Anatomy & Physiology: Current Research
ISSN: 2161-0940

Sahin, Anat Physiol 2015, 5:S4
DOI: 10.4172/2161-0940.S4-003

Research Article Open Access

The Electrodermal Activity in Rats with Sleep Deprivation

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Rec date: Jul 10, 2015; **Acc date:** Jul 20, 2015; **Pub date:** July 22, 2015

Abstract

Sleep deprivation causes a wide range of cognitive deficits like impairments in vigilance, memory and physiological processes. To our knowledge, few chronic sleep deprivation studies have related the possible electrodermal activity (EDA) changes that show sympathetic activation. In this study, we aimed to investigate the effects of a 21-days sleep deprivation on EDA and neurobehavioral changes in open field area. The study was occurred with young and young adult Wistar Albino rats in Physiology laboratory of Erciyes University Medical Faculty. The rats were randomly divided in six groups in total as a sleep deprivation group, pedestal control group and cages control group, and three of aged-matched groups.

The skin resistance levels (SRL) and skin resistance response (SRR) were significantly decreased in substantive level in young and young adults sleep deprivation groups according to control groups. In open field test evaluations in young and young adult sleep deprivation groups significant increase in the number of crossline, rear and defecation. Sleep deprivation caused a decline in the electrodermal activity due to giving rise to increase in sympathetic tonus and anxiety in young and young adult rats.

Keywords: Sleep deprivation; Electrodermal activity; Skin resistance level; Skin resistance response

Introduction

Sufficient sleep is a very important factor in being healthy for both physically and mentally. Increasing workload and alternating life styles with modern life lead to change in stress levels and sleep patterns especially in adolescents. They can cause the sleep deprivation (SD) as not sleeping enough may be caused by abnormal life conditions or changes in sleep patterns affect physiologic processes in a person which in turn lead to problems in adaptation to normal life conditions.

SD may cause some pathologies including hyperphagia, weight loss, elevated energy expenditure, increased plasma catecholamines, hypothyroidism, reduction in core temperature, deterioration in physical appearance, reduced levels of anabolic hormones and declines in integrity of the immune system [1-6].

It was shown that sleep deprivation has affected like decreasing in number of Corticotrophin-Releasing-Factor (CRF) receptors in various regions of brain, the weight loss, decreasing in the weight of thymus and body temperature, increasing in the weight of adrenal gland and skin resistance level (SRL), deterioration in cognitive and behavioral processes and emotional condition [7-14].

The electrodermal activity is formed from activities of sympathetic and cholinergic inducible 'sudorific eccrine sweat glands' and 'non-sudorific dermal-epidermal tissues'. The eccrine sweat glands increase sweat secretion as activation of sympathetic and cholinergic nerves and lead to changes in EDA. In the other word, it has been claimed that the electrodermal activity can give indirect information about sympathetic nervous system activation [15].

However, there has been a few published about relationship of EDA and chronic sleep deprivation. Therefore, it was aimed to investigate to this relationship in rats with chronic sleep deprivation in this study.

Materials and Methods

Experimental Protocol

The Erciyes University's Committeeon Ethics in animal experimentation approved all experimental protocols. The experiments were carried out on 2 months young (n=24) and 8 months young adult (n=30) Wistar Albino ratsin Physiology laboratory of Erciyes University Medical Faculty and a cross sectional study. Because of age-related circadian sleep disturbances, we chose the young and the young adult animals. This was an inclusion criterion for us. The rats were fed with tap water and purina rodent chow ad lib. Rats were randomly divided into threesubgroups: the SD group, pedestal control (PC) group and cage control (CC) group.

Experimental animals were deprived from sleep by placing into Plexiglas tanks with multiple small platforms surrounded by water. The small platform prevented animals to sleep because in case of sleep, they would consequently fall into the water and wake up. PC animals were also placed in a similar water tank with 10 cm diameter platforms. This larger diameter pedestal permitted rats to sleep, but PC rats were also subject to relative immobilization producing stress, due to limited motor activity. Animals for the SD and PC groups were remained on the pedestals from 02:00 p.m. to 08:00 a.m. and returned to the vivarium from 08:00 a.m. to 02:00 p.m. for 21 days. The remaining six rats were normally sleeping in their home cages all day.

