NON-INVASIVE TEST OF TEACHERS' OCCUPATIONAL STRESS USING ELECTRODERMAL ACTIVITY: A PILOT STUDY
NEINVAZÍVNY TEST PRACOVNÉHO STRESU UČITEĽOV POMOCOU ELEKTRODERMÁLNEJ AKTIVITY: PILOTNÁ ŠTÚDIA

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ABSTRACT
Background: Teaching is a highly demanding occupation with widely discussed research based mostly on questionnaire analyses.
Aim: The aim of this study was to evaluate electrodermal activity (EDA) changes by quantitative skin conductance level (SCL) in high-school teachers in the beginning and at the end of the school year.
Methods: We examined 50 participants (28 high-school teachers, 22 administrative workers). EDA was continuously recorded during the stress protocol: baseline, Go/NoGo test, recovery, supine position, orthostasis. Subsequently, the SCL was evaluated as median and interquartile range (IQR), the reactivity of SCL as percentage change (%).
Results: In the rest phase, teachers had significantly reduced median SCL compared to administrative workers (0.25 µS, IQR 0.06 – 0.52 vs. 0.48 µS, IQR 0.21 – 0.83). The reactivity of SCL was significantly higher in response to mental task (Go/NoGo test) in teachers (288.47 µS, IQR 100.86 – 654.33 vs. 97.45 µS, IQR 62.32 – 161.74). The teachers had a significant decrease of SCL at the end of the school year (baseline 0.29µS, IQR 0.10 – 0.52 vs. 0.43 µS, IQR 0.21 – 1.09; Go/NoGo 0.91µS, IQR 0.21 –1.80 vs. 1.16 µS, IQR 0.50 – 1.93; recovery 0.80µS, IQR 0.33 – 1.31 vs. 1.16 µS, IQR 0.50 – 1.65; supine position 0.54 µS, IQR 0.26 – 0.87 vs. 0.84 µS, IQR 0.38 – 1.24).
Conclusion: This study revealed insufficient sympathetic cholinergic activity indexed by EDA in teachers. It seems that EDA could represent a promising and objective, non-invasive tool for the determining pure sympathetic nervous system activity suitable in preventive occupational medicine that perfectly fits stress measurement.

Key words: Teachers. Occupational stress. Electrodermal activity. Skin conductance level

ABSTRAKT
Východiská: Učiteľstvo je náročné povolanie so široko diskutovaným výskumom založeným väčšinou na dotazníkových analýzach.
Ciele: Cieľom tejto štúdie bolo vyhodnotiť zmeny elektrodermálnej aktivity (EDA) prostredníctvom kvantitatívnej úrovne vodivosti pokožky (SCL) u stredoškolských učiteľov na začiatku a na konci školského roka.
Metódy: Vyšetrovali sme 50 účastníkov (28 stredoškolských učiteľov, 22 administratívnych pracovníkov). EDA sa nepretržite zaznamenávala počas stresového protokolu: východisková hodnota, Go/NoGo test, zotavenie, poloha na chrbte, ortostáza. Následne bol SCL vyhodnotený ako medián a medzikvartilový rozsah (IQR), reaktivita SCL ako percentuálna zmena (%).
Výsledky: V pokojovej fáze mali učitelia výrazne znížený medián SCL v porovnaní s administratívnymi pracovníkmi (0,25 µS, IQR 0,06 – 0,52 vs. 0,48 µS, IQR 0,21 – 0,83). Reaktivita SCL bola významne vyššia v reakcii na mentálne úlohy (test Go/NoGo) u učiteľov (288,47 µS, IQR 100,86 – 654,33 vs. 97,45 µS, IQR 62,32 – 161,74). Učitelia mali na konci školského roka významný pokles SCL (východisková hodnota 0,29 µS, IQR 0,10 – 0,52 vs. 0,43 µS, IQR 0,21 – 1,09; Go/NoGo 0,91 µS, IQR 0,21 – 1,80 vs. 1,16 µS, IQR 0,50 – 1,93; zotavenie 0,80 µS, IQR 0,33 – 1,31 vs. 1,16 µS, IQR 0,50 – 1,65; poloha na chrbte 0,54 µS, IQR 0,26 – 0,87 vs. 0,84 µS, IQR 0,38 – 1,24).
Záver: Táto štúdia odhalila nedostatočnú sympatikovú cholinergnú aktivitu vyjadrenú prostredníctvom EDA u učiteľov. Zdá sa, že EDA by mohla predstavovať sľubný a objektívny neinvazívny nástroj na určovanie aktivity sympatického nervového systému, vhodný v preventívnom pracovnom lekárstve, ktorý vyhovuje meraniu stresu.

