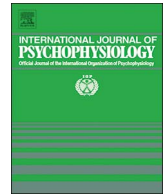




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Training of support afferentation in postmenopausal women

O.M. Bazanova^{a,b,*}, N.V. Kholodina^a, E.D. Nikolenko^a, J. Payet^c^a Research Institute of Physiology and Basic Medicine, Timakova, 4, Novosibirsk 630117, Russia^b Novosibirsk State University, Russian Federation^c Kyoto Aikido Mugenjuku, Kyoto, Japan

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ABSTRACT

We have recently shown a diminishing of the Menopause Index in old-aged women who underwent special training directed at the enhancement of support afferentation by increasing the plantar forefoot sensitivity (Bazanova et al., 2015). Based on these results we hypothesized, that purposeful training of support afferentation through stimulation of plantar graviceptors by Aikido practice will decrease excessive postural and psychoemotional tension not only in rest condition, but during cognitive and manual task performance too. Fluency of cognitive and motor task performance, EEG alpha power as an index of neuronal efficiency of cognitive control, amount of alpha power suppression as a visual activation measure and EMG power of forehead muscles as a sign of psychoemotional tension were compared in three groups of post-menopausal women: i) 8 years training with forefeet support afferentation with Aikido practice (A), ii) 8 years fitness training (F) and iii) no dedicated fitness training for past 8 years (N). Simultaneous stabilometry, EEG, and frontal EMG recording were performed in sitting and standing up position in eyes closed and eyes open condition. Recording done at rest and while performing cognitive and finger motor tasks. We compared studied parameters between groups with one- and two-way analyses of variance (ANOVAs) with Bonferroni correction for multiple comparisons, followed by post hoc two-tailed unpaired *t*-tests.

The fluency of tasks performance, EMG and alpha-EEG-activity displayed similar values in all groups in a sitting position. Center of pressure (CoP) sway length, velocity and energy demands for saving balance increased when standing up, more in group N than in groups F and A (all contrasts *p* values < 0.002, $\eta^2 > 0.89$). Post hoc *t*-tests showed increased fluency in standing in both Aikido (*p* < 0.01) and Fitness (*p* < 0.05) subjects in relation to untrained subjects. Increasing fluency in motor task performance was in parallel with enhancing the EEG alpha-2-power and decreasing EMG power only in A group ($\eta^2 > 0.77$). Fluency in motor task and alpha EEG power decreased, but frontal EMG power increased in response to standing in untrained women (group N) and did not change in F group. Post hoc *t*-tests showed that EEG amount of alpha-2 power suppression in response to visual activation and frontal EMG power was lower in A than F and N groups (*p* < 0.004) during motor task performance in the standing position. These results were interpreted as showing that training of forefoot plantar surface sensitivity in postmenopausal women decreases levels of psychoemotional tension and increases cognitive control caused by the psychomotor and postural challenges. Thus, Aikido training aimed at learning coordination between manual task performance and balance control by increasing the plantar support zones sensation decreases the cost of maintained vertical position and dependence of motor coordination on visual contribution.

1. Introduction

1.1. Why aging is a risk factor for falling

Decreasing physical activity and sedentary lifestyle, common in aging people, leads to a generalized slowing and weakening of muscle contractile properties (Doherty et al., 1993; Miller et al., 2013); to

impairment of visual, vestibular and proprioceptive sensitivity (for a review, see Berthoz and Güell, 1998; Nagamatsu et al., 2013); to reducing functional neuronal connectivity (Huang et al., 2015). This could influence the fine motor performance and postural control (Marneveck et al., 2011; Heise et al., 2013). Specific interest here is in the decrease in plantar sole sensitivity (Schlee et al., 2009) that could result in reductions in fine motor skill with older age (Mickle et al.,

* Corresponding author at: Department of Experimental and Clinical Neuroscience, Lab. of Affective, Cognitive and Translational Neuroscience, Federal State Budgetary Scientific Institution "Scientific Research Institute of Physiology and Basic Medicine", Novosibirsk State University, Timakova str., 4, 630117 Novosibirsk, Russian Federation.

E-mail address: bazanovaom@physiol.ru (O.M. Bazanova).

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2011). Leandri et al. (2015) demonstrated the association between decreasing balance and sensorimotor control in postmenopausal women (Leandri et al., 2015).

1.2. Role of support afferentation in the postural control and fine motor task performance

There is evidence that physical exercise can prevent falls in older community dwellers (Lord, 2007; Sherrington et al., 2011), as well as improve cognitive performance (for a review see Etnier et al., 2006; Park and Reuter-Lorenz, 2009). However, Kanegusuku and coauthors showed that training focusing only on strength and power in the elderly does not prevent falling/frailty and does not improve quality of life (Kanegusuku et al., 2011). Balance trainings such as motor-demanding exercises (cf. Voelcker-Rehage and Niemann, 2013) and partnered dance (Merom et al., 2013; Hackney et al., 2013) are known as the most effective in prevention of falls in the elderly (see for review Hrysonmallis, 2013; Melzer et al., 2010). Among others types of balance trainings, the martial art Yoshinkan Aikido places particular emphasis on performing manual tasks in a special stance (Shioda, 2002). Aikido's distinctive stance or 'kamae' (lit. "Stance" in Japanese), stresses the position of feet and hips in order to control sensation of pressure on the plantar support areas such as toe and forefoot that are enriched by pressure receptors (Roy, 1988; Saotome, 1989; Orlin and McPoil, 2000; Mickle et al., 2011). Practitioners of Aikido strive to perfect their "kamae" so that their overall manual techniques performance will be strengthened (Shioda, 2002). We have recently shown an alleviation of postmenopausal symptoms such as hot flashes, feeling dizzy or faint, night sweats, rapid heartbeat, and difficulty sleeping indexed with Greene Climateric Scale (Greene, 1976) in old-aged women who underwent special training directed to enhancement of support afferentation by using Yoshinkan Aikido practice (Bazanova et al., 2015). This paper is directed towards the answering question whether training of support afferentation could increase the efficiency of cognitive and motor tasks performance in older women?

