ASSOCIATION BETWEEN INTENSITY OF INFORMATION AND COMMUNICATION TECHNOLOY USAGE AND SLEEP QUALITY AMONG SCHOOL AGED CHILDREN

By

Sandra. O. Ononogbu

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This thesis describes the association between the intensity of Information and Communication Technology (ICT) usage and the quality of sleep among school-aged children. The increase in usage of ICT in the recent years has been discussed as a potential contributor to certain health and behavioral challenges in previous literature.

A cross- sectional study was conducted in five school in a large city in Finland with 74 subjects (age 10 to 14), involving questionnaires, diary, and ambulatory recording of heart rate variability (Holter monitor). The sleep quality of participants in the two categories of ICT usage (high and low) was obtained and analyzed.

The study showed a difference in sleep quality between high and low ICT user, when analyzed with the standard deviation of all normal sinus R-R internal (SDNN) measure of heart rate variability. However, analysis with root mean square of successive normal sinus R-R interval difference (RMSSD was insignificant.

The results suggest that, low ICT users seem to have a higher parasympathetic dominance during sleep. Thus, indicating a more restorative and better quality of sleep.

It would be useful to investigate further the adverse effects of intensive use of information and communication technology especially among school-aged children and implement measures to reduce associated risks.

Keywords: ICT, heart rate variability, sleep quality, children

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ABBREVIATIONS

BMI	Body Mass Index
HRV	Heart Rate Variability
ICT	Information and Communication Technology
SDNN	The standard Variation of all Normal to Normal Sinus R- R interval
RMSSD	Root Mean Square of successive normal sinus R-R Interval

1 LITERATURE REVIEW

1 .1 Introduction

This thesis is part of a larger study: named "Stress, strain, restoration and social-emotional development from middle childhood to adolescent":-The role of information and communication technology (ICT). The aim of this present part of the study is:

To examine the pattern of autonomic nervous system activity with heart rate variability measures during sleep-time and wake up time.

To examine, if there are differences in autonomic nervous system activity between categorized high and low Information and Communication Technology (ICT) users.

1.2 Information and communication technology and health

1.2.1 Stress and ICT

Stress has been defined in several ways by different researchers, with little success in constructing a single universally accepted meaning that incorporates all aspects of stress. Nevertheless, in relation to this study, I will define stress as a complex process by which individuals respond to changing demands induced by internal or external environmental factors that alters the body's homeostasis.[1] These factors are called stressors[2] and can be assessed through parameters such as frequency, intensity, duration, complexity, controllability, familiarity, and predictability. The corresponding responses can be physiological, cognitive, affective and behavioral,[3] as presented in table 1. The reliability of these measures have been questioned especially with regards to subjective self reports such as, feeling of weakness, fatigue, strength and other self assessed index, as a result of varying individual perception or interpretation of symptoms.[4]

Affective	Behavioral	Cognitive	Physiological
Anxiety	Escape/Avoidance	Worry	Autonomic Stimulation
Depression	Substance Use/Abuse	Catastrophic Thinking	Neuroendocrine activation
Anger	Social Withdrawal	Poor Concentration	Muscle Tension
Guilt	Over/Under Eating	Selective Attention	Hyperventilation
Fear	Irritability Aggression Inactivity	Thought Blocking Rumination Hopelessness	Compromised Immune function

Table 1. Various stress response.

The different methods employed in processing the interaction between individuals and their environment is called models. Among these includes, the response- based model which assesses stress in relation to response rather than stimulus. Selye[6] observed that different stimuli irrespective of their direct effects produced similar response he termed "non specific" stress response. The positivity or negativity of the stimuli did not alter the response. However, Dijksterhius & Aarts[7] have reported a faster processing of stimulus with negative impact. Furthermore, the result of these responses varied in their usefulness with regards to whether its effect is beneficial or harmful on the individual. There seems to be a link between this model and the arousal theory which postulates that increased demands placed on an individual by a stimulus could result to increase the performance until an optimal level is attained, after which subsequent increase in demands leads to a decline in performance as illustrated in figure 1[8]. However, Spence & Spence[9] observed that the direction of the performance curve is largely dependent on individual's familiarity or capability with tasks being perform

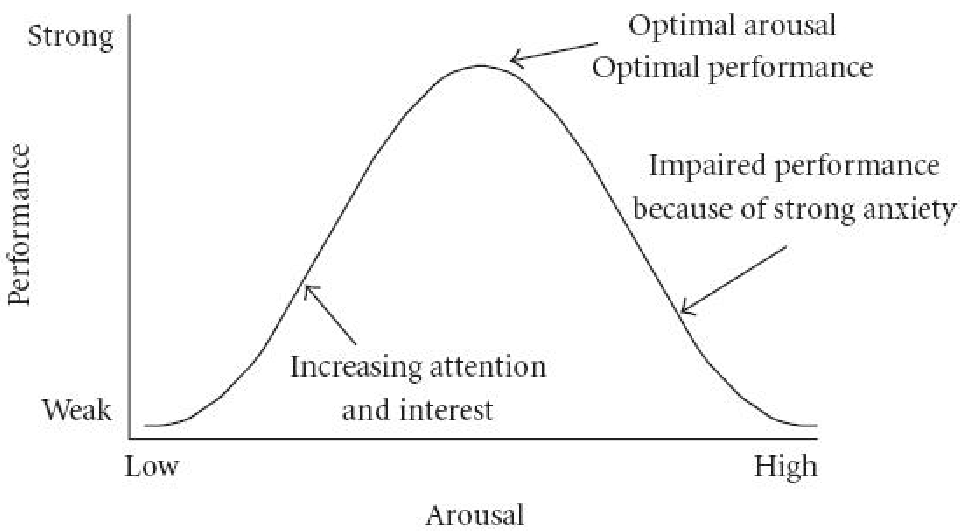

Figure1. Performance curve.[10]