Electrophysiological Recording

EDA was measured by using a MP 30 system (MP30; Biopac Systems Inc., Santa Barbara, CA) and the electrophysiological recordings, took place in a dimly lit, electrically and acoustically shielded experimental room. Before the recordings, rats were allowed to adapt to the system and recording room for 5 min. EDA was recorded, employing a constant voltage technique and sampling the absolute, via direct current skin conductance at the rate of 20 samples per second, from plantar surface of the posterior extremities of each rat using Ag/AgCl electrodes during the interictal period.

Animals were conscious during recording and multipurpose gel (Sigma Gel) was used between skin and electrodes. Electrodes were connected to the MP30 system. The incoming signals of skin response were converted to digital signals via an MP30 data acquisition unit and processed with off-line analysis. There are two main components to the overall complex referred to EDA as follow:

Tonic EDA: A period of 2 min was allowed at the start of recording in order to register non-specific SRL (μmho/cm2) during a no-stimuli period.

Phasic EDA: The 15 auditory stimuli were presented at the end of the tonic EDA period (no-stimuli period). All were 1 s, 90 dB, and 1000 Hz tones with 50 ms rise and fall times. They occurred at pseudo-random intervals during 10 s. The mean SRR (μmho/cm2) values were calculated also off-line for phasic EDA.

Open Field Test

Locomotor activity, emotional behavior and autonomic functions were measured in open field area. The apparatus is a square area (100 cm×100 cm×30 cm), divided into 16 small units. The rats are individually placed in center of the open field and allowed to explore the area freely. The activity level is expressed as the total number of squares crossed, whereas anxiety is expressed as the total number of rearing, and fear is expressed as the total number of fecal boli, the spent time in the open field center and grooming during a 5 min testing period [16-18].

Statistical Analysis

The results were analyzed by SPSS 16.0 statistic software using oneway ANOVA test followed Post hoc Tuckey test. In all cases, $p<0.05$ was considered to be significant. All data were presented as mean ± SEM.

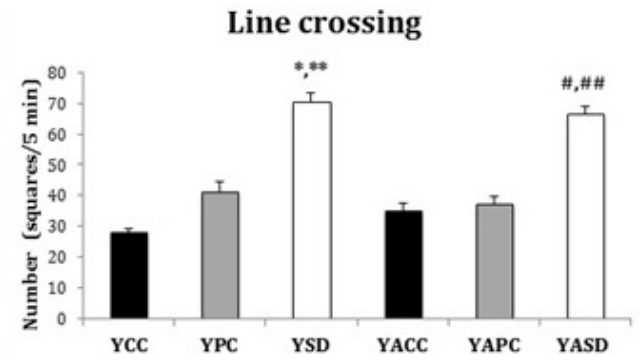

Figure 1: YCC: Young home cage controls group, YPC: Young pedestal control group and YSD: Young REM-sleep deprivation group, YACC: Young adult home cage controls group, YAPC: Young adult pedestal control group and YASD: Young adult REM-sleep deprivation group. *p<0.001 vs. YCC, **p<0.001 vs. YPC, #p<0.001 vs. YACC, ##p<0.05 vs. YAPC.

Results

Tonic EDA and phasic EDA measurement

SRL value in YSD group was decreased according to YPC and YCC groups (p<0.001, Table 1). SRL value in YASD group was significantly lower compared to YAPC and YACC groups (p<0.001, Table 1). SRL values of YCC group rats are significantly higher to YACC group rats (p<0.001, Table 1). SRR value from phasic EDA, in YSD group was significantly lower according to YPC and YCC group (p<0.001, Table 1).

When SRR values from young adult rats were evaluated, its value in YAPC and YACC groups were significantly lower according to YASD group (p<0.001, Table 1). SRR value in young cage of control group was significantly lower according to YACC group (p<0.001, Table 1).

0pen field test

When line crossing numbers and rearing numbers was compared in open field, YSD group values were significantly higher to YCC and YPC group (p<0.001, p<0.05, Figures 1 and 2). In evaluated grooming numbers, YSD group values were significantly higher to YPC group rats (p<0.05, Figure 3). YSD group more less time spent in the open field center than YCC (p<0.001, Figure 4). All data were expressed as mean ± SEM (Average time spent value in the open field center in open field area).

