depend on circadian rhythms, lending more credence to the notion that meal-timing is important (Hussain et al. 2015).

The evidence for the impact of fat intake on sleep is more equivocal, with some studies showing a positive correlation between the two (Lindseth et al. 2016) while others demonstrate the opposite effect (Grandner et al. 2014). For example, the consumption of monounsaturated fats improved sleep quality in pregnant women, while consumption of carbohydrates was associated with worse sleep (Bennett et al. 2019). The results of this study stand in contrast to others. A randomized cross-over trial of adults showed that greater fiber intake led to more restorative sleep, while a negative correlation was found between saturated fat and sleep quality (St-Onge, Roberts et al. 2016). Another study using a 24-hour dietary recall and wrist-actigraphy measurements of 240 adolescents found that sleeping less than 8 hours per night was associated with greater fat intake and fewer calories from carbohydrates (Weiss et al. 2010). The study also found that sleep duration decreased with excess energy intake from snacks. These findings illustrate the potential for macronutrient needs to differ between ages and throughout the lifecycle. Moreover, the types of each macronutrient in these studies vary. The fiber that increased sleep quality is nutritionally very different from other carbohydrates, such as refined sugars, which appear to have the opposite effect on sleep. The high saturated fat content of snack foods is not comparable to a healthy amount of monounsaturated fatty acids either. Therefore, it is essential to examine overall diet quality and its effect on sleep.

## Diet Quality and Sleep

The Healthy Eating Index has long been used as a way of assessing diet quality. It has proven useful in studies observing the effect of diet quality on sleep. A study of Hispanic and Latino adults comparing HEI scores and accelerometry data showed a link between diet quality and both sleep duration and efficiency (Mossavar-Rahmani et al. 2017). Other researchers found the same positive link between HEI scores and sleep (Van Lee et al. 2017; Cristina et al. 2017). When the diet and sleep patterns of healthy pregnant women were examined, sleep quality was again positively associated with HEI (Van Lee et al. 2017). In another study, Brazillian shift workers reported shorter sleep duration alongside lower HEI scores (Cristina et al. 2017).

More recent studies have focused on how diet quality can affect sleep specific disorders. For instance, a diverse cohort of adults with obstructive sleep apnea exhibited lower overall HEI scores, resulting largely from a high intake of processed red meat and lower intake of whole grains (Reid et al. 2019). In fact, fruit and vegetable intake proved an important driver of diet quality and sleep efficiency in many related studies (Mossavar-Rahmani et al. 2017; Van Lee et al. 2017). Not only do these fruits and vegetables provide a necessary source of fiber, they also constitute an important source of micronutrients that may be vital to promoting healthy sleep.

## Micronutrients and Sleep

A variety of micronutrients have been implicated in sleep homeostasis. Recent findings from a cross-sectional study using NHANES data found that falling below the estimated average requirement (EAR) was linked to short sleep duration (Ikonte et al. 2019). A multitude of nutrients were implicated, including copper, folate, iron, magnesium, riboflavin, zinc, and vitamins A, C and K (Ikonte et al. 2019). Key nutrients from this and other studies demonstrate the importance of micronutrients in regulating sleep.

An association between low levels of carotenoids and short sleep duration has also been foregrounded by recent surveys and dietary data (Noorwali et al. 2018; Beydoun et al. 2014). In fact, a carotenoid found in saffron was shown to promote sleep quality in a randomized control trial (Umigai et al. 2018). Researchers discovered improvements in delta waves during sleep as well as a decrease in daytime sleepiness in the experimental group.

Understanding the mechanism behind these results is difficult, as these results may be explained by vitamin A's many roles ability to modulate gene expression, it's role in photoceptors, or it's antioxidant action. The versatility of this particular micronutrient could affect sleep in a variety of ways. Still, a recent study investigating how antioxidants mediate sleep found that serum carotenoids were positively associated with sleep duration (Kanagasabai & Arden 2015). The study also revealed a positive relationship between antioxidants and sleep, in addition to an inverse relationship between inflammation and sleep duration. These results point to inflammatory stress as a potential disruptor of sleep while simultaneously highlighting the role that antioxidants may play in affecting sleep.

Another antioxidant with a strong link to sleep regulation is melatonin, a hormone produced by the pineal gland (Reiter et al. 2018). It is synthesized using the amino acid tryptophan as a precursor. Melatonin has been shown to affect circadian rhythms in mammals through the mechanism of cell excitability and potassium channel regulation (Kun et al. 2019; Lewis 2016). For example, in an observational study of patients with traumatic brain injury, endogenous melatonin secretion decreased by 42% compared to healthy individuals (Grima et al. 2016). Nutritionally, melatonin has become a compound of interest as studies have demonstrated that exogenous sources can have beneficial effects (Gomes et al. 2019). However, the extent to which food sources contribute to sleep health is still unknown, presenting a novel area for research.

Given the complexity of sleep and the biochemical pathways involved, many vitamins have shown effects on sleep. In fact, a recent meta-analysis found that being vitamin D deficient increased the risk of sleep disorders (Gao et al. 2018). The analysis also revealed a correlation between vitamin D deficiency and poor sleep quality, short sleep duration, and tiredness (Gao et al. 2018). Correlations between serum vitamin D and sleep disorders were observed in a study of children with familial Mediterranean fever (Ekinci et al. 2018).

The same study also foregrounded associations between sleep quality and vitamin $B_{12}$. Although studies on B vitamins and sleep are less prevalent in the literature, in a randomized control trial, the intake of $B_6$ increased the number of dreams during sleep, while proving no effect on sleep quality (Aspy et al. 2018). However, a study of hemodialysis patients found that higher intake of B vitamins had a positive effect on sleep quality (Ongan et al. 2017). Another study of participants with insomnia demonstrated that treatment with vitamin $B_6$, $B_{12}$, melatonin and magnesium improved symptoms (Djokic et al. 2019). These studies open the door to the further investigation of potential effects of minerals and how they may interact with vitamins in aiding sleep.

Minerals have also appeared in the literature on diet and sleep, with several key cations being of interest. Calcium, iron, and magnesium have all been shown to have an effect on sleep. In mammalian bodies, calcium acts as an important secondary messenger in neurons. Calcium signaling capacity has appeared in multiple studies examining its role in sleep. For example, knockout of genes encoding for voltage-gated calcium channel proteins was reported to decrease sleep duration and affect sleep architecture in mice (Münch et al. 2013). Another rodent study saw calcium activity in the hippocampus shift throughout different phases of the sleep-wake cycle (Zhou et al. 2019). Calcium levels were lowest during the slow-wave sleep period but increased during REM sleep to levels almost on par with the waking period (Zhou et al. 2019). This suggests that calcium is a dynamic mineral, mirroring the patterns of our circadian rhythms. In humans, low calcium intake has been linked to poor sleep quality, indicating an opportunity for potential interventions (Alkhatatbeh et al. 2020).

Iron has mostly been associated with periodic limb movement and restless leg syndrome in children, with inadequate iron status and deficiency positively influencing disordered sleep (Simakajornboon et al. 2003; Lane et al. 2015). This correlation often occurs alongside autism (Lane et al. 2015). A 2020 review showed iron deficiency increased the risk of sleep disorder and that iron supplementation may mediate this risk, particularly in children (Leung et al. 2020).

Magnesium plays major roles in neuron excitability in the central nervous system, as well as neurotransmitter synthesis, both of which are important factors in sleep homeostasis. (Chollet et al. 2001). Additionally, fluctuations in intracellular magnesium concentration have been shown to affect clock gene expression (Feeney et al. 2016). Magnesium has also been implicated in endogenous melatonin production, by enhancing serotonin N-acetyl transferase activity, an important enzyme needed for melatonin synthesis (Durlach et al. 2002).

Studies have shown dietary magnesium to have an effect on sleep, yet the results are mixed. A longitudinal study of Chinese adults found that magnesium intake decreased daytime sleepiness among women but not men (Cao et al. 2018). Another study of elderly patients in Italy with insomnia found a combination of magnesium, melatonin and zinc to improve sleep quality (Rondanelli et al. 2011). These results emphasize the fact that multiple dietary compounds may be at play and have a synergistic effect.

## Diet and Sleep Among Children from Low-Income Families

Both diet and sleep recommendations change throughout the lifespan. Of course, much emphasis is placed on children meeting these requirements, given that childhood is an important period of growth and development. Not all children, however, have access to the same food. Furthermore, sleep quality and duration may vary depending on household income (Seo et al. 2017). For adolescents in the U.S., HEI-based dietary quality is still poor, but this is especially true for children of lower socioeconomic status (Gu & Tucker et al. 2016). This problem is compounded by the food insecurity that many children face, which is negatively associated with HEI scores (Landry et al. 2019). Since food insecurity is also linked to poor sleep quality in children, it is important to address this issue in studies working with marginalized populations (Na et al. 2020).

Research on how diet relates to sleep among children from low-income families is less common; what does exist has yielded mixed results. Some studies have focused on the connection between short sleep duration and obesity. One such study found an inverse relationship between poor sleep behaviors, such as late bedtimes and night awakenings, and HEI scores among toddlers (Hager et al. 2016). Another study of ethnically diverse preschoolers found that short sleep duration was associated with higher intake of fat and negatively correlated with carbohydrate consumption (Petrov et al. 2017). Also, sleep irregularity was associated with a higher proportion of calories from fat and protein. These results were echoed in a Dutch study of toddlers in which a greater proportion of calories from fat was associated with short sleep duration when compared to carbohydrates and protein (Kocevska et al. 2016).

Still, some of the available evidence on sleep in marginalized populations presents conflicting results. In a study of Mexican American adolescents, longer sleep duration was associated with higher intake of fat while shorter sleep trended alongside higher carbohydrate intake (Martinez et al. 2017). Specifically, polyunsaturated fats had the biggest influence on increased sleep duration. These inconsistent findings underscore the need for more research on this subject.