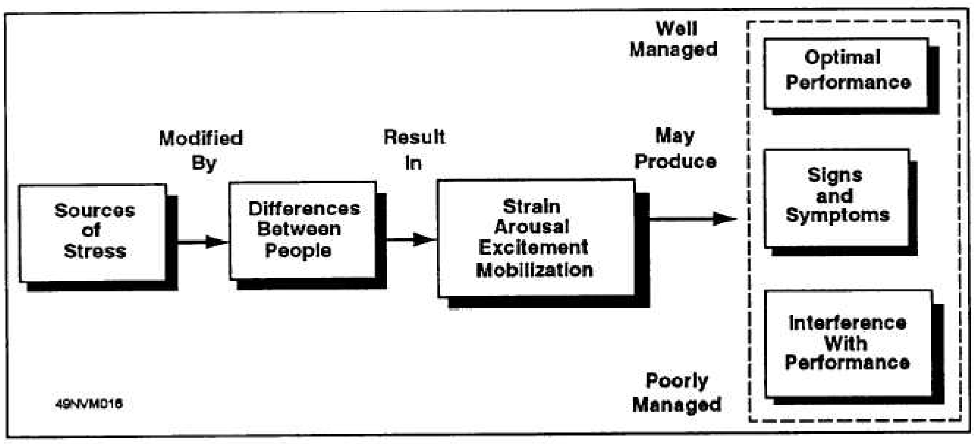

Figure 2. Stress- response model.[11]

The response- based model have been criticized for its assumption of lack of difference between various stressors and failure to account for factors that can function both as stimulus and response, among which is emotions. In addition, disregard for individual perceptions have also been mentioned[12]. Broadbent [13,14] reported a difference in stress response in relation to different stressors. Thus, rejecting the theory of universal response for all stressors as stated above. On the other hand, the stimulus-based model[15] relates stress to life altering experience. These events are considered to place demands that an individual maybe unable to meet, thereby predisposing to stress. The stressors are evaluated through a scale that categories events from least stressful (such as traffic violation) to most stressful (such as death of a loved one). However, this model did not account for individual personality. In contrary, the Transactional model[16] considers the individuals appraisals of the situation and perception of their ability to meet the demand which determines response and coping strategies undertaken. Therefore, stress results from perception of deficiency.[17] There are two types of appraisals, the primary and the secondary. A primary appraisal is made when the individual makes a conscious evaluation of the situation, determining if it is a threat or challenge. However, in secondary appraisal the individual tries to figure out the best way to respond by evaluating the coping resources accessible to them. These resources can be physical, (such as determining how healthy they are as individuals), social (support system such as family and friends available to them), psychological (such as self-esteem and efficacy) and economic(such as financial and technological support accessible).[18] In other words, individual's perception of the situation affect the outcome.[19] The initial assessment of the situation potentiates application of effective response.[20] However, it has been reported that this immediate evaluation depends more on inherent abilities than acquired skill based on the short interval needed between stimulation and initial assessment. In addition, the speed of response is related to the extent of emotional stimulation.[21] Ennis et al,[22] observed that study participants who considered a forthcoming test a challenge rather than threat had a lower adrenal-medullary pathway activation at the period of testing in comparison to the individuals who had perceived the assessment as a threat . Therefore, interaction between the characteristics of stressor and individual has been considered to play a large role on response elicited as illustrated by Figure 3.[23]

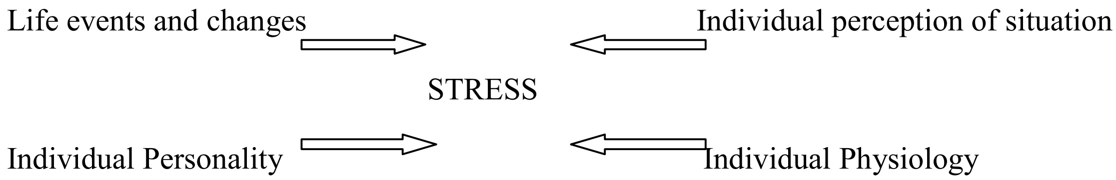

Figure 3. Factors involved in stress response. [23]

The body goes through different stages of adaptation during stress in order to counteract the effect of prolonged stressors.[1] The first stage of stress adaptation involves stressor recognition and production of adrenaline, giving the so called ‘fight or flight’ reaction. Nevertheless, there is complete recovery at elimination of the stressor. However, the second stage, known as resistance stage occurs from sustained stress, leading to involvement of more adaptive mechanisms in coping with prevailing stressor. This notwithstanding, recovery is usually limited by remnant physiological deterioration (maladaptation). In the last stage, called exhaustion or 'burnout' there is inability to maintain body's normal functioning, which may be characterized by elevated blood pressure, insufficient adrenal hormones or other manifestation of stress related ill health.[24] Figure 4 shows the changes the body goes through after exposure to stress, the final outcome is determined by the characteristics of the stressor such as duration (acute or chronic), other stress parameter, as well as individual factors.

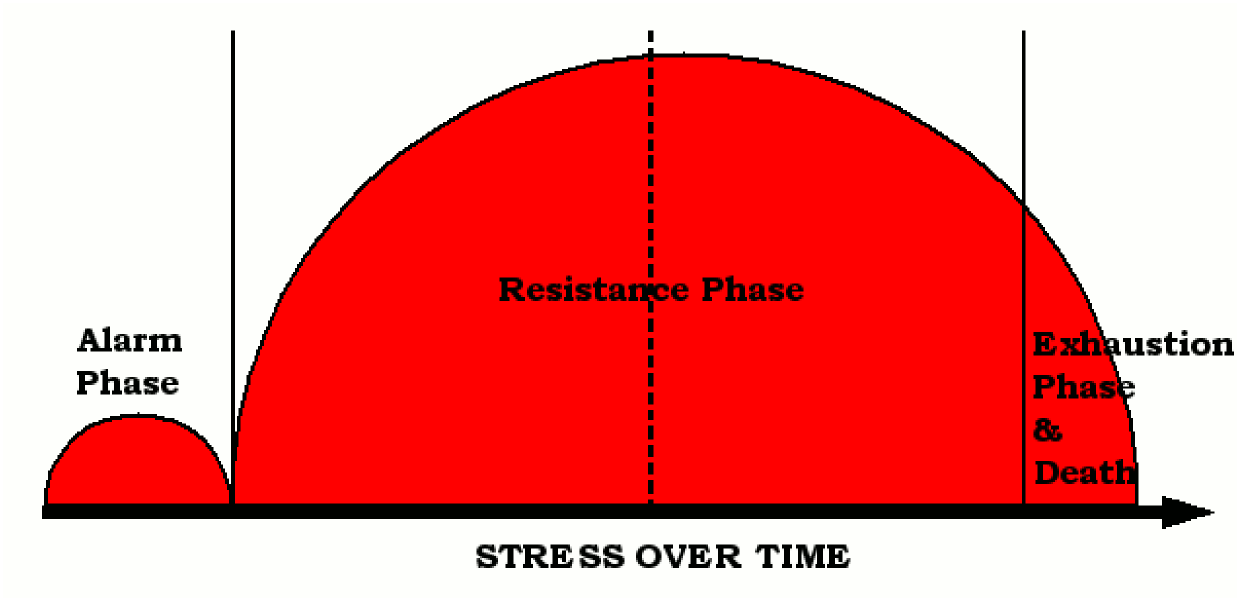

Figure 4. Stress- response model.[24]