Kľúčové slová: Učitelia. Profesionálny stres. Elektrodermálna aktivita. Úroveň vodivosti pokožky

BACKGROUND

Teaching is a highly demanding occupation due to the presence of many specific stressors in the work environment. Teachers' mental health is affected by cumulative stressors on the micro and macro levels [1]. Time pressure, lack of chances for career development and recognition from parents, constant performance evaluations, and frequent conflicts were described as predictors of exhaustion, fatigue, and thus higher risk of burnout [2-4]. Also, many unfavourable characteristics are linked to teaching, such as a higher proportion of females, retired teachers, and fewer graduates who want to become teachers [5]. Some studies suggested that workplace stress measures are consistently associated with alterations in the autonomic nervous system (ANS) leading to adverse health outcomes [6, 7]. Teachers must cope with a range of challenges at work, which may induce chronic stress situations that alter physiological regulatory mechanisms. In this context, the psychophysiological stress profile could be beneficial for identifying and managing stress at work.

Electrodermal activity (EDA), a biosignal modulated by the changes in the skin conductance, represents an electrical manifestation of the sudomotor activity [8, 9]. More specifically, EDA reflects the sympathetic cholinergic innervation of the eccrine sweat glands controlling the sweat synthesis and excretion. Sweat produced by the glands' activation passes *via* sweat ducts to the upper skin layer that consequently becomes conductive, which allows the measurement of the skin's electrical conductivity between two electrodes placed on the fingers [10]. To summarise, human eccrine sweat glands are predominantly innervated from cholinergic sudomotor fibres purely linked to the sympathetic nervous system activity [11, 12]. Further, eccrine sweat glands are more responsive to psychological than thermal stimuli. In this context, EDA seems to increase linearly with perceived arousal [13]. Thus, EDA is considered as an important psychophysiological index reflecting not only quantitative measure of the sympathetic nervous system activity but also an objective arousal assessment [9, 14], perfectly fitting for stress measurement [15]. Tonic activity of EDA signal – skin conductance level (SCL) referring to overall conductance computed as the mean of slowly EDA varying over time period SCL reflects sympathetic nervous system activity [16, 17] and represents an appropriate parameter when stress is measured for a long time [12]. Importantly, specific stress cases such as occupational stress can be evaluated by ANS markers. However, studies regarding EDA as a marker specifically related to teaching-linked stress are rare.

The aim of present study was to evaluate electrodermal activity quantified by SCL as an index of sympathetic nervous activity in high-school teachers during long-term exposure of stress: in the beginning and at the end of the school year.

METHODS

Study population

The research included 60 study participants (Fig 1). The studied sample included healthy participants, aged 18 and older, following strict exclusion criteria for both groups: history of recent acute illness or chronic cardiovascular, respiratory, endocrine, neurological, metabolic, psychiatric, or infectious diseases; pregnancy; weight abnormalities (underweight/obesity); alcohol abuse; excessive caffeine consumption; and smoking. After considering the initial exclusion and inclusion criteria, 53 (29 teachers and 24 administrative workers) participants were involved (88.3 %). The whole group of teachers (experimental group) worked full-time in two types of public secondary schools (grammar school and business college). The experimental group of teachers (28 healthy participants) was subanalysed at different times during the school year. The sub-analysed group of 17 teachers (participated repeatedly) was selected in two categories: experimental subgroup I (the end of the school year – "stressed") and experimental subgroup II (the beginning of the school year – "relaxed").