# Methods

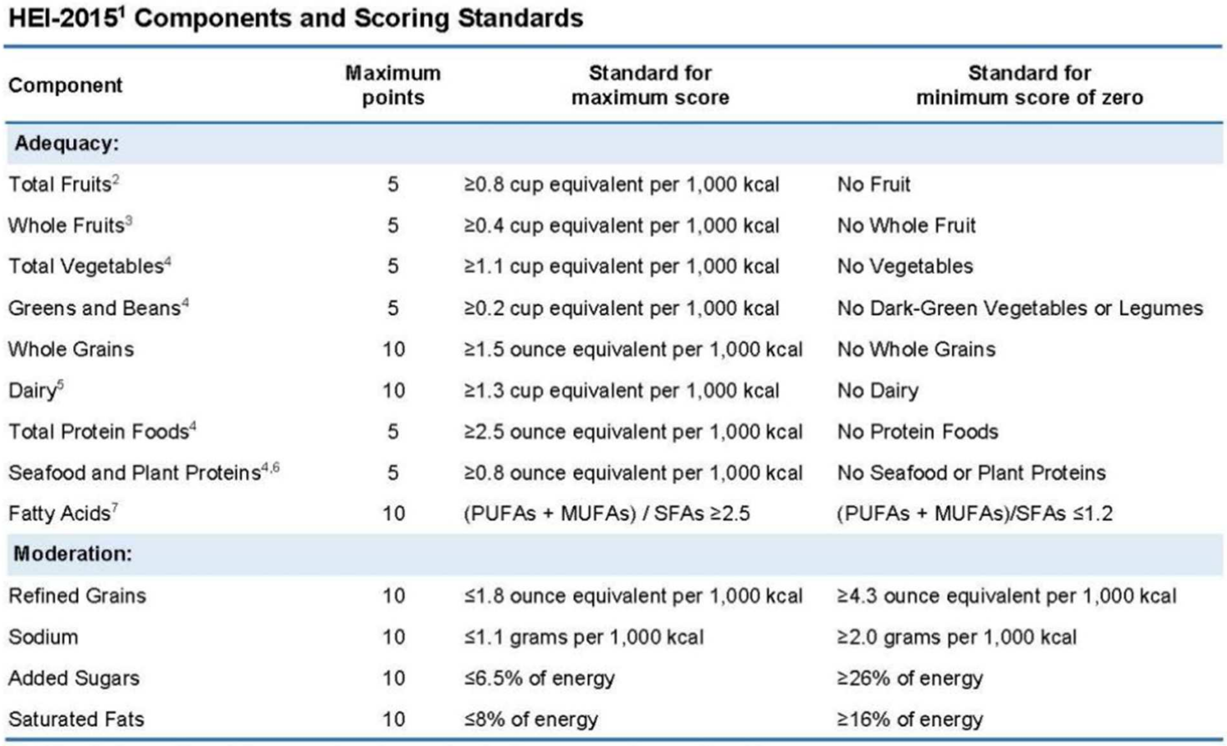
## Population

Participants selected for this study were initially part of the Syracuse Lead Study, conducted by researchers at Falk College at Syracuse University (Syracuse Lead Study 2019). Children were ages 9 to 11 at the time of data collection and identified as either Black/African American or White/European American. Both sex and race were equally represented in the final data analyzed. For the original study, low to middle-income households were targeted, all being from low SES zip codes in the Syracuse area. After excluding for missing data, 125 participants' diet and sleep measures were assessed.

## Dietary Assessment

Dietary intake data was collected using the Automated Self-Administered 24-hour method (ASA-24). Immediately following the period of sleep measurement, the ASA24 was administered to capture a detailed picture for two days of each participant’s diet. Data were collected on a Friday and Saturday to represent both weekdays and weekends. HEI scores were calculated as part of the Syracuse Lead Study. The most current Healthy Eating Index was used for scoring (Table 1). Nutritional data are further broken down into component scores using this system.

*Table 1**: HEI-2015 Scoring Components and Scoring Standards (USDA 2018)***



**HEI-2015[1] Components and Scoring Standards**

| Component | Maximum points | Standard for maximum score | Standard for minimum score of zero |
|---|---|---|---|
| **Adequacy:** | | | |
| Total Fruits[2] | 5 | ≥0.8 cup equivalent per 1,000 kcal | No Fruit |
| Whole Fruits[3] | 5 | ≥0.4 cup equivalent per 1,000 kcal | No Whole Fruit |
| Total Vegetables[4] | 5 | ≥1.1 cup equivalent per 1,000 kcal | No Vegetables |
| Greens and Beans[4] | 5 | ≥0.2 cup equivalent per 1,000 kcal | No Dark-Green Vegetables or Legumes |
| Whole Grains | 10 | ≥1.5 ounce equivalent per 1,000 kcal | No Whole Grains |
| Dairy[5] | 10 | ≥1.3 cup equivalent per 1,000 kcal | No Dairy |
| Total Protein Foods[4] | 5 | ≥2.5 ounce equivalent per 1,000 kcal | No Protein Foods |
| Seafood and Plant Proteins[4,6] | 5 | ≥0.8 ounce equivalent per 1,000 kcal | No Seafood or Plant Proteins |
| Fatty Acids[7] | 10 | (PUFAs + MUFAs) / SFAs ≥2.5 | (PUFAs + MUFAs)/SFAs ≤1.2 |
| **Moderation:** | | | |
| Refined Grains | 10 | ≤1.8 ounce equivalent per 1,000 kcal | ≥4.3 ounce equivalent per 1,000 kcal |
| Sodium | 10 | ≤1.1 grams per 1,000 kcal | ≥2.0 grams per 1,000 kcal |
| Added Sugars | 10 | ≤6.5% of energy | ≥26% of energy |
| Saturated Fats | 10 | ≤8% of energy | ≥16% of energy |

## Accelerometry

Sleep data were collected using MotionWatch 8® actigraphy from an 8-day period of Saturday to Sunday of the following week. Participants continuously wore MotionWatch 8® on their wrists for the duration of the period. Both movement and light exposure were captured using 15-second epochs (Figure 1).

Using the actigraphy data, 8 variables were measured including: sleep duration: number of hours from falling sleep to waking up, sleep efficiency: percentage of time spent asleep while in bed, sleep latency: amount of time between going to bed and falling asleep, wake bouts: number of waking periods as determined by the epoch-by-epoch wake/sleep categorization, immobility time: percentage of time spent without any recorded movement during sleep, immobility bouts: number of period spent without any recorded movement as determined by the epoch-by-epoch wake/sleep categorization, total activity: the total of all the activity counts per epoch during the assumed sleep period and sleep fragmentation: a ratio of the percentage of time spent mobile versus immobile during sleep. Actigraphy has been validated and demonstrated to be a more powerful determinant of actual sleep compared to self-reported sleep (Girschik et al. 2012).

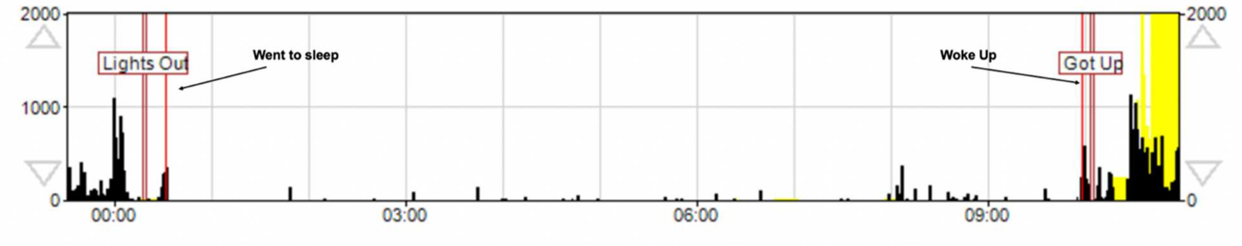


*Figure 1:* ***MotionWatch® actigraphy example (Camtech 2020)***

## Data Analysis

The statistics for this study were computed using IBM SPSS 22 Statistics for Windows (Armonk, NY; IBM corp). In all analyses, sleep measurements were used as the dependent variables with dietary data as independent variables. Tests for normality were conducted and transformations were made where appropriate. Significance levels were set at $\alpha = 0.05$. Descriptive statistics, including means, frequencies, and standard deviation, were calculated for all variables. Covariates included factors that may influence sleep outcomes, including age, race, sex, and BMI.

Patterns that emerged from the descriptive statistics and a comprehensive correlation analysis were used to guide subsequent analyses. Additional correlation, linear regression and path analyses were used to identify relationships between diet (HEI scores, HEI sub-scores, and individual nutrient intakes, both macro- and micronutrient, calculated from the ASA24 dietary recalls) and sleep variables. As a combination of fat and minerals (osmotic concentration) are known to contribute to satiety, all micronutrient analyses included fat as a variable. Relationships between diet and sleep were further evaluated with hierarchical linear regression to understand the relative contributions of covariates (SES, BMI, race, etc.) and diet components to variation in sleep measures. Finally, a multivariate regression analysis was done to develop a path analysis to better understand the direction of relationships between the study variables.