In the recent years, ICT use have increased in the general population, children and adolescents inclusive.[25] The rise in use have been reported to affect academic skills positively.[26] This notwithstanding, certain psychosocial health changes have also been observed.[27] Mental overload following inadequate recovery due to ICT use have been reported as a predisposing factor to certain ill health such as cardiovascular diseases and other stress related diseases.[28] Ashcraft & Kirk [29] found that stress induced anxiety reduces mathematical problem-solving ability. Furthermore, Hambree[30] revealed inability of restoring optimal performance was also noted in study participants who possess required mathematical skills, thereby showing that the reduction in performance could not be attributed to lack or insufficient skills but stress induced anxiety. The restorative ability to baseline state prior stress stimulus has been attributed largely to the parasympathetic autonomic nervous system during rest and sleep.[31]

1.2.2 Sleep and ICT

Sleep is considered a state of reversible reduction in consciousness, which has been shown to be vital for development and maintenance of health in children/adolescents.[32] The amount of sleep needed for optimal functioning varies with age, 10 hours- prepubescent, 8hours mid adolescent, and 7hours adolescent.[33] Nevertheless, it has been observed that under ideal condition, even old adolescent sleep for 9 hours per night.[34] An increase in the prevalence of sleep disturbance has been reported, reluctance going to bed (27%) was the most common problem with coexisting concurrent delay in sleep onset (34%) in majority of the cases. Difficulty with waking up and tiredness(17%) were also recorded.[35-37] In all, 23% of 350 children/adolescent aged 10-17 years reported delayed sleep onset problems, 11% experienced interrupted sleeps, 18% had difficulty getting up in the morning, while a smaller percentage (3%) complained of early waking.[38] Maintenance of sleep (16.8%) and reduced duration (mean 7.64 hours) was reported by Liu X.[39] In addition, according to National sleep foundation : sleep in America poll highlights and key findings, children/adolescents go to bed late due to television viewing (76%), surfing the internet (44%), speaking on the phone (40%), 55% admitted to delaying sleep-time due to television program schedule and internet.[40] Sleep deprivation have been used experimentally as a stressor, study participants after 40 hours of sleep loss showed evidence of reduced cognition and other signs of altered mental functioning.[41] Blake[42] found a decreased performance in subjects with altered circadian rhythm. This alteration is not uncommon among school aged children due to irregularity of sleep schedule as a result of ICT usage .[40]

Sleep is regulated by endogenous and exogenous factors, psychological stressors inclusive.[43] Sleep consists of non-rapid eye movement (NREM), made up of stages from 1-4 and rapid eye movement (REM) states. Most of the NREM sleep occurs during the first half of the night, while REM state, which occurs approximately 90 minutes from onset of sleep is more frequent in the last half .[44] Furthermore, the longer the prior period of wakefulness, the more stage 4 increases during the first part of night, the less REM state in the second half. However, REM is essential for sleep prolongation and memory consolidation, therefore it's shortening predisposes individuals to reduced ability to perform, learn complex task and declining attention to details. A study has shown that NREM is modulated largely by parasympathetic activity with low sympathetic contribution.[31] In addition, night-time computers use has been reported to inhibit melatonin, a hormone produced in the body and responsible for stimulation of the feeling sleepiness in the absence of light, which is disrupted by direct light from computer screens.[45,46] Decrease in melatonin production was not shown with television viewing from appropriate distance.[47] However, with a bright room light, same effect of melatonin inhibition was observed.[48] Physical excitement with associated physiological changes caused by some programs on computers, television and other media sources has been implicated in reduced sleep quality and quantity.[49,50]

1.3 Physiological response to stress

1.3.1 Autonomic nervous system.

The Autonomic Nervous System (ANS) regulates individual organ function and homeostasis, which is mostly under involuntary control. The ANS is predominantly an efferent system transmitting impulses from the Central Nervous System (CNS) to peripheral organ systems. Its effects includes, control of heart rate, force of contraction, constriction and dilatation of blood vessels, contraction and relaxation of smooth muscle in various organs, visual accommodation, pupillary size and secretions from exocrine and endocrine glands. There are some afferent autonomic fibers which are responsible for visceral sensation , regulation of vasomotor and respiratory reflexes, these includes the baroreceptors, chemoreceptors in the carotid sinus and aortic arch which are important in heart rate, blood pressure and respiratory activity control .The ANS is divided into parasympathetic and sympathetic systems, on the basis of anatomical and functional differences.[51]

The sympathetic nervous system is often referred to as the "fight or flight" system which prepares the body for action, thus increased in states of anxiety or emotional arousal. Sympathetic responses include increase in heart rate, blood pressure and cardiac output. In addition, there is diversion of blood flow from the skin and splanchnic vessels to those supplying skeletal muscle, increased pupil size, bronchiolar dilation, and contraction of sphincters. Response to physical or psychological stress usually involves the activation of the hypothalamus-pituitary-adrenal (HPA) axis as shown in Figure 5. The resulting release of hypothalamic corticotrophin-releasing hormone, anterior pituitary adrenocorticotropic hormone, and adrenal glucocorticoids such as cortisol accounts for the adaptive changes. The glucocorticoid released under stressful condition helps in meeting the increased metabolic demands of the body through mobilization of fat and glycogen from stores.[52] The length and degree of exposure to the stressor correlates with variation in rise of glucocorticoids in experimental animals.[53]The above mentioned relationship between glucocorticoid and physical or psychological stress such as mental over load from ICT use, as in our present study have also been observed in humans.[54,55] Beatty[56] reported that rising mental activity was associated with papillary changes and energy consumption. Prolonged stimulation of the sympathetic nervous system have been found to be a predisposing factor to cardiovascular disorders such as hypertension, stroke and other adverse health condition involving entire systems of the body.[51] Gender difference in acute stress response have been reported, cortisol and blood pressure increase was higher in men while heart rate was more increased in females.[57]

