

Salivary Cortisol in Relation to the Use of Information and Communication Technology (ICT) in School-Aged Children*

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ABSTRACT

Long periods of use of Information and Communication Technology (ICT) may raise strong emotions and lead to cognitive fatigue. The current study focused on the impact of ICT use the preceding day on the next-day salivary cortisol pattern in 72 school-aged children (39 at the age ten and 33 at the age 13). Salivary cortisol levels were measured at five time points from awakening to bedtime. Time spent in different ICT activities the day before salivary sampling was measured by an activity diary. Results showed that the participants who had used ICT on an average three hours the preceding day showed a significantly reduced cortisol increase one hour after awakening (awakening response) compared to those who had used ICT not at all or less than one hour after controlling for pubertal status and the level of depression. The results suggest a stress response as a consequence of a long period of ICT use.

Keywords: ICT, Salivary Cortisol, Stress, Children, Adolescents

1. Introduction

Information and communication technology (ICT; mobile phone, digital games, computer, the Internet) is matching the popularity of traditional media in the lives of Western children and adolescents. Recent findings show that digital game playing exceeds time spent in television viewing among children [1]. Younger children and boys spend more time in digital game playing while adolescents (14-18 years) spend increasingly time in Internet surfing and chatting [2,3]. ICT use serves many motives and functions among children and adolescents. For example, digital game playing offers restoration, social compensation as well as possibilities to experience and learn new or escape worries [4]. Thus, ICT may provide an extra dimension to life in which children and adolescents are able to accomplish things which are not possible for them

in reality [5]. The psychophysiological effects of daily ICT use among children and adolescents have not been studied so far. In this study, we examine relations between the intensity of daily ICT use and psychophysiological stress indicated by diurnal salivary cortisol secretion in school-aged children.

Interactions with ICT can be understood as mental tasks which may comprise different components [6]. These interactions may elicit strong emotional responses, such as enthusiasm, fear, and surprise, affect the individual's arousal level, and demand voluntary, directed attention and cognitive processing. Although adolescents experience the different ICT activities mainly positively, long-lasting use of ICT may, however, result in more negative consequences, such as directed attention fatigue [7] and heighten arousal level which is often antecedents of physiological stress response [7]. Directed attention fatigue as a result of prolonged period of mental effort is independent of the content of a task [8]. Physiological measures of stress can be seen even after a long period of a pleasant task [9]. Thus, the mental tasks during ICT use,

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although experienced positively, may cause stress. In addition, findings suggest that the auditory input, such as built-in music during video game playing, may contribute significantly to the stress response [10]. Recovery from directed attention fatigue occurs during sleep and during involuntary attention, or fascination, requiring no effort, for instance in nature environments [11]. In everyday life children and adolescents may use multiple forms of ICT daily or even at the same time. Also, directed attention is needed most of the time during schooldays and when doing home works. We hypothesize that directed attention fatigue is increased by increasing the total time used in ICT. We further hypothesize that psychophysiological stress results as a consequence of directed attention fatigue and insufficient attentional resources with joint effect of possible other stress-related features of ICT interactions, such as high arousal level and noise.

When an individual is exposed to stress, a cascade of physiological events occur along the hypothalamic-pituitary-adrenal (HPA) axis. Subsequent release of the steroid hormone cortisol is considered the body's major neuroendocrine response to stress [12]. Prior research among children and adolescents shows that the daily rhythm characteristic to cortisol can be disrupted by psychological and environmental influences, such as cumulative environmental risks [13], poverty [14], day-care [15], post-traumatic stress disorder [16], social deprivation [17], performance challenge [18], and violence exposure [19].

In the diurnal profile of cortisol secretion, the cortisol awakening response (CAR) has been recognised as a distinct phenomenon. Under basal conditions, cortisol secretion follows a circadian rhythm, manifested in 50-160% increase in salivary-free cortisol during the first 30-40 min after awakening, drop rapidly in the next few hours and then more gradually throughout the day [20]. The cortisol awakening response has shown to be an intra-individually stable phenomenon [21]. A majority (70%) of 10-12-year-old children show a cortisol awakening rise, although lower than in adults, with higher levels in girls than boys [22,23]. Results concerning relations between cortisol measures and pubertal stage are somewhat contradictory. While some studies have found no relationships [22,23], some findings show correlations between higher pubertal stage and elevated cortisol curves and lower cortisol awakening response [24]. The cortisol awakening response is unrelated to the mean underlying level of cortisol secretory activity throughout the rest of the day [25].