# Results

### Descriptive Statistics for Demographics, Sleep, Socioeconomic Status, and Dietary Quality

Among the participants for whom complete sleep and dietary data were available, the mean age was 10.6 (SD = 0.9) years (Table 2). There were a greater number of children who identified as Black (N= 86) than those who identified as white (N=39). The average BMI percentile was calculated to be 74.8 and 64.8 for Black and white participants respectively, with no significant difference (p = 0.225). According to CDC guidelines, these children are within the percentile range for healthy weight (CDC 2020). SES z-scores were also found to be significantly different with respect to race, with Black children having a lower z-score than white children in the study (p = 0.020). Differences were also seen between the fragmentation index and diet quality. White children in this study experienced greater sleep fragmentation (p = 0.030), lower HEI total scores (p = 0.007), and higher saturated fat intake (p = 0.003). It should be noted, though, that both mean HEI scores fell below the national average for this age group and indicates that overall, this population is not meeting dietary recommendations (USDA 2018).

*Table 2: Descriptive statistics of study demographics, sleep variables, socioeconomic status, HEI subcomponent scores, fat, protein, and total caloric intake.*

| | Black | | | White | | | Significant Difference ($p < 0.05$)* |
|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | N | Mean | Std. Dev. | N | |
| **Child Age** | 10.4 | 0.9 | 86 | 10.7 | 0.9 | 39 | 0.196 |
| **BMI Percentile** | 74.8 | 28.0 | 86 | 64.8 | 34.7 | 39 | 0.086 |
| **Gender**** | 1.5 | 0.5 | 86 | 1.5 | 0.5 | 39 | 0.783 |
| **SES Z-Score** | -0.1 | 0.9 | 86 | 0.3 | 0.9 | 39 | ***0.020*** |
| **Sleep Duration** | 86.3 | 4.4 | 86 | 84.9 | 4.9 | 39 | 0.113 |
| **Sleep Efficiency** | 85.2 | 4.6 | 86 | 84.2 | 4.9 | 39 | 0.284 |
| **Fragmentation Index** | 25.0 | 7.9 | 86 | 28.3 | 7.2 | 39 | ***0.030*** |
| **Total Activity Score** | 6367.9 | 3772.7 | 86 | 6665.1 | 4235.4 | 39 | 0.695 |
| **Kcals** | 2100.2 | 580.3 | 86 | 2016.1 | 564.6 | 39 | 0.450 |
| **HEI Total Score** | 48.7 | 9.9 | 86 | 43.4 | 9.3 | 39 | ***0.007*** |
| **HEI Saturated Fat** | 6.1 | 2.6 | 86 | 4.5 | 2.6 | 39 | ***0.003*** |
| **HEI Added Sugars** | 5.4 | 2.8 | 86 | 5.9 | 3.0 | 39 | 0.406 |
| **HEI Sodium** | 3.7 | 3.1 | 86 | 3.9 | 3.0 | 39 | 0.737 |
| **HEI Total Vegetable** | 2.2 | 1.4 | 86 | 2.1 | 1.2 | 39 | 0.733 |
| **Total Fat** | 77.4 | 26.6 | 86 | 77.2 | 26.6 | 39 | 0.972 |
| **Protein** | 77.1 | 27.2 | 86 | 73.4 | 23.4 | 39 | 0.469 |

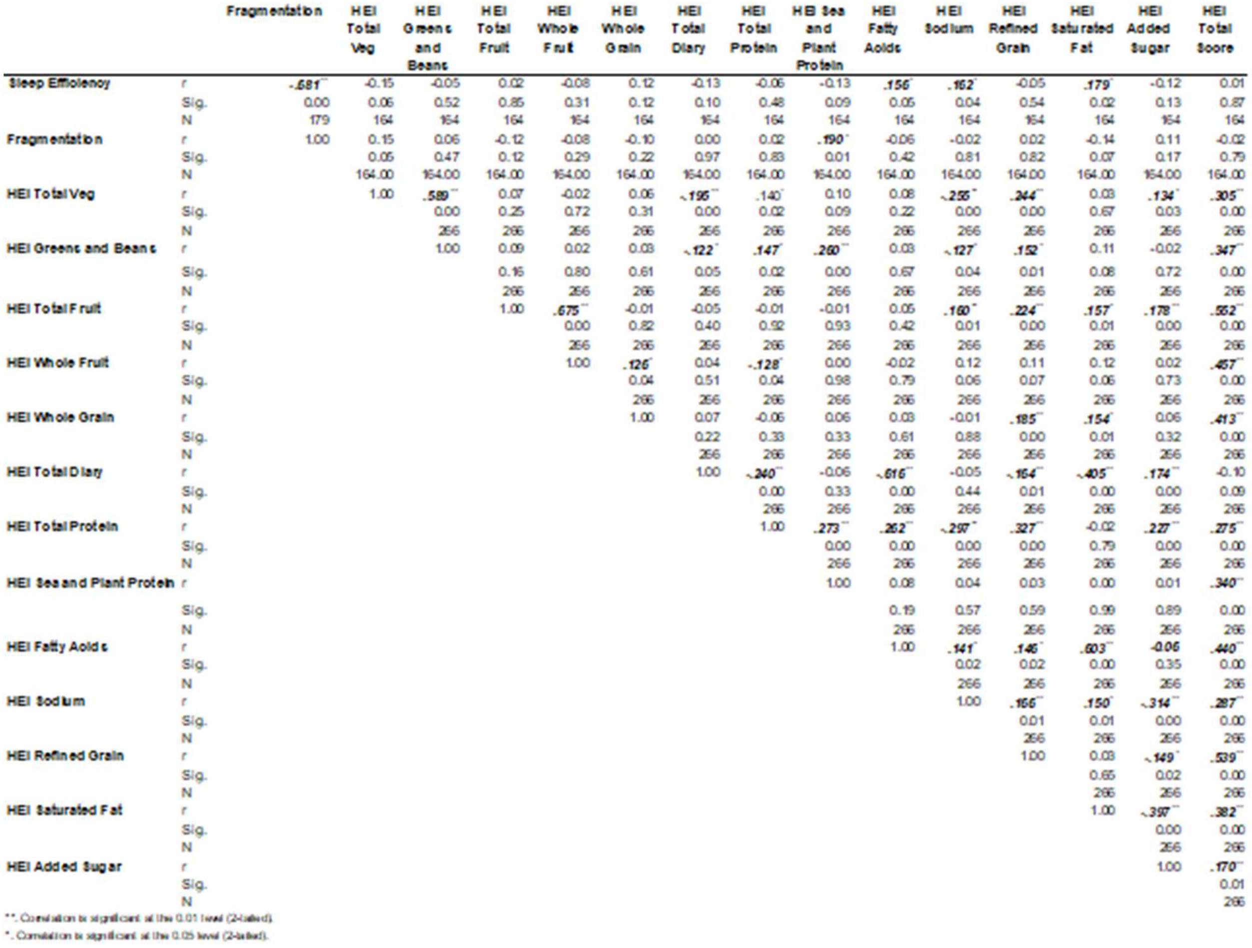
*Alpha = 0.05; **Male = 1, Female = 2

Independent samples T-test assuming equal variances

## Correlation Analysis of Sleep Variables and HEI sub-scores

The HEI sub-scores collapse the dimensionality of complex nutrient intake data into discrete dietary categories. These sub-scores were compared to sleep efficiency and fragmentation in a correlation analysis (Table 3). Sleep efficiency increased with increased fatty acids (r=0.156, p=0.05), sodium (r=0.162, p=0.04), and saturated fat (r=0.179, p=0.02) in the diet. Sleep fragmentation appeared to increase with increased sea and plant protein in the diet.