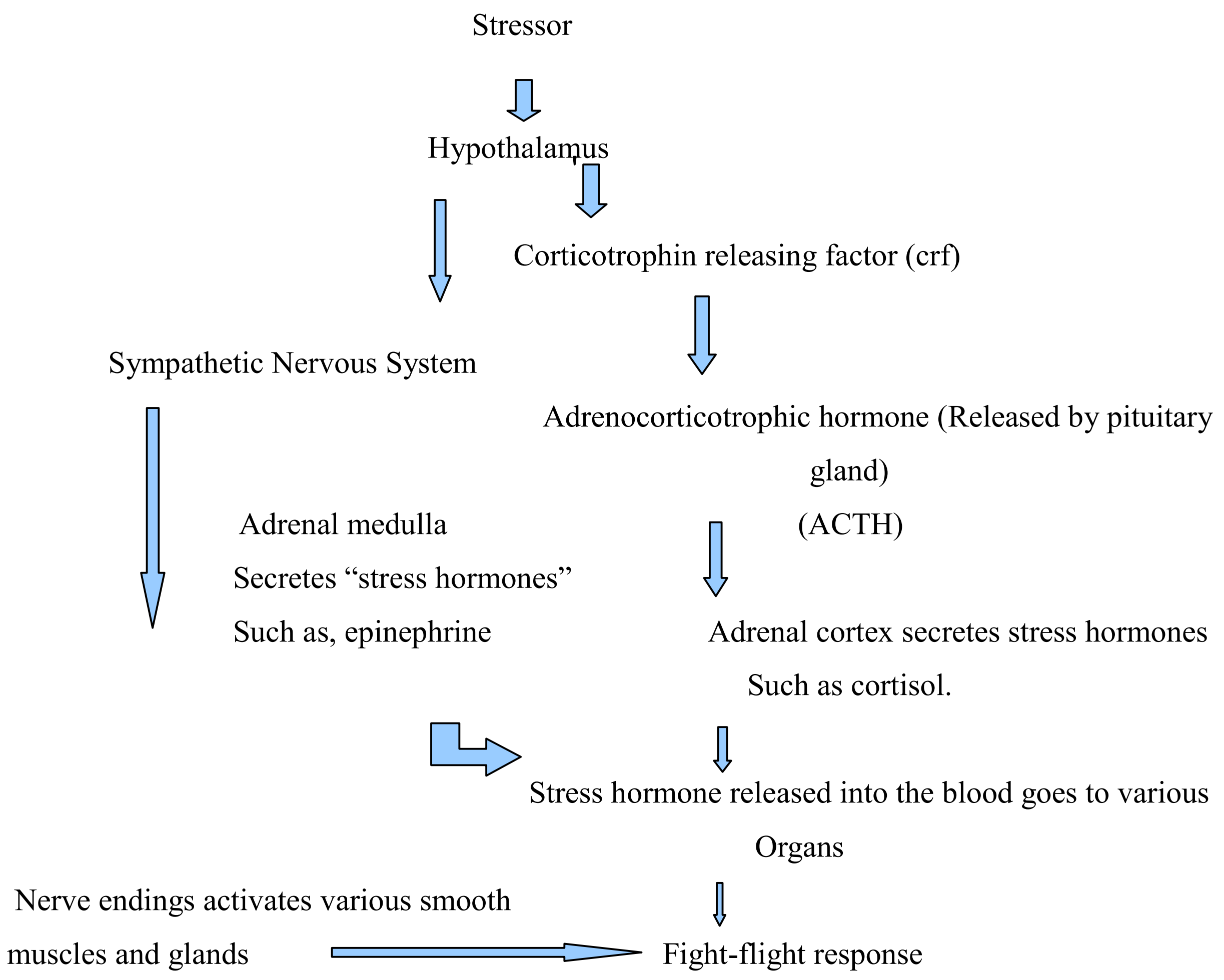

Figure 5. Central nervous system response pathway.[52]

The parasympathetic system is concerned with conservation and restoration of energy, leading to reduction in heart rate, blood pressure, increased digestion, absorption of nutrients, and consequently enhanced excretion of waste products. Stress response has been shown to be more associated with reduction in parasympathetic stimulation than an increase in sympathetic activity.[31] However, at rest both sympathetic and parasympathetic systems are active with parasympathetic dominance. Nevertheless, the actual balance between them is constantly changing in attempt to achieve optimum homeostasis, taking account of all internal and external stimuli.[31] Our study is investigating the effect of prior exposure to mental stress (ICT use) on the balance between sympathetic and parasympathetic tone during sleep.

Sympathetic "fight-flight" response	Target Organ	Parasympathetic " relaxation response"
Dilatation	Pupils of the eyes	Constriction
Thick	Saliva	Thin
Increased rate	Heart	Decreased rate
Dilatation	Bronchi	Constriction
Decreased digestion	Stomach and Intestine	Increased digestion
Glucose secretion	Liver	No significant effect
Epinephrine secretion	Adrenal Gland	No significant effect
Relaxation	Bladder	Contraction
Constriction (skin, abdomen); dilatation (muscles)	Blood vessels	No significant effect
Increased activity	Skin sweat glands	No significant effect
Ejaculation/orgasm	Genitals	Erection/lubrication

Table 2. Effects of autonomic nervous system.[5]

1.3.2 Heart rate variability (HRV)

HRV shows the variations over time of the period between consecutive heart beats. The variability is influenced by physiologic, demographic and pathological conditions. Alteration in cardiac activity is due to changes in sympathetic and parasympathetic autonomic system, which can be evaluated with R-R interval (beat to beat variation), systolic blood pressure (Sbp) and diastolic blood pressure (Dbp).[58,59] This relationship between autonomic nervous system (ANS) and cardiovascular system have been used in assessment of severity and possible outcome of certain cardiac diseases.[60,61] Respiration have also been shown by several studies to effect ANS by modulating vagal activity through the baroreceptors.[62-64] Furthermore, the inverse relationship between the respiration and ANS is more pronounced with low respiratory rates.[65]

