



Sleep Duration in Children and Its Influence on Glucose Homeostasis, Ingestive Behavior and Primary Examination Performance

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Sleep is a natural periodic state of rest essential for normal psychophysiological responses. This study revealed the influence of sleep on ingestive behavior, glucose homeostasis and primary examination performance. Six hundred children between 10 to 12 years of age were sampled. The study design included 4 groups, *a* to *d*, comprising 150 samples each. Sleep duration was 8pm to 6am, 10pm to 6am, 12am to 6am and 2am to 6am for groups *a*, *b*, *c* and *d* respectively. The results were collected after careful observation and scientific experimentation. Statistical analysis revealed values to be significantly different ($P \leq 0.05$) compared to group *a*. There was an inverse relationship between duration of sleep, quantity of food ingested and blood glucose level. As the duration of sleep was increased, there was a corresponding improvement in primary examination performance and blood glucose homeostasis. From the outcome of this study, sleep duration may influence ingestive behavior, blood glucose level and primary examination performance.

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1. INTRODUCTION

Sleep is a highly complex physiological process that accounts for approximately 40% of a child's life by the age of 18 years [1]. Obtaining sufficient sleep has been reported to be important for multiple aspects of health and well-being in children [1,2]. Recently, the National Center for Sleep Disorders issued a research plan that called for development of new measures of pediatric sleep to advance clinical outcomes in research [3]. Sleep is assessed in children with objective monitoring, sleep diaries, and questionnaires [4]. As children get older, sleep patterns change with later bedtimes and less parental involvement with the child's sleep routine [5]. There have been conflicting reports that sleep has an influence on academic success [6], attention, memory, intelligence and behavioral responses [7], with most conclusions as mere statements not backed by any form of scientific evidence. A relation is also suspected between abnormal sleep patterns and having a decrease in rate of participation in activities outside of school and missing social or sportive activities [8]. The amount of sleep that a person needs varies from one person to another, but on average most children need nine hours of nightly sleep or more, depending on their age [4]. Glucose homeostasis is firmly controlled by insulin and also by leptin adipocytokines [9]. These hormones act significantly on regulating adiposity and food intake in human beings [9,10]. A healthy system requires the proper functional state of the nerves, muscles and adipose tissues to maintain blood glucose level [11]. Blood glucose level can be used in clinical practice to detect the possibility of any disturbance which could be physiologic or pathologic. In West Africa, primary academic performance can be assessed using various examinations after each term or session. These examinations consist of questions from the syllabus of all courses taught in same term or session. This study investigated sleep duration in children and its influence on blood glucose homeostasis and primary examination performance.

2. MATERIALS AND METHODS

2.1 Study Participants

This study sampled six hundred (600) children from a primary school within Asaba in Delta

State, Nigeria. Every member of the population had an Equal Probability of Selection (EPS). The sample included male children of different ethnic and religious background aged between 10 to 12 years old, weighing 27-30 kg. All participants were students receiving education in grade 3, 4, and 5 in same institution. The students, their teachers and parents were reached as a result of repeated visits by researchers.

2.2 Study Protocols

Questionnaires were filled out by selected students, the students' teacher and parents. It involved questions about sleeping/wake up time, having problems with falling into sleep, taking naps in the daytime, waking up at night, having problems with waking up in the morning and daytime sleepiness with respect to the student.

The inclusion criteria include:

- ✓ Human subjects
- ✓ Students from same institution between grade 3 to 5
- ✓ Age range; 10 to 12, body weight; 27-30 kg
- ✓ 85% attendance in school prior and throughout study period
- ✓ Physically and mentally healthy

The exclusion criteria include;

- ✓ Non-human subjects
- ✓ Students from a different institution
- ✓ Age and body weight below or above the recommended
- ✓ Student with a history of social, mental or physical illness
- ✓ Poor attendance in school
- ✓ On any form of medication including caffeine

2.3 Study Design

The duration of study was 56 days.

Table 1. Study design

Groups	Night sleep	Dinner period
a	8pm-6am	6pm-7pm
b	10pm-6am	7pm-8pm
c	12am-6am	8pm-9pm
d	2am-6am	9pm-10pm
n=150		

2.4 Blood Glucose Assay

Fasting blood glucose was assayed after collecting blood samples from the tip of the thumb before and after the study period using a Fine Test[®] glucometer U.S.A.

2.5 Statistical Analysis

The statistical tool used for this study was SPSS version 20.0. Data was presented as Mean± Standard Deviation (SD). Using One-way Analysis of Variance, all values were considered statistically significant at a confidence interval less than or equal to 95%. Tabulated data was presented and percentage change (%C) was calculated using standard methods previously described [12].