Many studies have found perceived stress to be linked to some aspects of the cortisol awakening response for a review see [20]. Especially the attenuated cortisol awakening response is related to stress, such as acute [26] and long-lasting stress [27], chronic fatigue [28], early loss experience [29] and violence exposure [19]. Contrary to adult studies, adolescents with higher levels of

depressive symptoms showed lower diurnal cortisol levels [24].

Results on the association between ICT use and cortisol levels are limited, describing only short-term experimental conditions concerning digital playing. Some studies have found raised cortisol levels [30] but others have found no change during a digital game [31]. Still some results suggest that higher cortisol levels are due to built-in music of digital games [10]. Instead, psychophysiological effects of daily ICT use have not been studied.

The present study investigated whether the amount of time used on ICT the preceding day was related to salivary cortisol among school-aged children. For cortisol, we used both levels and dynamics of cortisol concentration. We hypothesized that higher ICT use the preceding day is related to higher total cortisol levels and an attenuated cortisol awakening response.

2. Methods

2.1 Participants

Participants for the laboratory measurements were selected from those 222 (123 girls) fourth and 256 (137 girls) seventh graders from seven schools (five elementary and two middle schools) in a city in Finland who completed a survey questionnaire. The age groups were chosen according to the developmental saliency in transition from middle childhood to adolescence [32]. Altogether 88 subjects were stratified into fourth and seventh graders (10- and 13-year-olds), and boys and girls.

Altogether 72 (33 girls, 39 boys; 39 10-year-olds, 33 13-year-olds) schoolchildren took part in the study. The dropouts were due to refusals and unwillingness to provide informed consent on the part of either the schoolchildren or their parents.

2.2 Procedure

Before data collection the approval of the Ethical Committee of Pirkanmaa Hospital District (Code Nr. R 04050) was acquired. Permission was also obtained from the school principals. At each school an information meeting was held, usually for each participating class separately, and an information letter was delivered both for the pupils selected for the study and their parents. Written consents for the participation were obtained from all children willing to participate, and their parent/guardian. The researcher gave directions for an activity diary and the subjects had possibility to ask questions.

At each school, in a peaceful room, the participants were given the saliva collection kits with verbal and written instructions. Children took their saliva samples during one day, and next day they returned the samples and the activity diary to the researcher. One day saliva samples of all the participants were collected during three weeks, from the end of April to the beginning of May.

The sampling day was always an ordinary school day. As a reward for taking part in the study, the subjects received a cinema ticket each.

2.3 Measures

2.3.1 Content and Intensity of ICT Use

Exposure to ICT was measured by use of an activity diary covering the day preceding saliva sample collection. High subject compliance rate and data reliability have been obtained with diary method using objective measures as criterion, both among children and adolescents [33]. The participants were instructed to record in 15 minutes intervals the time spent on different ICT activities with alternatives 1) using mobile phone e.g. for phone calls, text messages, 2) playing mobile phone games, 3) playing TV or console games, 4) playing computer or Internet games, 5) using computer for homework, writing etc., 6) using computer for communication by e-mail, discussion groups, and chatting, and 7) general surfing on the Internet. Participants also recorded their sleeping hours, from going to bed until waking up the next morning. Total time spent on different ICT activities was calculated summing up the 15 min intervals for each activity. Child-reports on time they use for different activities have been shown to have moderately high validity [34].

2.3.2 Salivary Cortisol

Participants took five saliva samples (immediately at wake-up, at 1 hour after wake-up, at 3 hours after wake-up, late in the afternoon and before going to bed) using the Salivette sampling device (Salivette®, Sarstedt, Germany). The Salivette tube consists of a plastic sampling vessel with a suspended insert containing a sterile neutral cotton wool swab that has to be chewed for about one minute and then returned to the insert. Children were instructed not to drink or eat or brush teeth half an hour before collecting the saliva sample. Salivary cortisol sampling compliance has shown to be reasonably high when verified electronically in adults [35]. The next day, the saliva samples were returned to the researcher and immediately mailed to the Finnish Institute of Occupational Health for cortisol assay. Free cortisol levels in saliva were measured using a commercially available chemiluminescence assay (IBL, Hamburg, Germany).

2.3.3 Pubertal Status

In the survey questionnaire, pubertal status was measured by asking ‘How old were you when you got your first period/spermarche?’ The adolescents had to select one of the options: not yet, at the age of 10, 11, 12, 13, 14, and 15. For this study pubertal status was dummy coded: yes/no at puberty.