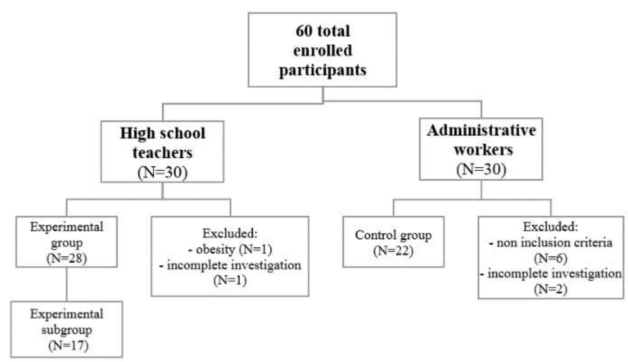

Figure 1 Study participation diagram

The control group consisted of 22 administrative workers from a other working area than the experimental group of teachers. Their common job tasks consisted of a variety of roles and responsibilities, such as managing and implementing office processes, dealing with finances including the organization and tracking of payments, receiving, and dealing promptly with incoming telephone calls, etc.

The study was approved by the Ethics Committee of Jessenius Faculty of Medicine in Martin, Comenius University, Bratislava (no. 54/2018). All participants were carefully instructed about the study protocol and provided written informed consent related to participation in the study before examination.

The protocol of examination

Demographic characteristics consisted of questions about age, years of experience (only in teachers), and items related to physical activity (frequency), sleep (quality and length), and eating habits (breakfast, numbers of meals per day). Examinations were performed in the psychophysiological laboratory (Biomedical Center, Jessenius Faculty of Medicine in Martin) under standard conditions (a quiet room, indoor temperature 22 °C, between 8:00 a.m. and 01:00 p.m.). The participants were asked to fill in the questionnaires before the examination. The anthropometric parameters were assessed by body composition analyser (InBody). Then, participants were instructed to sit comfortably and relax in a special armchair for 10 min. to avoid potential effects of a stressful environment (laboratory and examining person). The examination protocol consisted of five phases, and each lasted 5 min: basal phase, mental task (Go/NoGo test), rest period (all in the sitting position), supine position (in lying position), and active orthostasis (after posture change from lying to standing).

Physiological parameter

EDA was recorded using FlexComp Infinity Biofeedback (Thought Technology Ltd. Canada) with sampling frequency of 256 Hz, required by hardware [18]. The signal was monitored by two electrodes composed of 10-mm diameter Ag-AgCl placed on the middle phalanges of two fingers on the left hand (non-dominant). The SCL was assessed as a mean amplitude of tonic EDA distribution providing thus information about quantitative changes in the sympathetic cholinergic nervous system. The physiological values of SCL derive from the size of the sensor used (for 10 mm sensors, the range is from 0 to 30 micro-Siemens) [19]. EDA reactivity (%) for both tests (Go/NoGo and orthostasis) in response to mental and physiological stressors was calculated as [(value during Go/NoGo test or orthostasis) - (value during baseline phase or supine position)] / (value during baseline phase or supine position) x 100 (%).

Go/NoGo test

The Go/NoGo test was performed using BioGraph Infinity Software (Thought Technology Ltd. Canada) [18]. The participants were instructed to respond to the presentation of Go stimuli only (green circle) by pressing the button and not to respond to the NoGo stimuli (red letter X). Results were evaluated in terms of commission and omission errors as well as reaction time. The errors of omission are considered a reflection of inattention, while errors of commission reflect impulsivity [20, 21].