*Table 3: Correlation analysis of sleep variables and HEI sub-scores*



| | | Fragmentation | HEI Total Veg | HEI Greens and Beans | HEI Total Fruit | HEI Whole Fruit | HEI Whole Grain | HEI Total Diary | HEI Total Protein | HEI Sea and Plant Protein | HEI Fatty Acids | HEI Sodium | HEI Refined Grain | HEI Saturated Fat | HEI Added Sugar | HEI Total Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sleep Efficiency** | r | -.681** | -0.15 | -0.05 | 0.02 | -0.08 | 0.12 | -0.13 | -0.06 | -0.13 | .156* | .162* | -0.05 | .179* | -0.12 | 0.01 |
| | Sig. | 0.00 | 0.06 | 0.52 | 0.85 | 0.31 | 0.12 | 0.10 | 0.48 | 0.09 | 0.05 | 0.04 | 0.54 | 0.02 | 0.13 | 0.87 |
| | N | 179 | 164 | 164 | 164 | 164 | 164 | 164 | 164 | 164 | 164 | 164 | 164 | 164 | 164 | 164 |
| **Fragmentation** | r | 1.00 | 0.15 | 0.06 | -0.12 | -0.08 | -0.10 | 0.00 | 0.02 | .190* | -0.06 | -0.02 | 0.02 | -0.14 | 0.11 | -0.02 |
| | Sig. | | 0.05 | 0.47 | 0.12 | 0.29 | 0.22 | 0.97 | 0.83 | 0.01 | 0.42 | 0.81 | 0.82 | 0.07 | 0.17 | 0.79 |
| | N | | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 | 164.00 |
| **HEI Total Veg** | r | | 1.00 | .589** | 0.07 | -0.02 | 0.06 | -.195** | .140* | 0.10 | 0.08 | -.255** | .244** | 0.03 | .134* | .305** |
| | Sig. | | | 0.00 | 0.25 | 0.72 | 0.31 | 0.00 | 0.02 | 0.09 | 0.22 | 0.00 | 0.00 | 0.67 | 0.03 | 0.00 |
| | N | | | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 |
| **HEI Greens and Beans** | r | | | 1.00 | 0.09 | 0.02 | 0.03 | -.122* | .147* | .260** | 0.03 | -.127* | .152* | 0.11 | -0.02 | .347** |
| | Sig. | | | | 0.16 | 0.80 | 0.61 | 0.05 | 0.02 | 0.00 | 0.67 | 0.04 | 0.01 | 0.08 | 0.72 | 0.00 |
| | N | | | | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 |
| **HEI Total Fruit** | r | | | | 1.00 | .675** | -0.01 | -0.05 | -0.01 | -0.01 | 0.05 | .160* | .224** | .157* | .178** | .552** |
| | Sig. | | | | | 0.00 | 0.82 | 0.40 | 0.92 | 0.93 | 0.42 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| | N | | | | | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 |
| **HEI Whole Fruit** | r | | | | | 1.00 | .126* | 0.04 | -.128* | 0.00 | -0.02 | 0.12 | 0.11 | 0.12 | 0.02 | .457** |
| | Sig. | | | | | | 0.04 | 0.51 | 0.04 | 0.98 | 0.79 | 0.06 | 0.07 | 0.06 | 0.73 | 0.00 |
| | N | | | | | | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 |
| **HEI Whole Grain** | r | | | | | | 1.00 | 0.07 | -0.06 | 0.06 | 0.03 | -0.01 | .185** | .154* | 0.06 | .413** |
| | Sig. | | | | | | | 0.22 | 0.33 | 0.33 | 0.61 | 0.88 | 0.00 | 0.01 | 0.32 | 0.00 |
| | N | | | | | | | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 |
| **HEI Total Diary** | r | | | | | | | 1.00 | -.240** | -0.06 | -.616** | -0.05 | -.164** | -.405** | .174** | -0.10 |
| | Sig. | | | | | | | | 0.00 | 0.33 | 0.00 | 0.44 | 0.01 | 0.00 | 0.00 | 0.09 |
| | N | | | | | | | | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 |
| **HEI Total Protein** | r | | | | | | | | 1.00 | .273** | .262** | -.297** | .327** | -0.02 | .227** | .275** |
| | Sig. | | | | | | | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.79 | 0.00 | 0.00 |
| | N | | | | | | | | | 266 | 266 | 266 | 266 | 266 | 266 | 266 |
| **HEI Sea and Plant Protein** | r | | | | | | | | | 1.00 | 0.08 | 0.04 | 0.03 | 0.00 | 0.01 | .340** |
| | Sig. | | | | | | | | | | 0.19 | 0.57 | 0.59 | 0.99 | 0.89 | 0.00 |
| | N | | | | | | | | | | 266 | 266 | 266 | 266 | 266 | 266 |
| **HEI Fatty Acids** | r | | | | | | | | | | 1.00 | .141* | .146* | .603** | -0.06 | .440** |
| | Sig. | | | | | | | | | | | 0.02 | 0.02 | 0.00 | 0.35 | 0.00 |
| | N | | | | | | | | | | | 266 | 266 | 266 | 266 | 266 |
| **HEI Sodium** | r | | | | | | | | | | | 1.00 | .166** | .150* | -.314** | .287** |
| | Sig. | | | | | | | | | | | | 0.01 | 0.01 | 0.00 | 0.00 |
| | N | | | | | | | | | | | | 266 | 266 | 266 | 266 |
| **HEI Refined Grain** | r | | | | | | | | | | | | 1.00 | 0.03 | -.149* | .539** |
| | Sig. | | | | | | | | | | | | | 0.65 | 0.02 | 0.00 |
| | N | | | | | | | | | | | | | 266 | 266 | 266 |
| **HEI Saturated Fat** | r | | | | | | | | | | | | | 1.00 | -.397** | .382** |
| | Sig. | | | | | | | | | | | | | | 0.00 | 0.00 |
| | N | | | | | | | | | | | | | | 266 | 266 |
| **HEI Added Sugar** | r | | | | | | | | | | | | | | 1.00 | .170** |
| | Sig. | | | | | | | | | | | | | | | 0.01 |
| | N | | | | | | | | | | | | | | | 266 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

## Analysis of Sleep Variables, Covariates, and Macronutrient Data from the ASA24 Dietary Recall

Sleep measures (duration, efficiency, fragmentation, and activity) were compared with HEI sub-scores, SES z-score and BMI. Both sleep efficiency and fragmentation showed strong associations with sleep duration. As duration increased, so did efficiency ($r = 0.936$, $p = 0.000$), while duration and fragmentation showed an inverse relationship ($r = -0.722$, $p = 0.000$). Total activity score also had a negative correlation with sleep duration ($r = -0.754$, $p = 0.000$). Furthermore, activity and fragmentation were strongly positively correlated ($r = 0.661$, $p = 0.000$). As expected, sleep efficiency and fragmentation were inversely related ($r = -0.693$, $p = 0.000$).

Several dietary component scores were significantly associated with sleep measures as well. Saturated fat ($r = 0.200$, $p = 0.026$) and sodium ($r = 0.191$, $p = 0.033$) scores had a positive relationship with sleep efficiency. Greater energy intake (kcals) increased alongside fragmentation ($r = 0.179$, $p = 0.046$). Total fat was also positively associated with fragmentation ($r = 0.233$, $p = 0.009$), as was total activity ($r = 0.191$, $p = 0.032$). In addition to diet, SES had a significant effect on all four indices of sleep. Duration ($r = 0.1814$ $p = 0.040$) and efficiency ($r = 0.208$, $p = 0.020$) increased alongside SES, while fragmentation ($r = -0.253$, $p = 0.004$) and total activity ($r = -0.200$, $p = 0.026$) had a negative correlation. Correlation analysis results for significant variables are presented in Table 4.

*Table 4: Correlation analysis of total activity, sleep duration, sleep efficiency, sleep fragmentation, activity, caloric intake, and macronutrient data from the ASA24 dietary recall*