2.3.4 Depression

In the survey questionnaire, depression was measured by

depressive and anxiety symptoms. Six items indicating depressiveness were derived from the Child Depression Inventory CDI; [36], and included items such as “I am sad”, “I cry easily and often” and “I feel that nobody cares about me”. Five items indicating anxiety and fears were from the Screen for Anxiety Related Emotional Disorders 5-item SCARED; [37] and included items such as “I fear that something bad will happen to me”, “Many things bother me”, and “I fear that I will fail”. The participants estimated how well the descriptions fitted them on a 5-point scale: (0) not at all, (1) somewhat, (2) quite well, (3) well, and (4) very well. The depressiveness and anxiety scales have been validated in a Finnish intervention study among children in depressive families [38]. Based on both scales a mean variable of depression was formed, and it had sufficient internal consistency of Cronbach’s alpha 0.79.

2.4 Statistical Analysis

For statistical analysis the participants were divided into two groups on the basis of the total sum of hours spent in different ICT activities during the day preceding saliva sample collection. Participants who had used ICT for less than one hour formed the low user group (N = 42). In this group 32 participants (76%) had not used ICT at all the day preceding salivary collection. The rest of the participants were called the user group (N = 30). In the user group, the total time of ICT usage of 19 participants (63%) was one to less than 3 hours, of six participants (20%) 3 to less than 6 hours, and of five participants (17%) 6-8 hours.

Differences between the ICT user groups in sex, age, classroom, and pubertal status were tested with Chi-square tests. Classroom was included in these analyses to be sure that the groups did not differ systematically according to the amount of ICT use or any other activity during the school day preceding cortisol measurements. Independent-samples t-tests were used to test group differences in depression, time spent in different ICT activities, wake-up time, sleeping hours before sampling, salivary sample times, and single salivary cortisol values. Group differences in daytime cortisol profiles were tested with general linear model (GLM) where five cortisol measures were within-subject repeated measures, and sex, level of depression and pubertal status were as covariates. Greenhouse-Geisser correction was applied because the assumption of sphericity was violated. Preliminary analysis indicated that girls showed significantly higher awakening cortisol levels than boys ($t(70) = 2.22, p = 0.030$) but cortisol values did not differ by age and pubertal status and were not correlated with the level of depression.

In addition to short daytime cortisol profiles, areas under the curve with respect to ground (AUC_G) and with respect to increase (AUC_I) based on five measurements were computed according to the formula described by Pre-

ussner, Kirschbaum, Meinlschmid, and Hellhammer [39]. These data were analysed with one-way ANCOVA using sex, the level of depression and pubertal status as covariates.

3. Results

3.1 Descriptive Statistics

The sample characteristics and the data for the two ICT user groups are summarised in **Table 1**. The low user and user groups did not differ by sex, age, classroom, level of depression or pubertal status. Participants in the user group differed significantly from the low user group both in the total time used ICT and in using different form of ICT except for mobile phone use. Hours slept before the salivary sampling, waking time, and sampling times did not differ between the ICT user groups.

3.2 Relations between ICT Use and Salivary Cortisol

The focus of the study was to examine the relation of the amount of time used on ICT to next-day salivary cortisol. In **Table 1** are shown group values for the different cortisol measures. The sample 2 cortisol value tended to be higher in the low user group than in the user group. Analysis of the short daytime cortisol profiles revealed no significant difference between the groups ($F(3.22, 215.90) = 1.58$; $p = 0.191$) (**Figure 1**). The total cortisol level indicated by AUC_G tended to be higher in the low user group than in the user group ($p = 0.09$). A significant group difference was found in AUC_I . As expected, the user group showed a significantly reduced awakening response compared to the low user group ($p = 0.03$) although the effect size was relatively small.

Table 1. Demographic characteristics, intensity of using information and communication technology (ICT), time of saliva collection, and salivary cortisol values in low ICT user and ICT user groups

