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Evaluation of psychological effects on human postural stability

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ABSTRACT

Human postural stability is commonly assessed by a set of posturographic tests during quiet upright standing. Numerous studies extend these tests with cognitive and mental tasks where various physiological and biomechanical sensors are used in combination with a force plate. The aim of our study was to determine whether psychological effects of sensor attachment and the awareness of the subject being measured could influence the posturographic tests performed using the force plate. An experiment was performed where complete data from 51 participants (13 women and 38 men) were obtained in four different conditions. Posturographic tests were performed either with eyes open or eyes closed, and either with biomedical instrumentation sensors attached or not attached. The results indicate that the presence of biomedical instrumentation sensors had a statistically significant impact on the centre of pressure path length and ellipse area as well as on the perceived difficulty of the task and its pleasantness. We conclude that the attachment of sensors on the body of the participants during biomechanical experiments significantly affects the perception of the experimental situation and alters the output of posturographic tests. It is therefore important to appropriately take into account the possible effects of psychological strain (such as the awareness of being measured) in the experimental design and in the interpretation of the results.

1. Introduction

1.1. Posture measurement

Balance is influenced by muscle performance, flexibility, vision and other sensory inflows, as well as cognitive and emotional factors. Since balance is a complex motor and cognitive function, each individual has to carefully coordinate information from the proprioceptive, visual and vestibular system with mobility initiatives. Many studies on standing and holding the balance have been performed by using a force plate. A force plate is a platform designed to measure the forces applied to its top surface as a subject stands, steps, or jumps on it. It is regularly used in studying balance, gait, and sports performance. These studies have mainly been used for medical purposes and to explore the maintaining of balance in different circumstances, at different mental loads and different tasks, etc. [1,2]. Studies often included implementation of a variety of cognitive tasks, e.g. calculation, tracking, video monitoring. It was determined that the centre of pressure (CoP) of some participants changed due to an additional cognitive task [3,4].

Besides measuring the CoP, individual studies also included monitoring of other physiological parameters (e.g. muscle activity, blood oxygenation, respiration and cardiovascular parameters) which were measured by means of various biomedical sensors. Sensors were usually positioned onto the participant's body in such a way as commonly found in a clinical environment [5–10]. These studies reported that in addition to physical and biochemical changes, attachment of biomedical instrumentation (BMI) might result also in changes of participant's physiology induced by psychological factors.

1.2. Psychological effects on posture

The impact of participant's awareness of being measured during research experiments is often ignored and not subject to systematic examination. A common example is in the process of non-invasive measurement of blood pressure where the process of measurement itself can also affect the blood pressure level of the monitored person. In the clinical field this phenomenon is well known, described and named the white coat hypertension or white

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coat effect [11]. White coat hypertension indicates the increase of individual's level of psychological arousal due to awareness of blood pressure measurement, which results in increased blood pressure level, similarly as other measurements in medicine depend on the psychological state of the measured participant, particularly when in a state of anxiety, e.g. variability of heart rate, electrocardiogram signal, autonomous nervous system parameters, etc. [12–14]. An expressed anxiety does appear in the majority of medical measurements, especially in those where the physician is present [11,12]. It is caused by the participant's awareness that she/he is being measured. Often the anxiety can influence the results of measurement or the measurement itself. In order to avoid the white coat effect in hypertension studies, a 24-h blood pressure measurement is used, which statistically limits or excludes the effect [15]. The effect of anxiety has been demonstrated also in biomechanical studies, e.g. where the measured participants under psychological stress or strain reacted with a change of physical stability strategy, i.e. with reduced movement amplitude of the CoP [16].

Anxiety is human physiological response that prepares the organism for struggling with future negative events and is a widely studied parameter [17–19]. Various forms of anxiety are stage fright, tension, nervousness, fear and concern. In the measurement situation, anxiety of the participant is caused by the act of measurement. It can be considered as a state of tension due to the performance of measurement and the participation in the monitoring process, i.e. a tension that emerges because the participant is being aware that she/he is being measured. As described above, such "measuring anxiety" could cause changes in measurement results and/or in the monitored physiological parameters.