Groups								
	YCC(n=8)	YPC(n=8)	YSD(n=8)	YACC(n=10)	YAPC(n=10)	YASD(n=10)	F	P
SRL	15,7±1,3	7,0±0,2***	2,9±0,04 *,**	13,5±1,2*	7,8±0,3$^{\#}$	2,8±0,1$^{\#,\#\#}$	47,2	0,000
SRR	0,6±0,1	0,7±0,1***	0,1±0,02*,**	1,7±0,1*	0,6±0,1$^{\#}$	0,2±0,01$^{\#,\#\#}$	11,9	0,000
*p<0.001 vs. YCC, **p<0.001 vs. YPC, ***p<0.05 vs. YCC, $^{\#}$p<0.001 vs. YACC. $^{\#\#}$p<0.05 vs. YAPC.								

Table 1: The effect of 21 days REM-sleep deprivation on average SRL and SRR values.

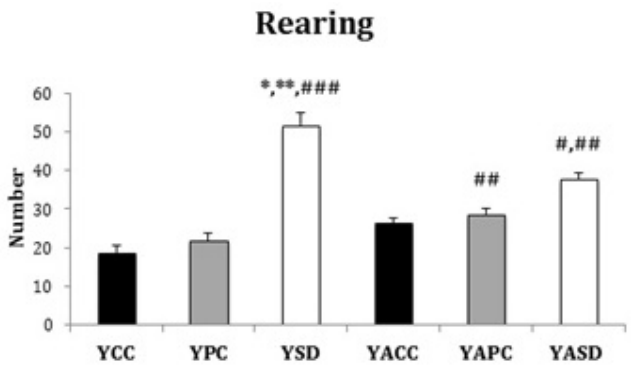

Figure 2: YCC: Young home cage controls group, YPC: Young pedestal control group and YSD: Young REM-sleep deprivation group, YACC: Young adult home cage controls group, YAPC: Young adult pedestal control group and YASD: Young adult REM-sleep deprivation group. *p<0.001 vs. YCC, **p<0.001 vs. YPC, ***p<0.05 vs. YCC, #p<0.001 vs. YACC, ##p<0.05 vs. YAPC, ###p<0.001 vs. YASD.

When young adult group line crossing and rearing numbers, YASD group values was significantly higher to YACC and YAPC group (p<0.001, p<0.05, Figures 1 and 2). In evaluated grooming numbers, YASD group values were significantly lower to YAPC group (p<0.05, Figure 3). The time spent in the open field center is significantly lower in YASD group than YACC group (p<0.001, Figure 4).

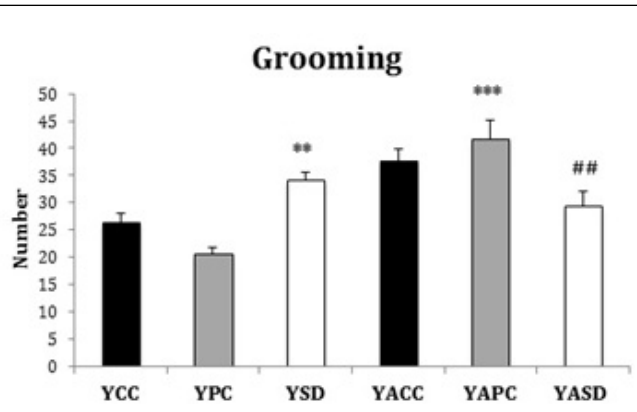

Figure 3: YCC: Young home cage controls group, YPC: Young pedestal control group and YSD: Young REM-sleep deprivation group, YACC: Young adult home cage controls group, YAPC: Young adult pedestal control group and YASD: Young adult REM-sleep deprivation group. **p<0.001 vs. YPC, ***p<0.05 vs. YCC, ##p<0.05 vs. YAPC.

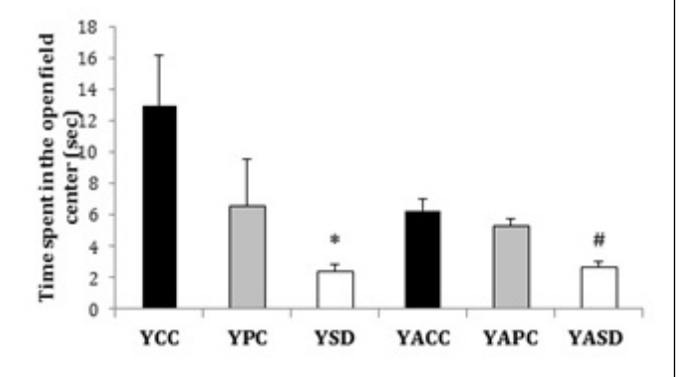

Figure 4: YCC: Young home cage controls group, YPC: Young pedestal control group and YSD: Young REM-sleep deprivation group, YACC: Young adult home cage controls group, YAPC: Young adult pedestal control group and YASD: Young adult REM-sleep deprivation group. *p<0.001 vs. YCC, #p<0.001 vs. YACC.