3. RESULTS

The results of this study are as follows;

Table 2. Sleep duration and its influence on quantity of food ingested daily

Groups	Day sleep (min.)	Daily ingestion (lb.)
a	11.4±4.4	5.73±2.4
b	62.0±2.1 ^a	11.51±1.3 ^a
c	98.1±2.3 ^a	20.7±1.2 ^a
d	121.4±3.4 ^a	32.3±1.4 ^a

Key; ^a=values are statistically significant at a confidence interval less than or equal to 95% compared to control

Table 3. Sleep duration and its influence on blood glucose level

Groups	Blood glucose (mmol/l)			% Change		
	0	28	56	0-28	28-56	0-56
a	3.2±0.4	3.1±0.3	3.4±0.4	-3.12	9.67	6.25
b	3.0±0.1	3.7±1.2	3.7±0.1	23.3	0	23.3
c	3.1±1.3	4.1±0.3 ^{a0}	4.4±1.2 ^{a0}	32.2	7.31	41.9
d	3.3±1.1	4.6±1.0 ^{a0}	4.8±1.1 ^{a0}	39.3	4.34	45.4

Key; ^{a,0}=values are statistically significant at a confidence interval less than or equal to 95% compared to control and day 0; %C→a change percentage change

Table 4. Sleep duration and its influence on primary test performance

Groups	Test scores (100%)			
	Lowest	(%C→a)	Highest	(%C→a)
a	71.2±2.1	0	97.4±1.4	0
b	63.4±1.4 ^a	-10.9	82.1±2.1 ^a	-15.7
c	56.2±1.1 ^a	-21.0	73.2±0.2 ^a	-24.8
d	44.1±1.0 ^a	-38.0	68.1±1.3 ^a	-30.0

Key; ^{a,0}=values are statistically significant at a confidence interval less than or equal to 95% compared to control and day 0; %C→a percentage change relative to group a

4. DISCUSSION

4.1 Sleep Duration and Its Influence on Quantity of Food Ingested Daily

From Table 2 in this study, reduction in the duration of night sleep was followed by a

compensatory increase in day sleep, which was accompanied by a corresponding increase in quantity of meal ingested daily. This result showed that sleep period during the day may reflect the extent of night sleep, and even though both are natural periodic state of rest, they may still influence the volume of food we ingest daily.

4.2 Sleep Duration and Its Influence on Blood Glucose Level

Blood glucose was assayed on three separate days- 0, 28 and 56th day of treatment period. As shown in Table 3, there was a significant ($P \leq 0.05$) increase in blood glucose level as the duration of night sleep was decreased. This increase was well observed on days 28 and 56 in treatment groups *c* and *d*. Blood glucose was assayed immediately after morning rise and reflects the nocturnal carbohydrate metabolic activity.

4.3 Sleep Duration and Its Influence on Primary Test Performance

Table 4 showed the effect of varying sleep duration on primary test performance. The average lowest and highest scores were presented. Sleep duration has a direct relationship with primary test performance. As the duration of sleep was decreased, there was a corresponding significant ($P \leq 0.05$) decrease in primary test scores, both lowest and highest showed significant progressive decline compared to group *a*.

This study was conducted on human subjects and revealed the possible link between sleep pattern in children and blood glucose homeostasis, ingestive behavior and primary examination performance. If a child does not get enough sleep, he or she may exhibit behaviors typical of sleep deprivation [1,5]. Sleep deprivation may cause learning, behavior, and mood problems in children [3,8]. If poor quality and quantity of sleep continues until adulthood, it may increase the risk of certain medical conditions like hypertension (high blood pressure) [13], obesity, adult-onset diabetes and depression [14,15]. From the current investigation, sleep has an inversely proportional relationship with quantity of food ingested daily and blood glucose level but a directly proportional relationship with primary examination performance. The increase in quantity of food ingested during wakefulness may be as a result of the increased central and peripheral metabolic activities [16] and the increased demand for nutrients that serve as energy source as a compensatory response. Mental and physical activities deplete the body's energy store. Food is ingested for replenishment in order to continue these normal processes [16] [17]. The increase in blood glucose when sleep was between 12am to 6am may be as a result of

hormonal changes. Recent investigations revealed the influence of circadian hormones on blood glucose [18,19]. Circadian hormones like melatonin inhibits insulin secretion and increases blood glucose level [18]. The biomolecular constituents of the food ingested at dinner period for groups *c* and *d* may have elicited insulin response, but this responses was probably inhibited by melatonin and this may have affected glucose homeostasis. This study is clear scientific evidence that late night meal ingestion prolongs increased blood glucose level by possible suppression insulin response. Glucose tolerance may be impaired if sleep duration is shortened. The test scores of groups *a* and *b* was more impressive than *c* and *d*. Abnormally increased level of blood glucose in central nervous system slows learning and memory [19]. Prolonged wakefulness may enhance the release of the stress hormone, cortisol [16]. Consolidation of memory by the hippocampus is impaired by cortisol [12]. It has been reported that cortisol causes degeneration of hippocampal neurons. This study is in agreement with previous reports that night sleep duration of at least 9 hours may enhance intellectual capacity in children.

5. CONCLUSION

Sleep is a behavior exhibited as a natural periodic state of rest and is essential for normal physiologic and biochemical processes in children. This study revealed that sleep duration may determine ingestive behavior, blood glucose level and higher intellectual performance in children 10 to 12 years of age.

ETHICAL CONSIDERATION

Ethical approval and a recommendation were given by Madonna University Research Ethics Committee and Madonna University Clinical Research Approval Committee. An informed written consent was also received from each sampled subject's parent/guardian.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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