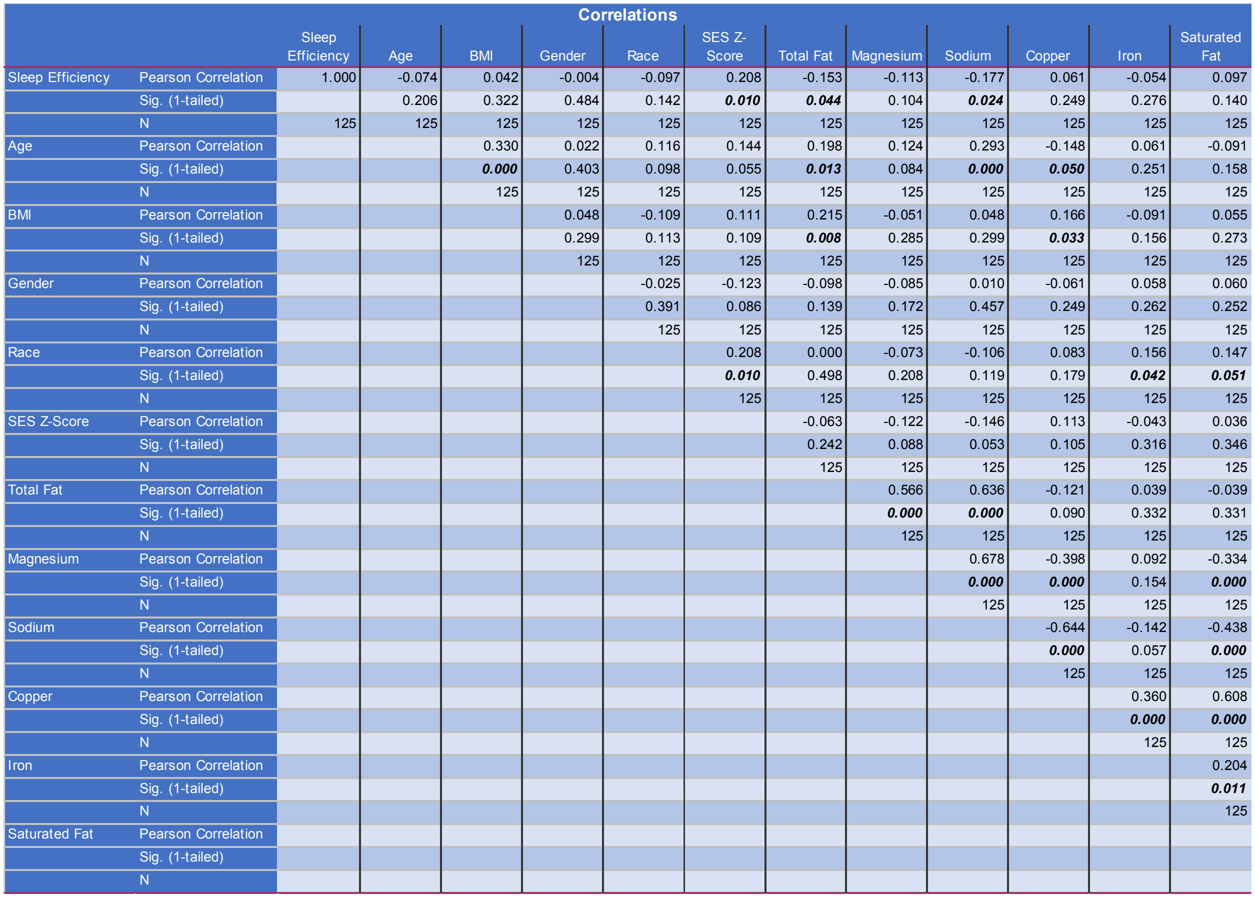
**Correlations**

| | | SES Z-Score | BMI | Sleep Duration | Sleep Efficiency | Fragmentation | Total Activity | Sodium | Saturated Fat | Added Sugar | Kcals | Protein | Total Fat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SES Z-Score | Pearson Correlation | 1 | 0.111 | .184$^{*}$ | .208$^{*}$ | -.253$^{**}$ | -.200$^{*}$ | 0.074 | -0.135 | 0.038 | -0.094 | -0.094 | -0.065 |
| | Sig. (2-tailed) | | 0.218 | ***0.040*** | ***0.020*** | ***0.004*** | ***0.026*** | 0.411 | 0.132 | 0.674 | 0.298 | 0.296 | 0.473 |
| | N | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| BMI | Pearson Correlation | | | 0.038 | 0.042 | -0.072 | 0.015 | -0.139 | -0.083 | 0.131 | 0.124 | .182$^{*}$ | .214$^{*}$ |
| | Sig. (2-tailed) | | | 0.672 | 0.644 | 0.422 | 0.866 | 0.121 | 0.360 | 0.147 | 0.168 | ***0.042*** | ***0.016*** |
| | N | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Sleep Duration | Pearson Correlation | | | | .936$^{**}$ | -.722$^{**}$ | -.754$^{**}$ | 0.125 | 0.163 | -0.122 | -0.120 | -0.098 | -0.162 |
| | Sig. (2-tailed) | | | | ***0.000*** | ***0.000*** | ***0.000*** | 0.165 | 0.069 | 0.174 | 0.184 | 0.278 | 0.071 |
| | N | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Sleep Efficiency | Pearson Correlation | | | | | -.693$^{**}$ | -.726$^{**}$ | .191$^{*}$ | .200$^{*}$ | -0.107 | -0.108 | -0.103 | -0.149 |
| | Sig. (2-tailed) | | | | | ***0.000*** | ***0.000*** | ***0.033*** | ***0.026*** | 0.235 | 0.231 | 0.252 | 0.097 |
| | N | | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Fragmentation | Pearson Correlation | | | | | | .661$^{**}$ | -0.043 | -0.106 | 0.074 | .179$^{*}$ | 0.106 | .233$^{**}$ |
| | Sig. (2-tailed) | | | | | | ***0.000*** | 0.636 | 0.237 | 0.412 | ***0.046*** | 0.241 | ***0.009*** |
| | N | | | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Total Activity | Pearson Correlation | | | | | | | -0.075 | -0.084 | 0.121 | 0.144 | 0.086 | .191$^{*}$ |
| | Sig. (2-tailed) | | | | | | | 0.406 | 0.351 | 0.179 | 0.108 | 0.339 | ***0.032*** |
| | N | | | | | | | 125 | 125 | 125 | 125 | 125 | 125 |
| Sodium | Pearson Correlation | | | | | | | | .286$^{**}$ | -.273$^{**}$ | 0.097 | -0.165 | -0.008 |
| | Sig. (2-tailed) | | | | | | | | ***0.001*** | ***0.002*** | 0.280 | 0.066 | 0.927 |
| | N | | | | | | | | 125 | 125 | 125 | 125 | 125 |
| Saturated Fat | Pearson Correlation | | | | | | | | | -.294$^{**}$ | -0.043 | -0.104 | -.336$^{**}$ |
| | Sig. (2-tailed) | | | | | | | | | ***0.001*** | 0.630 | 0.248 | ***0.000*** |
| | N | | | | | | | | | 125 | 125 | 125 | 125 |
| Added Sugar | Pearson Correlation | | | | | | | | | | 0.018 | .372$^{**}$ | .206$^{*}$ |
| | Sig. (2-tailed) | | | | | | | | | | 0.838 | ***0.000*** | ***0.021*** |
| | N | | | | | | | | | | 125 | 125 | 125 |
| Kcals | Pearson Correlation | | | | | | | | | | | .752$^{**}$ | .868$^{**}$ |
| | Sig. (2-tailed) | | | | | | | | | | | ***0.000*** | ***0.000*** |
| | N | | | | | | | | | | | 125 | 125 |
| Protein | Pearson Correlation | | | | | | | | | | | | .701$^{**}$ |
| | Sig. (2-tailed) | | | | | | | | | | | | ***0.000*** |
| | N | | | | | | | | | | | | 125 |
| Total Fat | Pearson Correlation | | | | | | | | | | | | |
| | Sig. (2-tailed) | | | | | | | | | | | | |
| | N | | | | | | | | | | | | |

### Hierarchical Regression Analysis of Sleep Efficiency, Fat and Micronutrient Dietary Data Recall

The hierarchical regression analysis consists of two parts. The first is a correlation analysis of sleep efficiency and ASA24 micronutrient variables that will be included in the subsequent regression analysis. Sleep efficiency had a significant positive correlation with SES (r = -0.208, p = 0.010). Total dietary fat (r = -0.153, p = 0.044) and sodium (r = -0.177, p = 0.024) showed an inverse relationship. No significant relationship was found between efficiency and saturated fat, nor for any other minerals in the diet (Table 5).

*Table 5: Correlation analysis of sleep efficiency and significant micronutrient data from the ASA24 dietary recall. Total fat is included in this analysis as the interaction of fat and minerals (osmotic concentration) may contribute to variation in sleep measures.*

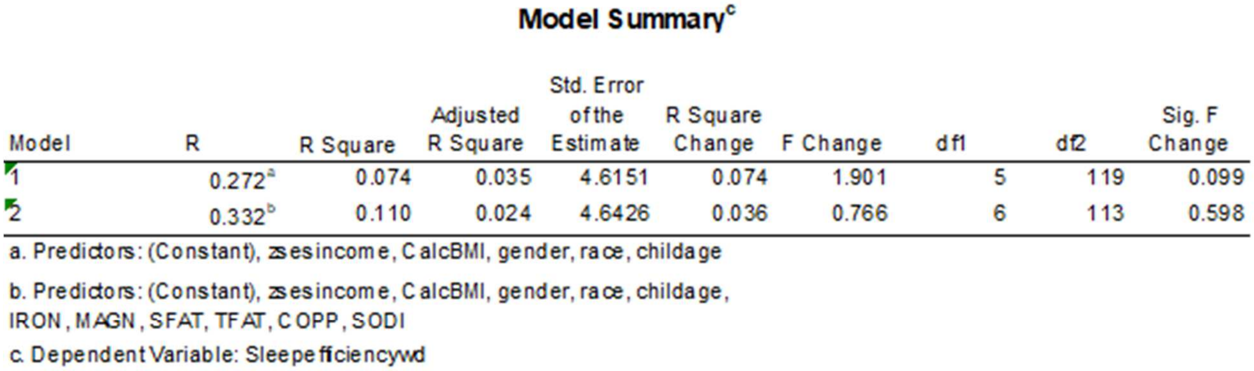


**Correlations**

| | | Sleep Efficiency | Age | BMI | Gender | Race | SES Z-Score | Total Fat | Magnesium | Sodium | Copper | Iron | Saturated Fat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sleep Efficiency | Pearson Correlation | 1.000 | -0.074 | 0.042 | -0.004 | -0.097 | 0.208 | -0.153 | -0.113 | -0.177 | 0.061 | -0.054 | 0.097 |
| | Sig. (1-tailed) | | 0.206 | 0.322 | 0.484 | 0.142 | ***0.010*** | ***0.044*** | 0.104 | ***0.024*** | 0.249 | 0.276 | 0.140 |
| | N | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Age | Pearson Correlation | | | 0.330 | 0.022 | 0.116 | 0.144 | 0.198 | 0.124 | 0.293 | -0.148 | 0.061 | -0.091 |
| | Sig. (1-tailed) | | | ***0.000*** | 0.403 | 0.098 | 0.055 | ***0.013*** | 0.084 | ***0.000*** | ***0.050*** | 0.251 | 0.158 |
| | N | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| BMI | Pearson Correlation | | | | 0.048 | -0.109 | 0.111 | 0.215 | -0.051 | 0.048 | 0.166 | -0.091 | 0.055 |
| | Sig. (1-tailed) | | | | 0.299 | 0.113 | 0.109 | ***0.008*** | 0.285 | 0.299 | ***0.033*** | 0.156 | 0.273 |
| | N | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Gender | Pearson Correlation | | | | | -0.025 | -0.123 | -0.098 | -0.085 | 0.010 | -0.061 | 0.058 | 0.060 |
| | Sig. (1-tailed) | | | | | 0.391 | 0.086 | 0.139 | 0.172 | 0.457 | 0.249 | 0.262 | 0.252 |
| | N | | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Race | Pearson Correlation | | | | | | 0.208 | 0.000 | -0.073 | -0.106 | 0.083 | 0.156 | 0.147 |
| | Sig. (1-tailed) | | | | | | ***0.010*** | 0.498 | 0.208 | 0.119 | 0.179 | ***0.042*** | ***0.051*** |
| | N | | | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| SES Z-Score | Pearson Correlation | | | | | | | -0.063 | -0.122 | -0.146 | 0.113 | -0.043 | 0.036 |
| | Sig. (1-tailed) | | | | | | | 0.242 | 0.088 | 0.053 | 0.105 | 0.316 | 0.346 |
| | N | | | | | | | 125 | 125 | 125 | 125 | 125 | 125 |
| Total Fat | Pearson Correlation | | | | | | | | 0.566 | 0.636 | -0.121 | 0.039 | -0.039 |
| | Sig. (1-tailed) | | | | | | | | ***0.000*** | ***0.000*** | 0.090 | 0.332 | 0.331 |
| | N | | | | | | | | 125 | 125 | 125 | 125 | 125 |
| Magnesium | Pearson Correlation | | | | | | | | | 0.678 | -0.398 | 0.092 | -0.334 |
| | Sig. (1-tailed) | | | | | | | | | ***0.000*** | ***0.000*** | 0.154 | ***0.000*** |
| | N | | | | | | | | | 125 | 125 | 125 | 125 |
| Sodium | Pearson Correlation | | | | | | | | | | -0.644 | -0.142 | -0.438 |
| | Sig. (1-tailed) | | | | | | | | | | ***0.000*** | 0.057 | ***0.000*** |
| | N | | | | | | | | | | 125 | 125 | 125 |
| Copper | Pearson Correlation | | | | | | | | | | | 0.360 | 0.608 |
| | Sig. (1-tailed) | | | | | | | | | | | ***0.000*** | ***0.000*** |
| | N | | | | | | | | | | | 125 | 125 |
| Iron | Pearson Correlation | | | | | | | | | | | | 0.204 |
| | Sig. (1-tailed) | | | | | | | | | | | | ***0.011*** |
| | N | | | | | | | | | | | | 125 |
| Saturated Fat | Pearson Correlation | | | | | | | | | | | | |
| | Sig. (1-tailed) | | | | | | | | | | | | |
| | N | | | | | | | | | | | | |