Orthostatic test

In psychophysiological research, an orthostatic test plays a role to evoke the orthostatic response associated with complex response of the ANS. During the orthostatic test, the ANS responds by an increase in sympathetic activity and decrease in vagal activity, resulting in tachycardic reaction [14, 22]. In contrast to mental stressors, neurocardiac reactivity induced by an orthostatic test is associated with autonomic regulatory subcortical centres (hypothalamus, brainstem) at the level of the peripheral organ, the heart [23]. Furthermore, psychological stressors are complex events that challenge the cardiac reactivity in multiple brain regions, including cortical (prefrontal cortex), subcortical (hypothalamus, brainstem) and peripheral adrenoreceptor function [23, 24].

Statistical analysis

Statistical analysis was performed using SPSS Software IBM version 18.0.0. The Kolmogorov-Smirnov test was used for evaluation of normality distribution. Parametric distributed data were expressed as mean and standard deviation. The chi square test was used for demographic data comparison. Non-parametric distributed data were expressed as median and interquartile range. Due to the non-normal distribution of the variables, the Mann–Whitney test was used for between-group comparison. The Wilcoxon test was used for comparison between periods (in the beginning and at the end of the school year). A value of p-value < 0.05 was considered statistically significant.

RESULTS

The sample size included 28 high-school teachers (experimental group) and 22 administrative workers (control group). The mean age of participants was 45.1 ± 7.9 (28 to 62 years old). The average number of years of experience was 18.6 ± 7.8 years. The mean age of the control group was 43.7 ± 7.4 (30 to 59 years old). The characteristics of the

Table 1 Sample characteristics

Parameters	Experimental group (n=28)	Control group (n=22)	p value
Age (years), means ± SD	46.2 ± 8.0	43.7 ± 7.4	0.278
Average sleep (hours), means ± SD	7.0 ± 1.3	6.8 ± 1.0	0.554
Sleep quality (morning fatigue), N (%)	5 (17.9)	8 (36.4)	0.139
Physical activity (frequency – every day), N (%)	18 (64.3)	19 (86.4)	0.077
Breakfast (yes), N (%)	11 (39.3)	17 (77.3)	0.007*
Numbers of meals per day (1-2), N (%)	13 (46.4)	14 (63.6)	0.226

Legend: *p < 0.05 (chi square test); SD = standard deviation

Table 2 EDA analysis – comparison the experimental (teachers) and the control (administrative workers) group

Parameter	Experimental group (n=28) median (IQR)	Control group (n=22) median (IQR)	p value
Baseline period: SCL (μS)	0.25 (0.06-0.52)	0.48 (0.21-0.83)	0.020*
Go/NoGo test: SCL (μS)	0.91 (0.25-1.70)	1.03 (0.44-1.91)	0.519
Rest period: SCL (μS)	0.57 (0.24-1.30)	0.65 (0.35-1.69)	0.439
Supine position: SCL (μS)	0.47 (0.24-0.99)	0.61 (0.29-1.42)	0.363
Active orthostasis: SCL (μS)	0.82 (0.27-1.64)	0.92 (0.51-2.16)	0.370
SCL reactivity			
Go/NoGo test: SCL (%)	288.47 (100.86-654.33)	97.45 (62.32-161.74)	0.020*
Orthostasis: SCL (%)	71.32 (14.46-126.17)	58.11 (36.03-92.51)	0.538

Legend: *p < 0.05 (Mann–Whitney U test); IQR = interquartile range; SCL = skin conductance level

Table 3 EDA analysis – comparison of teachers (experimental subgroup) in different periods of school year