In between group's results, YSD group rearing number values was significantly higher to YASD group rats (p<0.001, Figure 2) and YAPC group rearing number values are significantly high according to YPC group (p<0.05, Figure 2). Grooming numbers was significantly higher in YAPC and YACC group according to YPC and YCC group (p<0.05, Figure 3). Fecal boli numbers of YACC and YAPC group was significantly lower according to YCC and YPC group rats (p<0.001, Figure 5).

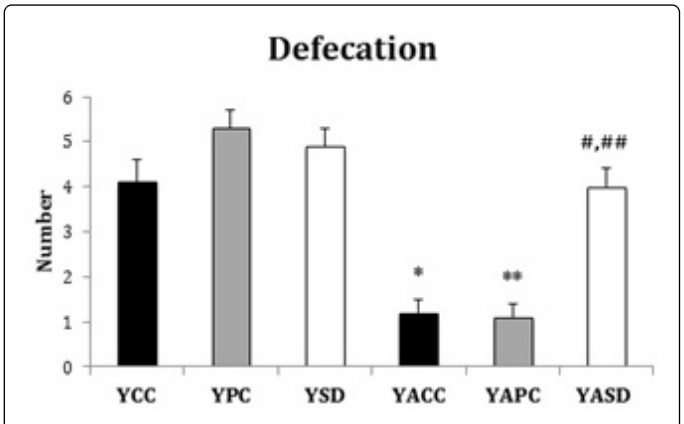

Figure 5: YCC: Young home cage controls group, YPC: Young pedestal control group and YSD: Young REM-sleep deprivation group, YACC: Young adult home cage controls group, YAPC: Young adult pedestal control group and YASD: Young adult REM-sleep deprivation group. *: p<0.001 vs. YCC, **: p<0.001 vs. YPC, #: p<0.001 vs. YACC, ##: p<0.05 vs. YAPC. All data were expressed as mean±SEM (Average Numbers of defecation in open field area).

Discussion

The sleep is different process than wakefulness and a process that has special dynamics. In previous studies, it was shown that water tank (Flower Pot=Multiple Platform) is the best method to perform sleep deprivation for rats. So, this method is generally used for sleep deprivation in the most of rat studies [7,19]. Jouvet et al. firstly used

the single platform method for SD in cats [20]. After this method was modified for rats by Cohen and Dement [21].

Unfortunately, this method provoked social isolation stress and affected the experiment results; multiple platform water tank was, therefore, developed. Thereby, it is possible to introduce sleep deprivation to multiple test animals in same water tank without causing any the social isolation stress. In the light of those information, it was used the multiple platform water tank in order to introduce sleep deprivation in the current study.

In order to discuss the effects of water tank media on results in sleep deprived group, although media control group is accepted as the best media control group, there is no way to absolute control of stress in water tank method. Even if it is studied with ideal control groups in previous studies, it is not possible to eliminate all effects of stress on experiment results, but it is claimed that stress can be minimized while introducing sleep deprivation by using multiple platform water tank and media control group [19,22,23].

Literature work shows the sleep deprivation in many studies is applied either by total or acute sleep deprivation. Conversely, the total sleep deprivation is not a likely situation in normal life conditions. In order to analyze the efficiency of multiple platform method, the study of Machado et al. [23,24], including 21-days, 18-hrs/day chronic sleep deprivation on rats shows REM period is completely inhibited during this time and it is compensated during rest of 6 hrs. Consequently, by the claims of Machado and his colleagues it is supported that 21-days, 18-hrs/day used in this study is adequate and efficient time for introducing chronic sleep deprivation.

The studies analyzing sleep deprivation effects on EDA are conducted by Forming total sleep deprivation (TSD). Since there is no study investigating effects of chronic sleep deprivation on EDA, this study is unique in terms of studying effects of 21-days, 18-hrs/day chronic sleep deprivation on EDA. In or study, there is a significant decrease in tonic parameter SRL and phasic parameter SRR values in chronic sleep deprived adolescent and adult rats Table 1.