The subsequent regression analysis did not reveal any correlation with gender, although race differed with respect to SES (r = -0.208, p = 0.010). Fixed factors (socioeconomic status (SES), race, gender, and body mass index) accounted for 7.4% of the variability in sleep efficiency, with dietary factors controlling an additional 3.6%; the overall contribution to sleep efficiency was not statistically significant [$R^2$=0.11, F (11,113) =1.272, p=0.250, Table 6]. In this model, the covariates accounted for most of the variability in sleep, with SES being the primary and only statistically significant driver. As SES increased, sleep efficiency increased (β=0.250, p=0.008)

*Table 6: Model summary and ANOVA of the hierarchical analysis of sleep efficiency and significant micronutrient data from the ASA24 dietary recall.*



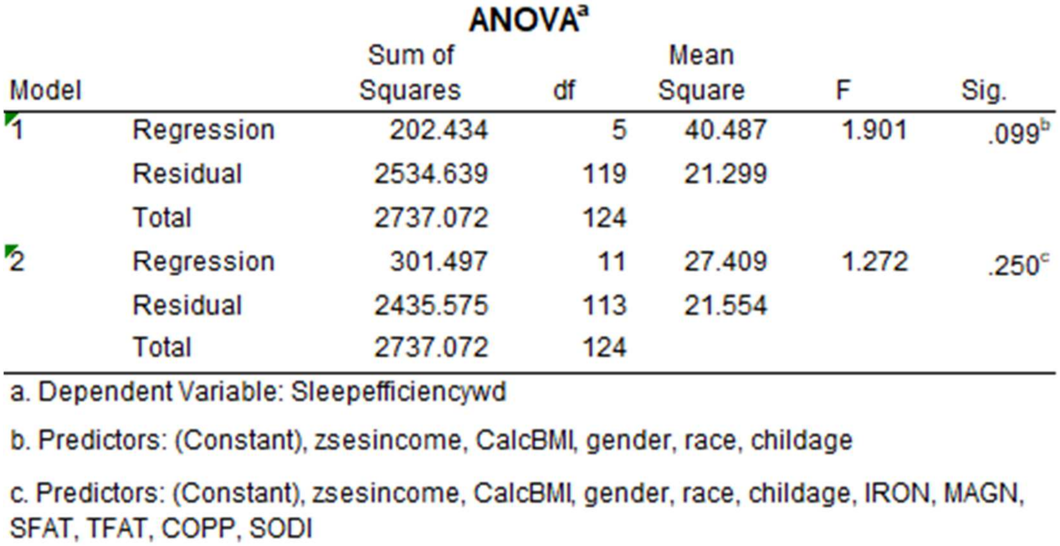
**Model Summary[c]**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | df1 | df2 | Sig. F Change |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.272[a] | 0.074 | 0.035 | 4.6151 | 0.074 | 1.901 | 5 | 119 | 0.099 |
| 2 | 0.332[b] | 0.110 | 0.024 | 4.6426 | 0.036 | 0.766 | 6 | 113 | 0.598 |

a. Predictors: (Constant), zsesincome, CalcBMI, gender, race, childage

b. Predictors: (Constant), zsesincome, CalcBMI, gender, race, childage, IRON, MAGN, SFAT, TFAT, COPP, SODI

c. Dependent Variable: Sleepefficiencywd



**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 202.434 | 5 | 40.487 | 1.901 | .099[b] |
| | Residual | 2534.639 | 119 | 21.299 | | |
| | Total | 2737.072 | 124 | | | |
| 2 | Regression | 301.497 | 11 | 27.409 | 1.272 | .250[c] |
| | Residual | 2435.575 | 113 | 21.554 | | |
| | Total | 2737.072 | 124 | | | |

a. Dependent Variable: Sleepefficiencywd

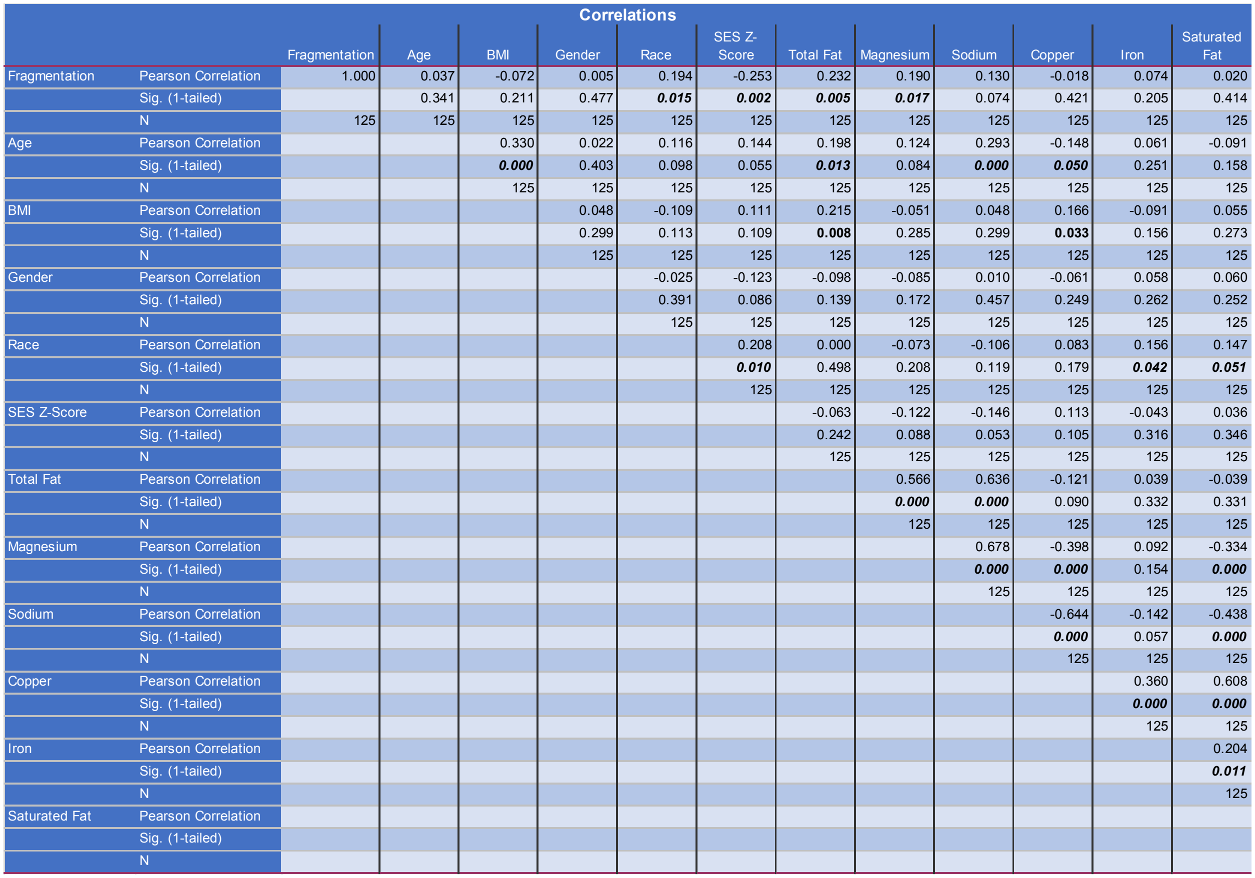
b. Predictors: (Constant), zsesincome, CalcBMI, gender, race, childage

c. Predictors: (Constant), zsesincome, CalcBMI, gender, race, childage, IRON, MAGN, SFAT, TFAT, COPP, SODI

## Hierarchical Regression Analysis of Sleep Fragmentation, Fat, and Micronutrient Dietary Recall Data

In agreement with previous analyses, sleep fragmentation positively correlated with race (r = 0.194, p = 0.015), while SES and sleep fragmentation had a negative association (r = -0.253, p = 0.002). Total fat (r = 0.232, p = 0.005), and magnesium (r = 0.190, p = 0.017) were the only dietary components to have a significant association with sleep fragmentation (Table 7).