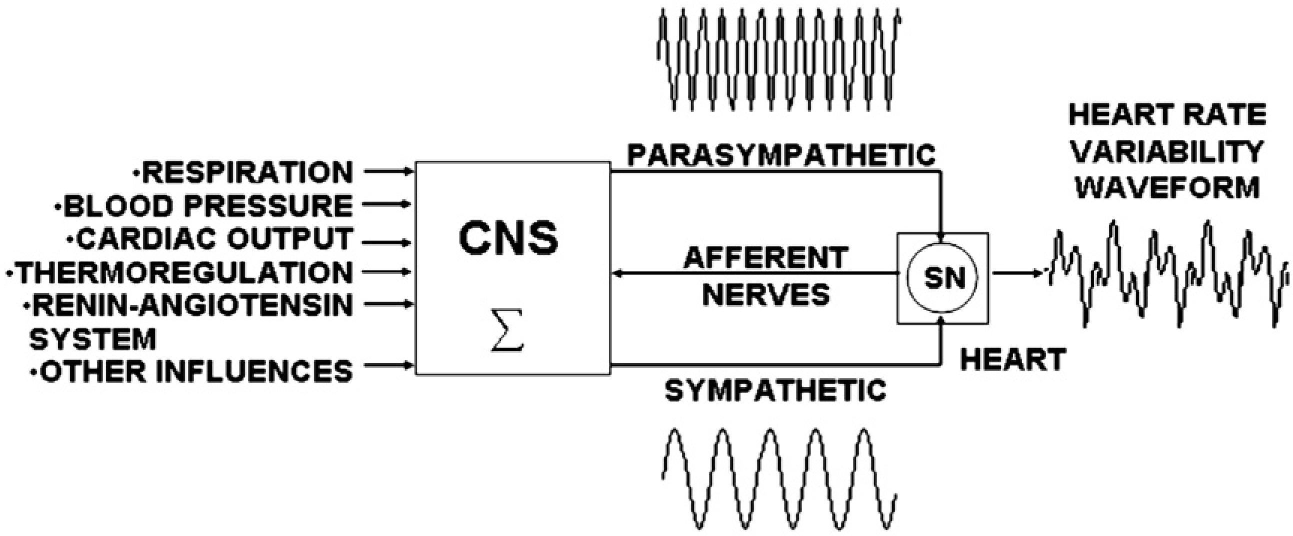

Figure 6: Factors of cardiovascular control and HRV.[66]

Different methods have been used in measurement and analysis of variations in heart rate. HRV is measured with electrocardiogram (ECG) of sampling rate above 250 Hz and an accurate algorithm for detection the QRS complex of cardiac cycle. Several ambulatory ECG recorders/Holter monitors have been developed to facilitate long term monitoring.[59] Analysis of the ECG recording is done by time and frequency domain, geometric, spectral methods.

However, recent research findings of non-linear components of cardiac signal have led to inclusion of non- linear methods of analysis.[67,68]The time domain method uses the recordings to calculate the mean normal to normal (NN) interval, which is derived from differences between adjacent QRS complex. The standard deviation of all NN intervals (SDNN) can be evaluated from a 5 minutes period recording, (SDNN ms) or 24 hours period known as cycle length variability. The root mean square of differences (RMSSD) of successive NN intervals, is considered the more informative and sensitive parameter for parasympathetic influence on the heart,[59] Nevertheless, it has been reported that sympathetic tone also contributes to RMSSD.[69] The proportion of differences between adjacent NN intervals of more than 50 ms (pNN50) is also used in R-R interval assessment.

Frequency domain analysis distinguishes parasympathetic and sympathetic heart control, parasympathetic is largely responsible for high frequency (HF, 0.15-0.40z) components,[70,71] while Low frequency (LF, 0.04-0.15z) has been indicated as a measure of sympathetic activity[72,73] and the very low frequency component (VLF) has a less defined physiological explanation. There is a positive relationship between psychological stressors such as ICT induced mental overload and Low frequency component of HRV.[74] However, HRV and ANS has been shown to vary considerably within a 24 hours periods.[75,76] HRV measure shows higher values in the night time in comparison with day time, revealing alternating balance between parasympathetic and sympathetic ANS throughout the day and night. High Frequency (HF) and LH component values of HRV rises within the night-time with declining ratio of LH to HF, due to more pronounced elevation of parasympathetic activity.[77] However, this day/night time variations can be altered by individual factors such as different circadian rhythm induced by personal wake -up and sleep time.

1.3.3 Heart Rate Variability, as a Stress Indicator.

Sympathetic activity as indicated by LH and HF ratio has been revealed as an indicator of the severity of physical and psychological stress the body has been/ is being subjected to.[78] Furthermore, mental stress have been shown to be associated with decreasing HF component.[79-81] Increasing blood pressure and heart rate (estimated from the distance between R-peaks in the ECG curve) is observed as declining distance between the periods and vice versa.[80] Experimental induction of stress prior to sleep resulted in decreased HF component during REM and non REM sleep, with subsequent rise in the ratio to LH to HF.[82] This study reveals that, sleep time measurement of HRV could be useful in evaluation of the effect of stressors, such as ICT induced mental stress. Studies in newborns showed that increased parasympathetic tone (HF) correlates positively with mental, social and motor development at the age of three.[83] On the other hand, parasympathetic activity was reduce in HRV analysis of panic attack and phobic patients in comparison with controls.[84]

A work- related stress study revealed declining parasympathetic and rising sympathetic tone in individuals less rewarded for their job. Furthermore, RMSSD values during duty and off duty days remained low in these subjects. In addition, night time RMSSD was found to be a more sensitive indicator of the health status of the individuals in comparison to daytime values.[85] Our study is evaluating the impact of intensity of ICT use on parasympathetic tone during sleep, through analysis of the sleep-time RMSSD and SDNN values. Work- stress related decrease in sleep-time total HRV during long work period is reversed by rest period.[86] However, in certain subjects with inadequate recovery, such as those mentioned above [85] complete reversal is hindered. Furthermore, decreased HRV indicating a disturbed autonomic system function [87] has been associated with mental stress in laboratory experiment.[88,89] However, use of color ward test in evaluating the physiologic effect of computer and mental stress yielded an insignificant result.[81] SDNN describes the balance between parasympathetic and sympathetic modulation of heart rate, a decreased values in subjects undergoing work strain indicated sympathetic activation.[90] Similar changes in heart rate and heart rate variability parameters have also been shown in patients in chronic pain due to certain disorders such as irritable bowel syndrome[91] and interstitial cystitis.[92]

In summary, heart rate variability can be used to assess the psycho-physiological state of the body. This function is facilitated by high sensitivity of heart rate to varying functional states. Periods of rise in both physical and mental activity induces an increase in heart rate while a decrease is caused by reduced activity. Furthermore, changes in autonomic control during different stages of the sleep-wake cycle can be dictated by corresponding variations in heart rate thus, providing a tool for assessment of the state of autonomic nervous system during sleep. However, the sleep quality analysis through parasympathetic- sympathetic balance evaluation is carried out in relation to individual baseline autonomic status.