Both postural control and manual task performance imply a complex neuronal mechanism based on unconditioned and conditioned reflexes, as well as on the actual cognitive processes. Because EEG alpha rhythm has a functional role in the regulation network properties of the vestibular, sensorimotor and visual areas (e.g., in gain regulation, Lopes da Silva et al., 1974), either cognitive processings (Klimesch et al., 2007; Bazanova and Vernon, 2014) training of support afferentation can be expected to modify alpha activity EEG, that is a key index of sensorimotor coordination (Lopes da Silva et al., 1974; Hughes et al., 2011; Bazanova and Vernon, 2014).

1.3. Alpha EEG activity in postural and motor task performance control

Over the last decade a prevailing theory has emerged that alpha oscillations as an important top-down mechanism of neuronal inhibition (see Pfurtscheller and Lopes da Silva, 1999; Klimesch et al., 2007; Klimesch, 2012) and thus may play a prominent role in the balance control and manual task performance. However only few studies investigated the relationship between support afferentation and the brain alpha-activity under daily-life condition such as i) changing pressure on the plantar surface in sitting – standing conditions (Zhavoronkova et al., 2012), ii) transferring center of pressure while body sway (Babiloni et al., 2008; Tse et al., 2013), and iii) during walking (Cheron et al., 2014; Cevallos et al., 2015). Meanwhile, results from mentioned studies are contradictory. According to some authors, an increase of support afferentation by standing and straitening the leg is associated with an increase in power in the upper alpha-2 band and a decrease in the coherence of the low frequency alpha-waves (8–10 Hz) (Cheron et al., 2014; Cevallos et al., 2015). Other researchers demonstrate that an increase of weight load pressure on foot support zones does not change (Babiloni et al., 2008) or may even decreases the

spectral power of alpha-wave (Tse et al., 2013; Zhavoronkova et al., 2012). A possible cause of these contrasting results is the use of different methodological approaches to EEG alpha-wave activity assessment: First, this is often used in non-individualized analysis of alpha-activity (Vaitl et al., 1996, Zhavoronkova et al., 2012; Tse et al., 2013; Maruši et al., 2014, Schneider et al., 2014). Second, measuring only amplitude/power does not address the Berger effect - alpha amplitude suppression in response to activation (for example to eyes open), as a neurophysiological measure of visual contributed activation (Barry et al., 2007; Babiloni et al., 2014; Kayser et al., 2014; Klimesch, 1997, 2012). Third, it is known that EMG contaminations in the low frequency (Halliday et al., 1998) may lead to misinterpretation of the results of the alpha EEG measurements (see for review Malmo and Malmo, 2000; Bazanova and Vernon, 2014).

Moreover, scalp EMG measurement itself could reflect the muscle activity involved in psychoemotional tension or mental stress (Cacioppo et al., 1988; Malmo and Malmo, 2000; Wijsman, et al., 2012) and characterize activation of redundant muscles not participating in saving of balance. Meanwhile EMG activity is in reciprocal relation with EEG alpha power in upper frequency range (Bazanova and Vernon, 2014). The increasing of the EEG upper alpha-amplitude may be interpreted as reflecting global inhibition of redundant cortical activation while the decreasing of the forehead EMG may be associated with excessive psychoemotional tension.

An improved characterization of alpha activity via measurements of EEG amplitude/power in individual alpha frequency ranges and magnitude of alpha suppression in response to eyes open, recorded simultaneously with stabilometry and EMG will potentially help more accurately pinpoint any alpha activity changes associated with postural perturbations and cognitive and fine motor tasks performance.

1.4. Hypotheses

Based on these we hypothesized, that purposeful training of support afferentation through stimulation of plantar graviceptors by Aikido practice will decrease excessive energy demands on balance saving, extra postural and visual activation and psychoemotional tension. It could be reflected in decrease of stabilometric characteristics of center of pressure (CoP) excursions, particular, kinetic energy (E) expended for balance maintains and electromyographic measures of redundant muscles activity and psychoemotional tension. To uncover the support afferentation influence on the cortical processing of postural and cognitive control alpha EEG markers of efficiency of sensorimotor integration in women trained and untrained of plantar forefoot support area sensitivity should be compared. Because alpha rhythm has a functional role in the regulation of network properties of the vestibular, sensorimotor and visual areas, training of support afferentation can be expected to modify the alpha EEG characteristics that will indicate the strength of this regulation in order to preserve the functionality of the network in a changing body positions. It could be reflected by EEG alpha power increasing and visual stimulated amount of alpha suppression decreasing. We propose that training the plantar graviocceptional sensitivity increases balance stability and decreases the role of visual activation in balance maintenance and psychomotor task performance too.

As a consequence, we suggest that support afferentation training will increase the efficiency of cognitive and manual task performance in standing posture in postmenopausal women. The main question of this study is whether Aikido, more than any cardio/strength exercise is beneficial to balance control and cognitive task performance in standing upright?

Thus, to demonstrate the effects that Aikido had over exercise alone, rather than over sedentary the aim of this study is to evaluate the impact of special support afferentation and ordinary physical exercises training in comparison with untrained control on the psychometric, stabilometric, EEG, and EMG indices of cognitive and fine motor tasks performance efficiency in a sitting and a standing position in old-aged women.

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