*Table 7*: *Correlation analysis of sleep fragmentation, covariates, and significant micronutrient nutrient data from ASA24 dietary recall. Total fat is included in this analysis as the interaction of fat and minerals (osmotic concentration) may contribute to variation in sleep measures.*

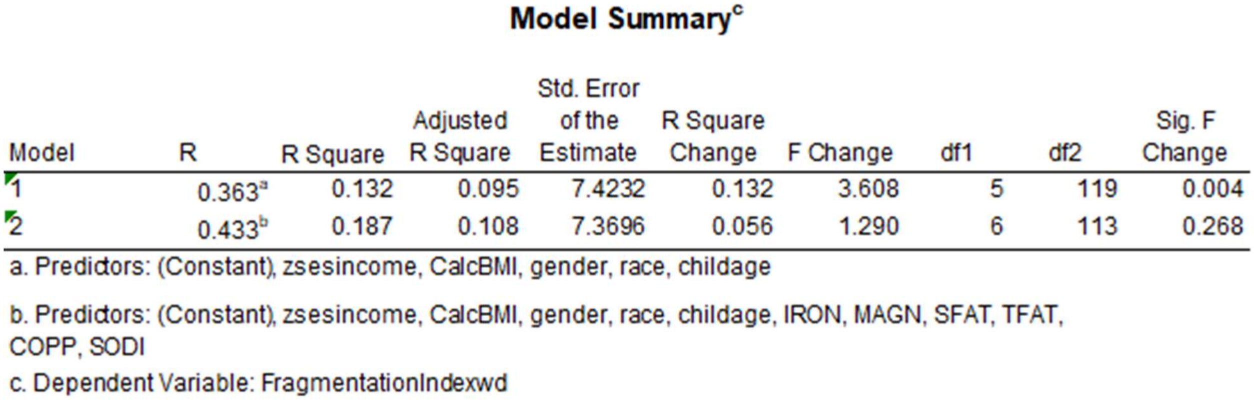


**Correlations**

| | | Fragmentation | Age | BMI | Gender | Race | SES Z-Score | Total Fat | Magnesium | Sodium | Copper | Iron | Saturated Fat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fragmentation | Pearson Correlation | 1.000 | 0.037 | -0.072 | 0.005 | 0.194 | -0.253 | 0.232 | 0.190 | 0.130 | -0.018 | 0.074 | 0.020 |
| | Sig. (1-tailed) | | 0.341 | 0.211 | 0.477 | ***0.015*** | ***0.002*** | ***0.005*** | ***0.017*** | 0.074 | 0.421 | 0.205 | 0.414 |
| | N | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Age | Pearson Correlation | | | 0.330 | 0.022 | 0.116 | 0.144 | 0.198 | 0.124 | 0.293 | -0.148 | 0.061 | -0.091 |
| | Sig. (1-tailed) | | | ***0.000*** | 0.403 | 0.098 | 0.055 | ***0.013*** | 0.084 | ***0.000*** | ***0.050*** | 0.251 | 0.158 |
| | N | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| BMI | Pearson Correlation | | | | 0.048 | -0.109 | 0.111 | 0.215 | -0.051 | 0.048 | 0.166 | -0.091 | 0.055 |
| | Sig. (1-tailed) | | | | 0.299 | 0.113 | 0.109 | **0.008** | 0.285 | 0.299 | **0.033** | 0.156 | 0.273 |
| | N | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Gender | Pearson Correlation | | | | | -0.025 | -0.123 | -0.098 | -0.085 | 0.010 | -0.061 | 0.058 | 0.060 |
| | Sig. (1-tailed) | | | | | 0.391 | 0.086 | 0.139 | 0.172 | 0.457 | 0.249 | 0.262 | 0.252 |
| | N | | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Race | Pearson Correlation | | | | | | 0.208 | 0.000 | -0.073 | -0.106 | 0.083 | 0.156 | 0.147 |
| | Sig. (1-tailed) | | | | | | ***0.010*** | 0.498 | 0.208 | 0.119 | 0.179 | ***0.042*** | ***0.051*** |
| | N | | | | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| SES Z-Score | Pearson Correlation | | | | | | | -0.063 | -0.122 | -0.146 | 0.113 | -0.043 | 0.036 |
| | Sig. (1-tailed) | | | | | | | 0.242 | 0.088 | 0.053 | 0.105 | 0.316 | 0.346 |
| | N | | | | | | | 125 | 125 | 125 | 125 | 125 | 125 |
| Total Fat | Pearson Correlation | | | | | | | | 0.566 | 0.636 | -0.121 | 0.039 | -0.039 |
| | Sig. (1-tailed) | | | | | | | | ***0.000*** | ***0.000*** | 0.090 | 0.332 | 0.331 |
| | N | | | | | | | | 125 | 125 | 125 | 125 | 125 |
| Magnesium | Pearson Correlation | | | | | | | | | 0.678 | -0.398 | 0.092 | -0.334 |
| | Sig. (1-tailed) | | | | | | | | | ***0.000*** | ***0.000*** | 0.154 | ***0.000*** |
| | N | | | | | | | | | 125 | 125 | 125 | 125 |
| Sodium | Pearson Correlation | | | | | | | | | | -0.644 | -0.142 | -0.438 |
| | Sig. (1-tailed) | | | | | | | | | | ***0.000*** | 0.057 | ***0.000*** |
| | N | | | | | | | | | | 125 | 125 | 125 |
| Copper | Pearson Correlation | | | | | | | | | | | 0.360 | 0.608 |
| | Sig. (1-tailed) | | | | | | | | | | | ***0.000*** | ***0.000*** |
| | N | | | | | | | | | | | 125 | 125 |
| Iron | Pearson Correlation | | | | | | | | | | | | 0.204 |
| | Sig. (1-tailed) | | | | | | | | | | | | ***0.011*** |
| | N | | | | | | | | | | | | 125 |
| Saturated Fat | Pearson Correlation | | | | | | | | | | | | |
| | Sig. (1-tailed) | | | | | | | | | | | | |
| | N | | | | | | | | | | | | |

The fixed factors of SES, BMI, gender, race, and age accounted for 13.2% of the total variation in sleep fragmentation, with diet contributing to an additional 2.6%. The overall model contribution to sleep fragmentation is statistically significant [$R^2$=0.187, F (11, 113) =2.37, p=0.011, Table 8]. SES was again the primary and statistically significant driver of variability in sleep fragmentation. As SES increased, sleep fragmentation decreased (β= - 0.313, p=0.001).

*Table 8: Model summary and ANOVA of the hierarchical analysis of sleep fragmentation and significant micronutrient data from the ASA24 dietary recall.*



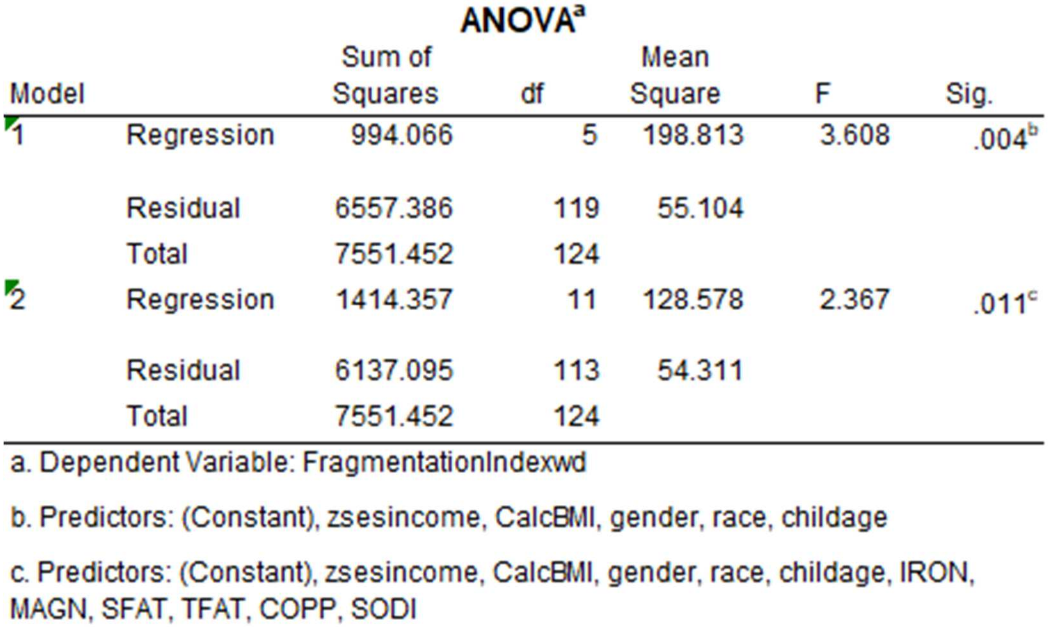
**Model Summary**[c]

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | df1 | df2 | Sig. F Change |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.363[a] | 0.132 | 0.095 | 7.4232 | 0.132 | 3.608 | 5 | 119 | 0.004 |
| 2 | 0.433[b] | 0.187 | 0.108 | 7.3696 | 0.056 | 1.290 | 6 | 113 | 0.268 |

a. Predictors: (Constant), zsesincome, CalcBMI, gender, race, childage

b. Predictors: (Constant), zsesincome, CalcBMI, gender, race, childage, IRON, MAGN, SFAT, TFAT, COPP, SODI

c. Dependent Variable: FragmentationIndexwd



**ANOVA**[a]

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 994.066 | 5 | 198.813 | 3.608 | .004[b] |
| | Residual | 6557.386 | 119 | 55.104 | | |
| | Total | 7551.452 | 124 | | | |
| 2 | Regression | 1414.357 | 11 | 128.578 | 2.367 | .011[c] |
| | Residual | 6137.095 | 113 | 54.311 | | |
| | Total | 7551.452 | 124 | | | |