Variable	Intensity of ICT-usage		Statistic
	Low user ¹ (N = 42)	User ¹ (N = 30)	
Sex (girl/boy)	20/22	14/16	$\chi^2(1, 72) = 0.00$; $p = 0.990$
Age-group (10/13)	21/19	15/15	$\chi^2(1, 72) = .24$; $p = 0.624$
Classroom (17 classrooms)	0-6 students/ classroom	0-4 students/ classroom	$\chi^2(16, 72) = 17.70$, $p = 0.342$
At puberty (yes/no)	14/28	11/19	$\chi^2(1, 72) = 0.13$; $p = 0.716$
Depression	7.86 (7.43)	9.00 (7.29)	$t(71) = -0.649$; $p = 0.518$
Hours used on ICT by activity			
Mobile phone calls, text messages	15 (0.29)	0.17 (0.38)	$t(71) = -0.27$; $p = 0.786$
Mobile phone games	01 (0.05)	09 (0.30)	$t(71) = -1.73$; $p = 0.088$
Playing TV and console games	04 (0.13)	56 (1.20)	$t(71) = -2.81$; $p = 0.006$
Playing computer games	05 (0.17)	1.16 (1.89)	$t(71) = -3.85$; $p = 0.000$
Using computer for writing, homework	01 (0.04)	37 (0.88)	$t(71) = -2.69$; $p = 0.009$
Using computer for communication	02 (0.09)	37 (0.89)	$t(71) = -2.53$; $p = 0.014$
Surfing in the Internet	00 (0.00)	52 (1.26)	$t(71) = -2.71$; $p = 0.009$
Total hours of ICT usage	14 (0.26)	3.15 (2.52)	$t(71) = -7.80$; $p = 0.000$
Wake-up time (h)	0648 (0054)	0707 (0055)	$t(71) = -1.63$; $p = 0.108$
Sleeping hours before sampling	8.60 (1.04)	8.98 (1.27)	$t(71) = -1.39$; $p = 0.170$
Time of saliva collection (h)			
Sample 1	0655 (0036)	0649 (0037)	$t(71) = 0.53$; $p = 0.596$
Sample 2	0758 (0036)	0754 (0050)	$t(71) = 0.26$; $p = 0.794$
Sample 3	1010 (0042)	1001 (0049)	$t(71) = 0.90$; $p = 0.372$
Sample 4	1528 (0100)	1553 (0114)	$t(71) = -1.58$; $p = 0.118$
Sample 5	2103 (0316)	2057 (0400)	$t(71) = 0.11$; $p = 0.913$
Salivary cortisol (nmol/l)			
Sample 1	18.28 (8.55)	20.32 (7.86)	$t(71) = -1.03$; $p = 0.308$
Sample 2	23.14 (17.87)	17.27 (7.88)	$t(71) = 1.68$; $p = 0.097$
Sample 3	16.24 (19.06)	10.94 (9.07)	$t(71) = 1.41$; $p = 0.163$
Sample 4	11.22 (13.49)	7.91 (8.27)	$t(71) = 1.19$; $p = 0.237$
Sample 5	6.70 (8.22)	4.77 (6.27)	$t(71) = 1.08$; $p = 0.282$
AUC_G	191.03 (142.06)	154.72 (85.05)	$F(1, 70) = 2.88$, $p = 0.094$, $\eta^2 = 0.041$
AUC_I	-79.95 (142.83)	-201.59 (175.68)	$F(1, 70) = 4.82$, $p = 0.032$, $\eta^2 = 0.067$

¹For sex, age group and puberty, frequency; for others, mean (standard deviation). AUC_G , area under curve with respect to ground; AUC_I , area under curve with respect to increase. Samples: 1 = at wake-up, 2 = at 1 hour after wake-up, 3 = at 3 hours after wake up, 4 = late afternoon, 5 = before going to bed

4. Discussion

This study provides support for a link between time used ICT and next-day salivary cortisol pattern among school-children. As expected, the participants who had used ICT on the average for three hours the preceding day showed a significantly reduced cortisol awakening response compared to those most of whom had used ICT not at all. This is in line with earlier results which show attenuated cortisol awakening response in relation to stress [19, 26-29].

In measuring cortisol different confounding factors have been identified, most of which, however, have been controlled in our study. According to earlier results both cortisol levels and the cortisol awakening response of 10-12-year-old children show seasonal variability, being highest during summer months [23] which may be related to greater amount of light [40]. Further, greater response has been reported on weekdays compared to weekends both by working adults [41] and children in day-care [15]. This kind of anticipation of a potentially stressful day has been observed in school-aged children, too [42]. In our sampling times there was no seasonal variation, and the sample collection day was always a weekday. Moreover, although earlier findings about the influence of awakening time on cortisol secretion are somewhat mixed [20], some recent studies imply that awakening time may be a confounding variable [43,44]. In this study, participants in the two ICT user groups did not differ according to waking-time or sleeping hours before salivary sampling, nor by sex, age, pubertal status or depression.