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3 MANUSCRIPT

Association between information and technology usage and the quality of sleep among school aged children.

Sandra Ononogbu 1), Clas-Håkan Nygård 1), Marjut Wallenius2), Raija-Leena Punamäki2) , Lea Saarni,1) Harri Lindholm3)

1) Tampere School of Public Health, University of Tampere, Finland
2) Department of Psychology, University of Tampere, Finland
3) Finnish Institute of Occupational Health, Finland.

Correspondence about this article should be addressed to Clas-Håkan Nygård ,Tampere School of Public Health, University of Tampere, Finland; email:Clas-Hakan.Nygard@uta.fi

RUNNING HEADLINE: ICT usage and Sleep quality in school-aged children

Abstract

Objective- To determine the association between intensity of information and communication technology (ICT) usage and quality of sleep in school aged children.

Material and Methods. In all 74 subjects, 10-14 years of age. Criterion for inclusion was absence of prior medical condition, duration and frequency of daily ICT use. A portable device (Holter monitor) was used to measure heart rate variability over a 24 hour period, while sleep diary was used to record sleep and wake up time. Statistical analysis was done with two independent samples Tests and factoral Anova.

Result- The higher ICT users showed a lower sleep time standard deviation of normal to normal interval (SDNN) measures in comparison to the low ICT Users

Conclusion- Our findings indicates that low ICT users have a better quality of sleep.

Keywords: ICT , heart rate variability, sleep quality, children

INTRODUCTION:

The use of information and communication technology (ICT) such as computer use, internet surfing and video game playing enhances certain academic skills[1]. However, the increase of intense ICT usage among adolescents[2] is associated with adverse effects such as poor psychosocial health status.[3] In addition, a reduction in average sleep duration due to delayed bedtime, early waking up, sleep disruption by nightmares and sleep walking, are related to the use of ICT during the night-time [4]

The compromise of the restorative potential of sleep by a reduction in its quantity and quality could undermine the daytime functioning of adolescents, manifesting as irritability, day time sleepiness, inability to concentrate or assimilate during academic activities.[5] Long term adverse health effects, like poor sleep, is related to depression. [6] Sleeping patterns of depressed subjects are shown to be irregular compared with the non-depressed subjects. [7] In addition, the probability of developing anxiety or depression is much higher among adolescents with poor sleep .[6] Also an increase of body mass index,[8] abnormal glucose metabolism,[9] predisposition to certain cardiovascular diseases such as hypertension ,[10] reduction of immune responsiveness to certain infection, [11] increased risk of accidents [12] and incidence of substance abuse,[13] aggravation of certain illnesses such as Seizure disorders[14] and psychiatric symptoms[15] are associated with anxiety or depression among adolescent. Violent gaming may induce different autonomic responses in boys compared to nonviolent gaming during playing and during the following night – suggesting different emotional responses[16]

Cardiovascular parameters such as heart rate, R-R interval and blood pressure vary with sleep quality[17]. Under normal physiological conditions, sleep period is dominated by parasympathetic autonomic activity, which potentiates adequate recovery from the daytime stress. However, an increased stress conditions such as ill health and persistent poor sleep disrupts recovery by raising sympathetic activity during sleep.[18] Heart rate variability (HRV) is used for assessment of cardiac autonomic activity. The square root of the mean squared difference of successive normal to normal (N-N) interval (rMSSD) correlates to the high frequency bands (HF, 0.15-0.40 Hz)[19] and the established measure of parasympathetic activity, which increases during sleep. On the other hand, the low frequency band (LF, 0.04-0.15 Hz) is related to heart rate and blood pressure, which increase with sympathetic dominance during the daytime.[20] Those variations could be influenced by age, sex, life style and health status.[21] The aim of this study was to investigate if the intensity of ICT usage is associated with the quality of sleep by using the measures of the standard deviation of Normal to normal interval (SDNN) and root mean square successive difference (RMSSD) which represented the parasympathetic activity during sleep.

SUBJECTS AND METHODS

Subjects

Participants were selected from those 222 (123 girls) fourth and 256 (137 girls) seventh graders from seven schools in the Tampere region of Finland. The total of ICT use including mobile phones, computer games, and internet surfing, emailing, group discussions and chatting was measured by the questionnaire. The frequency of ICT use (graded from 0= never, 1=less than once a week, 2=1-2 days a week, 3=3-5 times a week to 4= almost daily) and also the duration of the daily ICT use, during school days and the weekends (graded from 0 =not at all, 1= less than an hour, 2=1-2 hours, 3=3-4hours to 4=over 4hours) were measured. Altogether 88 subjects were stratified into fourth and seventh graders (10-11 and 13-14 -year-olds), and boys and girls. The group of “High ICT users” was selected from total number of the participants who reported the use of at least one form of ICT for three to four hours or more almost daily. However, the level for High ICT use was set at 1-2 hours among the 10-year-old girls, because only two of them reported to use some of the ICT contents 3-4 hours almost every day. The “Low ICT user group” consisted of subjects who have never used any form of ICT or use ICT for 1 to 2 days a week and less than 1 hour at anytime. Altogether 74 students participated in this study. However, six participants who had missing data on some sleep hours and additional 7 participants with holter’s recording error were excluded from the analysis. In the final sample there was 61 participants, with 27 (44.3%) high ICT users and 32 females

(52.5%).The number of the participants in the younger age group (10-11years) was 31 (50.8%), while in the older group(13-14 -years) the number was 30 (49.1%) (See Table 1). Among the high ICT user group, 47% belonged to the older age group (13-14 years).This study was approved by the ethnical committee of Pirkanmaa Hospital District (code Nr. R04050), permitted by the head of the schools involved and the informed consents of both the parents/guardian and the students for the participation were obtained.

Physiological measures

Holter monitor, an ambulatory battery operated device ,which records cardiac electrical activity when attached to the chest ,was used for heart rate and heart rate variability (HRV) measures. The memory card with stored signals were transferred to a computer program system for analysis.[22] Participants were required to have the monitor for a 24 hour duration and recorded their bedtime and wake up time . The standard time domain measures were obtained: standard deviation of all normal sinus R-R interval (SDNN), root mean square of the successive normal sinus R-R interval difference (rMSSD), percentage of successive normal sinus R-R interval longer than 50ms (pNN50) and the heart rate computed from the mean cycle length of R-R complexes. The body mass index (BMI) was calculated from the participant's reported height and weight using weight in kilograms / height in meters^2 formula. Prior to commencement of the study, participants were measured medically to exclude any cardiovascular or other chronic disorders that could confound heart rate variability recording.