Parameter	Experimental subgroup (N=17)		
	I. median (IQR)	II. median (IQR)	p value
Baseline period: SCL (μS)	0.43 (0.21 - 1.09)	0.29 (0.10 - 0.52)	0.028*
Go/NoGo test: SCL (μS)	1.16 (0.50 - 1.93)	0.91 (0.21 - 1.80)	0.041*
Rest period: SCL (μS)	1.16 (0.50 - 1.65)	0.80 (0.33 - 1.31)	0.041*
Supine position: SCL (μS)	0.84 (0.38 - 1.24)	0.54 (0.26 - 0.87)	0.009*
Active orthostasis: SCL (μS)	1.06 (0.61 - 2.02)	0.33 (0.33 - 1.77)	0.074
SCL reactivity			
Go/NoGo test: SCL (%)	60.87 (23.44 - 244.75)	310.94 (111.34 - 550.90)	0.002*
Orthostasis: SCL (%)	67.08 (27.49 - 85.73)	69.57 (28.56 - 127.22)	0.463

Legend: *p < 0.05 (Wilcoxon test); IQR = interquartile range; I. the beginning of the school year; II. the end of the school year; SCL = skin conductance level

experimental and control groups are summarised in Table 1.

SCL in the experimental group was significantly lower compared to the control group in the baseline period (p = 0.020). Reactivity of SCL was significantly higher in the experimental group compared to the control group during the mental test, Go/NoGo (p = 0.020). No significant differences in remaining phases of protocol were found between groups. All results are summarised in Table 2.

The experimental subgroup comparison revealed significantly lower values of SCL at the end of the school year during the baseline period (p = 0.028), Go/NoGo test (p = 0.041), rest period (p = 0.041), and supine position (p = 0.009). The reactivity of SCL was significantly higher during the Go/NoGo test at the end of the school year (p = 0.002). All results are summarised in the Table 3.

DISCUSSION

In this study, we evaluated the skin conductance level SCL (quantifying the EDA) as an index of sympathetic nervous system activity in teachers in response to long-term stress: the beginning ("relaxed") and at the end of the school year (after chronic work-related stress exposure). Firstly, our results revealed significantly lower baseline SCL in teachers compared to control group (administrative workers). It seems that baseline electrodermal hypoactivity in teachers could indicate discrete abnormalities in sympathetic activity detectable already in the beginning of the school year. Further, significantly reduced SCL in all phases of the protocol (except orthostasis) was found at the end of the school year in teachers, which may refer to long-term stress effects leading to insufficient sympathetic cholinergic activity indexed by EDA. Several mechanisms are suggested.

From this perspective, stress can be defined as a state of high general arousal characterised by the complex response to stress-inducing stimuli or situations. More specifically, processing and coping with stressors is regulated by the complex mechanisms integrating brain and body. The perception of the stressors is mediated by various brain structures and neural networks. The stressor identification consequently leads to the activation of two major axes of the stress system: sympathetic-adreno-medullar axis and the hypothalamus-pituitary-adrenal axis. This body–brain co-operation mediates physiological and behavioural responses enabling physiological adaptation and maintaining the body's homeostasis [25]. Physiological responses to stress (acute or long-term) can be quantified by the ANS activity-linked biosignals, such as heart rate, blood pressure, or EDA [26, 27].

EDA is considered as a non-invasive index widely used in psychophysiological research reflecting the activity only within the sympathetic branch of the ANS. More specifically, EDA evaluates resistance of the skin to a small electrical current depending on the activity of the sweat glands innervated by the sudomotor cholinergic nerves regulated by the sympathetic nervous system activity under central control [26]. In this context, ANS (sympathetic as well as parasympathetic) responses to external and internal environmental challenges are controlled and modulated by the central autonomic network (CAN) described by Benarroch [28]. Structurally, the CAN consists of the anterior cingulate, insular, ventromedial prefrontal cortices, central nucleus of the amygdala, paraventricular and related nuclei of the hypothalamus, periaqueductal grey matter, parabrachial nucleus, nucleus of the solitary tract, nucleus ambiguous, ventrolateral and ventromedial medulla, and medullary tegmental field [28]. In terms of EDA, central control is mediated by neural systems related to arousal (e.g., reticular formation), emotion (limbic structures), thermoregulation (hypothalamus), and locomotion (motor cortex and basal ganglia) [26].