Quiet upright standing is a dynamic biomechanical process where one maintains the centre of mass by continuously adjusting the position of body parts. Additionally, different sensors are commonly used in various studies on parameters of the centre of gravity [5,7,9,10]. We were interested whether attaching the sensors for measuring physiological functions can affect the posturographic parameters. Important psychological effects were reported in a study where the CoP excursions decreased during performance of simple cognitive task, assuming that focus of attention was diverted from the control of posture [2]. Further studies showed changes in dynamic responses during standing of elderly and neurological patients due to the attenuation of the underlying organs (vision, impaired basic stability, etc.) [20,21]. These research also indicated that in some cases periodic movements in muscles were increased with the increase of anxiety. Therefore, neural mechanisms responsible for the anxiety-associated-behaviour might significantly contribute to the pathophysiology of impairment of elderly. This was also evident for patients with disorders of central nervous system such as Parkinson's disease [22].

1.3. Aim of the study

Our main research question was whether we could deduce changes of CoP due to awareness of being measured. The purpose of this study was to determine whether we can use a common force plate to detect any additional changes in CoP when the measured participant is being aware of the measurement. Biomedical instrumentation (BMI) sensors for measuring physiological parameters were used as a source of strain (stressor). BMI sensors, which were attached onto the participant during force plate measurement, were thus representing only an additional source of error in postural balance. Measurements of CoP parameters were performed during two legs quiet upright standing with various combinations of open and closed eyes scenarios, and with and without the use of BMI sensors.

2. Methods

2.1. Participants

The measurements were performed on 54 healthy volunteers. From 54 participants three measurement sets were eliminated due to measurement errors and the remaining data of 51 participants was considered for data analysis; 13 women (age: 27.9 years ± 7.2 years (std), height: 1.67 m ± 0.04 m (std), weight: 61.2 kg ± 6.7 kg (std)) and 38 men (age: 28.4 years ± 6.4 years (std), height: 1.82 m ± 0.05 m (std), weight: 85.9 kg ± 14.2 kg (std)). Prior to data collection, each participant was provided a clear description of what was required for participation and was asked to carefully read and sign the consent form. Participants were given the right to withdraw from the study at any stage. The measuring protocol was approved by the National Medical Ethics Committee.

2.2. Experimental design

A set-up was designed and built for measuring the participants' centre of pressure (CoP), physiological parameters, and psychological parameters, i.e. subjective evaluations of experimental conditions. CoP measurements were performed by means of a force plate Leonardo Mechanograph® GRFP (Leonardo, Novotec Medical, Pforzheim, Germany) using its software application for stability and balance parameters estimation (Leonardo Mechanography RES, Novotec Medical, Pforzheim, Germany). Experiments were performed using common shoulder width two legs standing. Participants were performing a test in a quiet basic furnished room. They were required to assume a normal upright standing position on the elevated floor with the force plate, faced toward a wall 3 m in front of them and look at a point placed at eye level on the wall.

BMI was used as the psychological stimulus for inducing the psychological stress. For physiological measurements, i.e. measurements of the activity of the autonomous nervous system of the participant, the modular psychophysiological data acquisition (DAQ) device MP150 (Biopac Systems Inc., USA) was used. The Biopac measuring system was composed of the main DAQ module and amplifier modules for skin temperature, skin conductance, respiration and ECG heart rate measurements. Biopac wired sensors were selected because of their low weight for negligible disturbing effect on biomechanics of the participant.

Physiological parameters during the experiment were obtained from physiological signals of skin conductance (average skin conductance level and short-term temporal changes in skin conductance, i.e. SCR – skin conductance response [23]), skin temperature (average temperature of the skin), respiration (mean respiratory rate) and heart rate from the electrocardiogram. Skin temperature was measured at the tip of the ring finger on right hand. Wet electrodes with conductance gel for skin conductance measurements were placed on the forefinger and middle finger of the right hand. Breathing monitoring belt was placed around the chest of the participant on the lower edge of sternum. ECG electrodes were attached on wrists of both arms and on the inside ankle of the right leg (Fig. 1). These psychophysiological parameters were acquired and processed using Acqknowledge 4.2 software package (Biopac Systems Inc., USA).

Participants stood on both legs in four basic experimental conditions, a combination of (i) eyes open (EO) or eyes closed (EC) and (ii) presence of biomedical sensors (BMI+) or absence of sensors (BMI−). In two experimental conditions (BMI+ with EO and BMI+ with EC), participants were subjected to psychological stress during the CoP measurements, induced by the notion/awareness that their physiological functions are being measured with BMI. For the