Statistical analysis.

Differences by gender and age in quality of sleep were tested by chi squared tests. The relationship between the intensity of ICT use and quality of sleep was tested with two independent samples T tests among the groups of high and low ICT users. Further analysis of the effects of gender, age and body mass index on the outcome variables was done with factoral Anova. The data analysis was carried out with SPSS 15.0 for Windows.

RESULTS

The mean sleep time blood pressure did not differ between the ICT groups. However, there was a statistically significant difference in HRV between the ICT usage groups, when assessed with mean sleep time SDNN (p=0.035) (See Table 2). Comparison of the mean day and night HRV values between the ICT usage groups revealed lower night values, especially in older (13-14 years) high ICT users. Nevertheless, analysis with rMSSD (p=0.07) showed no statistical significant difference between the groups. HRV sleep period rose slower in high ICT users in both age groups compared to low ICT users (see Figures 1 and 2). Adjustment for the influence of body mass index, gender, and age with factoral Anova resulted in no significant effect on the outcome (Table 3).

DISCUSSION

This study revealed that HRV of high ICT users differed from low users during sleep on assessment with SDNN. High ICT users had lower night values. Positive relationship between intensity of ICT usage and sleep pattern have been shown in earlier studies.[23]However, certain studies have found no association,[24] which correlates also with this study finding, when HRV is assessed with rMSSD. Taking account of the fact that rMSSD is reportedly a more sensitive indicator for parasympathetic activity[18], the influence of the small sample size on this outcome can not be overruled.

Some of the mechanisms that have been implicated in the pathway by which ICT usage has effects on poor sleep, includes, direct encroachment of sleep time by ICT use through its increased accessibility, affordability, addictive tendancies,[25] physiological changes induced by emotional reaction to activities,[27]suppression of melatonin secretion [26] and reduction in physical activity.[28] Nevertheless, physical activity has also been shown to be insignificant in certain studies[28]. ICT usage has been found to be positively associated with weight status in adolescents, it has been reported that the displacement of physical activity with ICT usage enhances increase in weight, thus, a raise in body mass index. [21] In this study, the BMI was not associated with the quality of sleep, irrespective of gender and age. However, the aim of this study was to study, if intensity of ICT usage affects the quality of sleep.

The cross-sectional design of this study limits the ability to make causal inferences. It is difficult to rule out, sleep disturbance as an actual precipitator of high ICT usage. The result of this study will need further evaluation with a prospective study with randomized controlled study, in which children are randomized to either a high ICT group or a control group, and also their sleep quantity and quality should be analyzed. In addition, potential confounders such as sleep environment, diet, parental socio-economic status, physical activity and other factors that could affect the state of the autonomic nervous system during sleep should be measured and adjusted for more effectively. Another limitation of this study was the reliability of the information provided in the self reported questionnaire regarding intensity of ICT use, sleep and wake up time. The accuracy of the data can be improved by employing a more comprehensive method in obtaining this information.

CONCLUSION

This study shows that the intensity of information and communication technology use by children/adolescents seems to interfere with the quality of sleep. The participants with low ICT use seem to sleep better than the high users. Further studies are needed with larger number of participants, comprehensive account of other forms of ICT use beyond computer use, internet surfing and video game playing to enhance a more conclusive result of the effects of ICT use.

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Table 1 Characteristics of study participants

Variables	*N* (%)	ICT use, n (%)			SDNN	rMSSD
		Low users	High users	*P*-value	Mean (SD)	Mean (SI
Gender						
Males	29 (48)	19 (65)	10 (35)	0.143	108.35 (27.60)	80.45 (25.
Females	32 (52)	15 (47)	17 (53)		105.35 (28.10)	72.58 (27.
Age						
10-11 years	31 (51)	18 (58)	13 (42)	0.710	105.80 (26.41)	78.10 (26.
13-14 years	30 (49)	16 (53)	14 (47)		107.77 (29.40)	74.28 (26.

SDNN = Standard deviation of NN interval, rMSSD = root mean square of successive difference, BMI= body mass index, p= significant level, MSDP= mean systolic blood pressure, MDBP = mean diastolic blood pressure, ICT= information and technology use.

Table 2 Unadjusted means of SDNN and rMSSD by ICT use

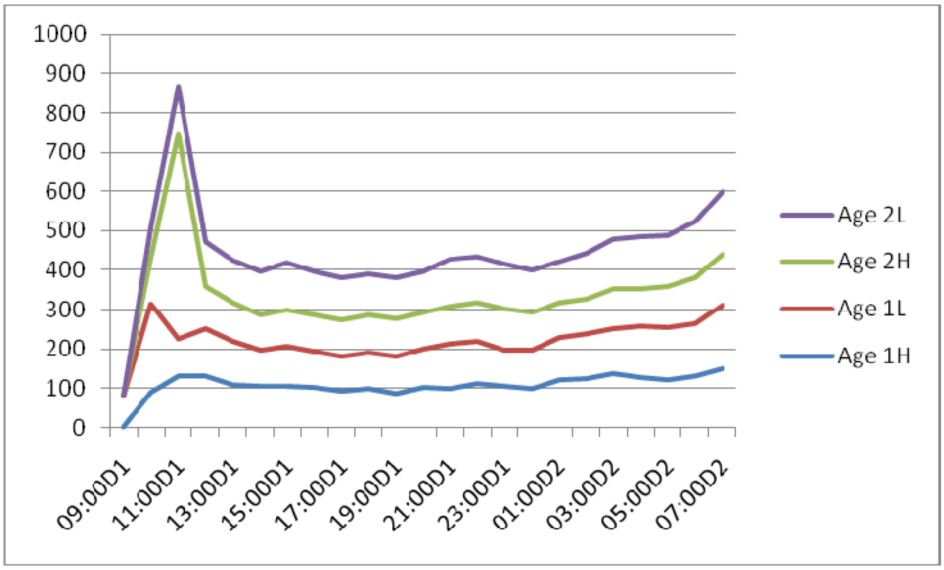
Variables	ICT use		Mean difference	*P*- valu
	Low users Mean (SD)	High users Mean (SD)	(95% CI)	
SDNN	114.12 (27.12)	99.05 (27.23)	15.07 (1.06-29.09)	0.035
rMSSD	82.61 (27.14)	69.87 (25.27)	12.73 (-0.85-26.32)	0.066

SDNN = Standard deviation of NN interval, rMSSD = root mean square of successive difference, ICT=information and technology use, p= significant level.