These findings are evaluated as sympathetic activity increases in chronic sleep deprivation, since EDA is an indicator of sympathetic tonus inducing sweating. This information is consistent with previous studies as sleep deprivation causes sympathetic tonus increment [25-27].

According to previous research [28], 36 hrs TSD studies, notice effect on orienting response is investigated, the latent is delayed and its amplitude is decreased after TSD. In an another study analyzing 48 hrs TSD effects on performance conducted by Miro et al. [29], SRL level increased and researchers think that it is due to increment in body temperature, stress and attention deficiency caused by sleep deprivation. In our study, the discernment in average SRL and SRR levels both in adolescent and adult rats sleep deprived groups compared to their control groups is not consistent with above studies.

It is thought as this situation is due to sleep deprivations consisting different time intervals and different sleep periods have different effects [30]. The chronic sleep deprivation method used in our study is a likely situation that can be encountered in normal life contrary to TSD method in different results declaring studies and in turn it is possible to evaluate validity and explanation of physiologic mechanisms of resulting information.

The significant characteristic of insomnia, obstructive sleep apnea, and restless legs syndrome like sleep defects in human is developing REM sleep deprivation. There is a significant increment in SCL response in insomnia patients compared to control groups [31]. Lader and Wing [32] stated that there is an increment in SCL and SCR responses in anxiety groups compared to control groups in studies conducted on anxiety patients.

Our findings are parallel with results of mentioned study. Hence, it is evaluated as long term sleepiness causes anxiety, since SRL and SRR levels are statistically lower compared to their media and cage control groups in 21-days 18-hrs/day wakefulness introduced chronic sleep deprived YSD and YASD rats.

It is thought as sleep deprivation media control conditions also can cause anxiety, because there is a decreasing of SRL and SRR responses in adolescent and adult media control groups compared to control groups. EDA is an important method used for assessing psychophysiological statements.

Since, it is shown as the central nervous system regions linked to notice and function activities introduce changes on EDA. There are some studies showing SRR discernment on EDA or increment in unresponsiveness compared to control groups in anxiety patients.

Similarly, it is stated that there is an increment in tonic and phasic SCL, SCR levels in autonomically hyper induced people and habitation that is adaptation to various stimuli did not occur or decreased significantly [33].

It is stated that the open field tests in order to analyze anxiety on animals, the decrease in time passing in the center is as a result of anxiety. Since time spent in the center of the open field is considered a measure related to anxiety [34], in order to further analyze this behavior [35]. The significant decrease of the spent time in the center in YSD and YASDgroups rats shows sleep deprivation causes anxiety; this finding is consistent with the decrease in SRL and SRR responses in both groups. Because it is known that increase in anxiety is accompanied by increase in sympathetic activity and sweating.

The 24 and 96 hrs sleep deprivation studies open field test in order to analyze anxiety, locomotor activity is increased in sleep-deprived groups and this result is evaluated as hyperactivity after sleep deprivation [36,37]. The results of 36 hrs sleep deprivation studies in human show increase in anxiety [38].

In our study, increasing locomotor activity is determined by increase in number of line choice and increase in rising number is evaluated as chronic sleep deprivation causes anxiety. This interpretation is consistent with increase in SRL and SRR in YSD and YASD group rats is associated with increase in anxiety, and literature findings stating increase in locomotor activity because of increase in anxiety in open field test. In evaluated grooming numbers, YSD and YAPC group were significantly statistically. Several recent studies have suggested the putative utility of some grooming measures or the evaluation of stress or anxiety in rodents [39].

Conclusions

We demonstrated that SD significantly reduced SRL and SRR besides decreasing the spent time of center and increasing locomotor activity in open field test. These effects may result from increasing sympathetic activity and anxiety by a 21-days schedule of SD. Sleep deprivation caused a decline in the electrodermal activity due to giving rise to increase in sympathetic tonus and anxiety in young and young adult rats.

Declaration of interest

This study was supported financially by the Research Foundation of Erciyes University (SBT-07-54).

Disclosures

The authors have no conflicts of interest to disclose.

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This article was originally published in a special issue, entitled: **"Physiology"**, Edited by Dr. Robert A Walker