a. Dependent Variable: FragmentationIndexwd

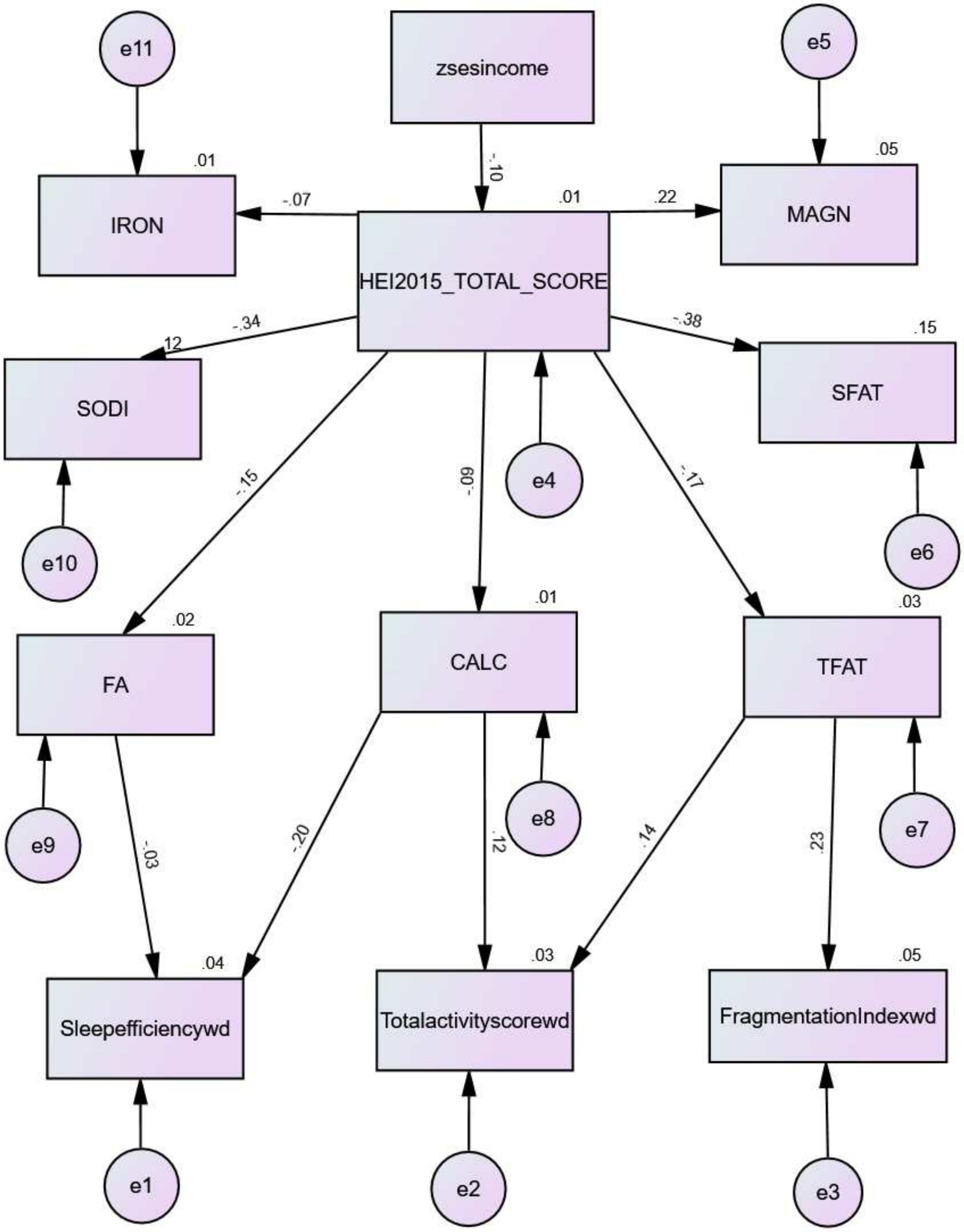
b. Predictors: (Constant), zsesincome, CalcBMI, gender, race, childage

c. Predictors: (Constant), zsesincome, CalcBMI, gender, race, childage, IRON, MAGN, SFAT, TFAT, COPP, SODI

## Multiple Regression and Path Analysis

Path analysis was used to assess the directed dependencies within the relationships between HEI scores, sub-scores, and specific nutrients from dietary recall with three sleep measures, efficiency, fragmentation, and total activity. Fatty acids and calcium had a negative impact on sleep efficiency. Total fat and calcium increased total activity, while total fat alone appeared to increase sleep fragmentation. The analysis also showed that SES negatively influenced total HEI score. It should be noted that, however, the strength of all these relationships is weak according to the model. The full analysis and all relationships are shown in Figure 2.

Figure 2: **Path Analysis**



# Discussion

The results of this study support those of similar studies. The correlation between HEI saturated fat score and sleep efficiency are echoed in the literature. Overall, saturated fat intake has been associated with less restorative sleep, while vegetable intake has demonstrated sleep-promoting effects. (St-Onge, Mikic et al. 2016). Both sleep efficiency and fragmentation showed a significant association with total fat intake. This relationship is supported in others studies as well, with fat seeming to have a negative relationship with sleep (Weiss et al. 2010). Similarly, sodium has previously been shown to impact sleep; diets high in salt are associated with poor sleep quality (Grandner et al. 2014; Ho et al. 2021). These dietary components are further associated with greater energy intake, which was found to increase sleep fragmentation.

The results from this study have much in common with Martinez et al., in which the diet and sleep of Mexican American children were compared using HEI and wrist-worn accelerometry (Martinez et al. 2017). The children in the Martinez Study, aged 9-11, experienced better sleep quality with a higher intake of polyunsaturated fatty acids and a lower intake of energy from carbohydrates, complementing the results of this study. The positive effect of PUFAs on sleep helps explain how fat can play a dual role. When the intake of saturated fat is high, it can impair sleep quality (St-Onge, Mikic et al. 2016; St-Onge, Roberts et al. 2016), as demonstrated in the current study. However, PUFAs seem to have the opposite effect (Patan et al. 2021; Wang et al 2020). The source of energy is as important as the calories consumed. While this study saw a correlation between high energy intake and less restorative sleep, more of that energy was coming from saturated fats than unsaturated fats. It is therefore important to understand that the composition of diet in relation to diet quality may make a meaningful difference in how food modifies sleep.

Although the role of minerals in regulating sleep is still unclear, evidence suggests a relationship. In addition to sodium, magnesium was observed to positively affect sleep fragmentation. This result contrasts with prior literature, in which magnesium was correlated with better sleep quality (Cao et al. 2018; Rondanelli et al. 2011). Similarly, calcium appeared to promote a slight decrease in sleep efficiency and increase in total activity, thus surprisingly lowering sleep quality. These findings were weakly significant and in conflict with prior studies on calcium and sleep (Alkhatatbeh et al. 2020). The incongruity apparent in this study may be due to the dietary sources of calcium. Foods such as ice cream and chocolate milk are high in calcium but also saturated fat and refined sugar. It is possible the effect of calcium on sleep is offset, or even negligible when compared with fat and sugar coming from the same sources.

A hierarchical regression analysis helped distinguish between the role fixed factors (i.e., SES, race, BMI, etc) and diet might play in promoting quality sleep. While diet was found to modify sleep fragmentation, SES was the biggest driving factor. Diet also had a greater effect on sleep fragmentation than sleep efficiency. Overall, the contribution of diet to sleep efficiency was not significant. Although this connection is strong elsewhere in the literature, the current study did not reveal that trend, and SES remained the strongest predictor of sleep across all analyses. Sleep duration, efficiency, fragmentation, and total activity were all highly correlated with SES z-scores.

As the participants of this study represented both African and European Americans, it is important to consider how race may factor into the study’s outcomes. A recent systematic review found that race mediated sleep patterns among preschool age children, with racial and ethnic minorities experiencing diminished sleep durations and less regular sleep schedules (Smith et al. 2019). Interestingly, this study saw white participants experiencing higher sleep fragmentation than Black participants. Total HEI scores were also higher among Black children in the study, and saturated fat intake was lower. However, for all participants in this study, the reported HEI scores were relatively low for this age group (USDA 2018). Interestingly, although SES was lower for Black participants in this study than white participants, white participants appeared to have slightly lower sleep and diet quality.

The fact that SES was the primary driver of sleep points to a key takeaway from this study. While diet is important for sleep quality, both diet and sleep are affected by larger environmental factors. Not surprisingly, an inclusive path analysis showed that SES does influence total HEI scores. This finding is supported in other studies (Gu & Tucker et al. 2016). Furthermore, SES has been shown to modify sleep patterns (El-Sheikh et al. 2013). In order to make a difference, the role of SES must be included when evaluating the influence of diet on sleep behavior. This is especially true when considering at populations at risk for food insecurity, such as children in low-income environments.

There are several limitations to be noted with this study. While many of the associations between diet and sleep were found to be significant, the correlation coefficients were considerably low. Another limitation was the sample size and racial diversity of the participants for whom complete data were available. Although this study observed a greater number of Black participants than white participants, this is a subset and not reflective of the larger Syracuse Lead

Study. Therefore, comparisons with respect to race, such as SES, are limited in their meaningfulness.

# Conclusion

Nutrition interventions that target food insecurity and hunger are needed to improve many health-related outcomes for underprivileged children in the U.S. Yet, the extent to which these interventions could impact sleep duration and quality is still largely unknown. However, this study provides a framework to examine the link between diet and sleep in such populations. Consideration of socioeconomic context for any dietary recommendations is essential, as evidenced by the findings presented here. Furthermore, this work casts light onto which nutrients may be important for sleep health among children deprived of the means to meet the necessary dietary requirements. Understanding how these variables are connected can help influence policy and inform interventions aimed at improving health in these communities in a meaningful way.

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# Vita

**Phone**: 585-489-9903 **Email**: nmari2517@gmail.com

## Education

2018 - 2021 **Master of Science in Nutrition Science**
Falk College of Syracuse University
900 South Crouse Ave. Syracuse, NY 13244

2014 **Welding & Fabrication Industry Certificate Program**
Rochester Arc & Flame Center
125 Fedex Way, Rochester, NY 14624

2011 - 2013 **Bachelor of Arts in English Literature**
Nazareth College of Rochester
4245 East Ave, Rochester, NY 14618

## Professional History

2019 - 2020 **Graduate Teaching Assistant**
Falk College of Syracuse University
Syracuse, NY

2019 **Nutrition Department Search Committee Member**
Falk College of Syracuse University
Syracuse, NY

2015 - 2016 **Welder/Fabricator**
Gorbel, Inc.
Fishers, NY

2015 - 2016 **Outpatient Access Associate**
Strong Internal Medicine

## Awards and Achievements

2020 **Falk College Falk Student Research Award**
Falk College of Syracuse University
Syracuse, NY