Table 3: Means of SDNN and rMSSD by ICT use, adjusted for gender, age, and BMI

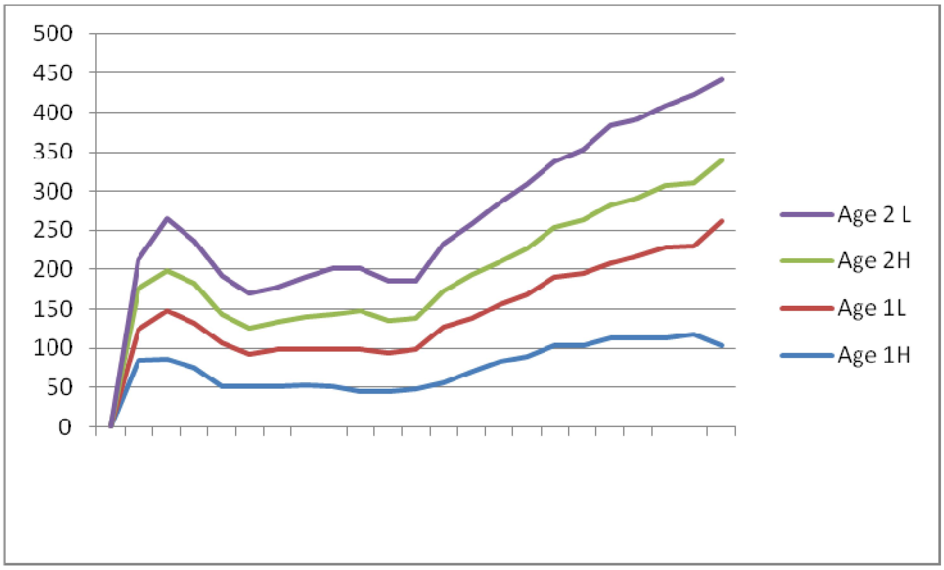
Variables	*N*	SDNN			rMSSD	
		Mean (SD)	*F* statistic	*P*-value	Mean (SD)	*F* statistic
ICT use						
Low users	34	114.12 (27.12)	11.17	**0.002**	82.61 (27.14)	7.84
High users	27	99.05 (27.23)			69.87 (25.27)	

SDNN = Standard deviation of NN interval, rMSSD = root mean square of successive difference, ICT=information and technology use, BMI= body mass index. , p= significant level.



Age 2L = 13-14 years low ICT usage (N=16)
Age 2H= 13-14 years high ICT usage (N=14)
Age1L=10-11years low ICT users (N=18)
AH=10-11years high ICT users (N=13)

Figure 1 Mean HRV (SDNN) over 9 hours of day/night



Age 2L =13-14 years low ICT users (N=16)
Age 2H=13-14 years high ICT users (N=14)
Age 1L= 10-11 years low ICT users (N=18)
Age1 H=10-11 years high ICT users (N=13).

Figure 2: Mean (rMSSD) over 9 hours of day/night.

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4 THESIS PROCESS

The search for a master's thesis project idea/ topic began at the start of year 2008. By April 2008, it was agreed for me to analyze a part of then completed study: stress, strain, restoration and social-emotional development from middle childhood to adolescent: The role of information and communication technology (ICT). My study was to investigate the effect of the intensity of ICT usage on sleep quality of school-aged children/ adolescents, under the supervision of Professor Clas-Hakan Nygard. Knowing very little about Heart rate variability (HRV) and its clinical applications, I had to begin from reviewing literature on its uses in the measurement of autonomic system balance during sleep and wake up time. My supervisor and Reetta Heinonen were very kind and generous to provide me with some materials and initial resources on HRV. I also reviewed the prevalence of sleep disturbance, ICT use among adolescents and their variation over recent years. My initial plan was to consider the following in the study participants: First, Are they using more ICT. Second, Is their sleep quality altered and thirdly, is there a relationship between any present alteration in sleep and how much ICT they use.

My data consisted of 74 subjects from a study carried out in five schools within Tampere region in 2004 with a follow- up in 2006. The variables were age, gender, height, weight, blood pressure, categorized ICT usage (high or low) and HRV variables such as root mean square of successive normal sinus R-R interval difference (RMSSD) and the standard deviation of all normal sinus R-R internal (SDNN). Lea Saarni amazingly interpreted the wake up and sleep time from the diary to English and send them to me on request. I got the mean sleep time RMSSD and SDNN from the average of each participants RMSSD and SDNN during sleeping hours between 24.00- 5.00 and Body mass index was calculated from reported height and weight. However, I was unable to get the data on physical activity, so it was unadjusted for in my analysis. This, notwithstanding the body mass index provides information that could assist in predicting level of activity, as previous studies have found an association between body mass index and physical activity.

In analysis, one of the methodological problems would be inability to establish a causal relationship. The unavailability of variable such as physical activity could act as a confounder. It is possible, that physical activity plays a role in determining autonomic status during sleep Thus, indirectly affects heart rate variability. Furthermore, though variables such as age, gender, body mass index were controlled for, it is difficult to adjust and account for certain environmental factors that could affect sleep. Nevertheless, by analyzing the difference in heart rate variability between the two categories of ICT users especially during sleep time, I aimed to evaluate any existing association.

In addition to the skills and knowledge of data analysis I obtained from biostatistics and introduction to computing with SPSS course work, I got advice from a senior colleague Bright Nwaru, on the best way to present my result to enhance reading and understanding. Harri Lindholm suggested I capture the pattern of rise in a graph to highlight the changes in HRV over a 24 hour period. However, because of missing data in a number of the subjects in the earlier hours of day, I decided to to give an illustration of the rise over 9 hours between later part of the day and night.

Over the course of my thesis writing, I relocated to the United States and faced challenges on how to effectively manage my time between analyzing my data, continued review of literature and an overwhelming task of settling into a new environment. However, with constant encouragement and guidance from my supervisor, counselor (Catarina Stahle-Nieminen) and the other members of the research team I was able to stay on track. At about the second to the last article review, Marjut Wallenius suggested a title change from effect of ICT usage on quality of sleep to Association between intensity of ICT usage and sleep quality, his reason being that, the later was more appropriate for the study than the former.

The thesis process is an eye opener and a good taste of the exciting world of research. I am very grateful to have been given this wonderful opportunity to partake in the analysis of phenomenal research by an outstanding research team.