Measurement of salivary cortisol, compared to serum cortisol, has the advantage of a non-invasive and stress-free sampling procedure in the subjects' natural environment [23]. However, when saliva samples are collected in a domestic setting, the accuracy of the measurements depends on participant adherence to the instructions [45]. Since no electronic monitoring was used, we have no means to objectively assess participants' compliance to saliva sampling in this study. However, we have no reason to believe that the ICT users were less compliant than the

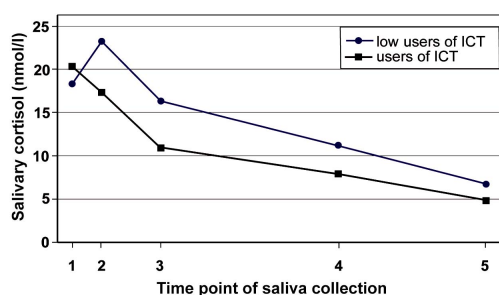


Figure 1. Salivary cortisol daytime profiles (1 = at wake-up, 2 = at 1 hour after wake-up, 3 = at 3 hours after wake-up, 4 = late afternoon, 5 = before going to bed) in the low ICT user group (N = 42) and ICT user group (N = 30)

other participants. Cortisol level is usually at its highest at 30 minutes after awakening. Had this measurement included, the cortisol level in the low user group might have been even higher during the second sample.

Generally, an altered cortisol awakening response is seen as an indicator of stress and stress-related changes in HPA-regulation. Adolescents rarely describe gaming and surfing in the Internet as stressing activities but, instead, as a way of passing time, getting positive experiences, and social communication. Gaming, Internet surfing, and other computer-based activities demand e.g. applying rules and strategies, quick reactions, and processing a lot of new information and experiences. Thus, in spite of the pleasant content, long period of focusing attention to game playing or Internet surfing may result in attention overload and directed attention fatigue [26]. Results have shown that subjective appraisals of stress and physiological reactions do not always match [46,47]. Besides directed attention fatigue, strong emotions may be associated with game and Internet contents, social communication, and successes and failures around these activities. Emotional processes involve both the subjective feelings of the individual and the neural and biochemical basis [9,30]. Thus, strong emotions are another possible source of physiological stress. Earlier results show physiological stress reactions immediately after a play session [30]. Our results suggest that a psycho physiological load due to ICT use can persist over night and have an impact on the regulation of HPA-activity even the next morning. Part of the participants in the user group had spent 1-3 hours on ICT which could be seen quite a moderate and usual amount of ICT usage per day at present. An experimental design would be needed to examine does even quite a moderate period of ICT use alone or only when combined with school work have an impact on diurnal cortisol secretion. The possibility of the low user group to recover and restore after school work may be as important as directed attention fatigue in the ICT user group in explaining group differences.

According to our results salivary cortisol may be a variable of interest when studying stress, strain and restoration in connection with ICT use. Some methodological questions need to be addressed, however. The result should be replicated in other, possibly larger samples, including salivary cortisol measurement at 30 minutes after awakening. Electronic monitoring of wake-up time and saliva sampling, and more objective estimates of time spent in different activities would be advantageous. Inclusion of more than one day would allow assessment of cortisol baseline values and enable measurement of within-subject differences based on ICT use. There are no standards for measuring pubertal development, but the selection of the method depends on which aspect of the puberty may be the most relevant to the research question [48]. In the current study, we were interested in the physical processes related to puberty which could affect

the diurnal cortisol secretion, not e.g. social or psychological development. Especially menarche appears quite late in the pubertal development [48]. Thus, a more fine-grained measure of stage of pubertal development [49] could be used.

In conclusion, our results suggest that long hours on ICT may imply stress responses during which the physiological regulation system is in imbalanced allostatic state [50]. Excessive use of ICT can be seen as a modern form of Type 2 allostatic load which refers to an individual's capacity to cope in the surrounding social context. It seems possible that long hours of ICT use day after day might work like a naturally occurring stressor, which would predispose some adolescents to the development of allostatic load. Stress from different sources may also have interactive effects [51]. In the face of multiple stressors, for instance, problems in family or peer relations, troubles at school, or living in a noisy or crowded environment, the negative effects of intensive ICT use may be strengthened. Turner-Cobb [50] suggests that under naturalistic conditions even changes within the normal range may be subtle early indicators of, and contributors to, physical health outcomes in adulthood.

Directed attention fatigue can be defined as an insufficient reserve of attention to perform demanding tasks [52]. In addition to physiological signs of stress, negative after-effects have also been observed in next-day performance [53]. It would be urgent to study whether excessive ICT use in the evening negatively affects adolescents' next-day school performance, for instance, in the form of poorer attention, persistence, or memory. There is evidence that changes in cortisol levels are associated with impaired cognitive performance, such as memory [54].

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