Importantly, the Neurovisceral Integration Model [29-31] integrating cognitive, emotional, and autonomic functions into one functional system clearly explains how the perception of stress is processed by the brain and how physiological systems serve to provide adaptive and flexible regulation. In this context, the sympathetic nervous system represents one of the key components involved in the stress-related regulatory mechanisms and responses substantially involved in the regulation and maintenance of homeostasis through the changes of physiological functions affecting multiple organ systems, including the eccrine sweat glands' response indexed by EDA. As stress (acute and chronic) is according to the WHO a "21st century health epidemic", its effective management is widely discussed according to the prevention of stress-related disorders. While acute (short-term) stress can push an individual to better performance [32], frequent, repetitive, or long-term stress can result in health problems [33], and the regulatory mechanisms and physiological responses under long-term repetitive or excessive stress exposition (including work-related stress) may become maladaptive [34].

From this perspective, teachers must cope with a range of challenges according to their occupation that may represent a chronic stress situation altering physiological regulatory mechanisms (body homeostasis), resulting in potential negative health outcomes. Given this, our results of decreased EDA in teachers at the end of the school year may reflect chronic work-related stress associated with alterations in the complex central–peripheral sympathetic integrity. Interestingly, the SCL reactivity was significantly higher only in response to cognitive stresssor (Go/NoGo test). In contrast to orthostatic test, the cognitive stressors are complex events that challenge the autonomic reactivity in multiple brain regions including cortical (prefrontal cortex), subcortical (hypothalamus, brainstem) and peripheral adrenoreceptor function [23, 24]. In terms of neurovisceral integration model [30], we suggest potential stress-related abnormalities in prefrontal inhibitory function resulting in sympathetic hyper-reactivity in teachers. Thus, EDA derived from SCL can represent an important psychophysiological index for quantifying the prolonged work-related stress changes in the sympathetic activity as well as for the detection of abnormalities in sympathetic regulation [35].

Previous studies suggested to use EDA measurement as screening tool quantifying occupational stress in different occupational settings. To our best knowledge, there are no studies referring to EDA measurement in teachers [36]. Darvishi et al. [37] reported positive correlation between EDA response and occupational noise levels at work. Choi et al. [38] investigated relationship between construction worker's perceived risk and EDA changes. They reported significant differences during low and high – risk working tasks, which refers to short-term EDA indices change. Mourtakos et al. [36] investigated stress resilience using EDA in military special forces. Authors found significant decrease of EDA components in HN-SEALs group during cognitive testing procedure compared to control group. Cendales-Ayala et al. [39] did a simulation study in which it was shown significantly increased EDA in bus drivers. Also, the systematic review of associations between job stress and sympathetic and parasympathetic activity strongly support the researcher's base [40].

Limitations and strengths of the study

The limitation of the pilot study was relatively small sample size, so it is important to verify the results in a larger group. Another limitation is the choice of teachers, so we have very carefully extrapolated results to another professions. The last limitation was the non-assessment of other autonomic parameters, e.g. heart rate variability due to logistic purposes.

The strength of the study was the first use of evaluation of EDA activity in teachers in order to assess stress during the school year with this non-invasive diagnostic method. This will be a suitable test to assess the impact of long-term work-related stress in teachers.

CONCLUSIONS

This study revealed insufficient sympathetic cholinergic activity in teachers. It seems that EDA quantified by SCL could represent a promising and objective, non-invasive tool for the determining pure sympathetic nervous system activity suitable in the preventive occupational medicine that perfectly fits stress measurement. We assume that the assessment of the earliest and subclinical abnormalities in the sympathetic regulation indexed by EDA may be helpful in the personalised prevention of potential occupational stress-related health problems in teachers.

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