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Relationship Between Skin Resistance Levels and One Leg Standing Balance in Healthy Subjects

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The aim of this study was to investigate relationship between Skin Resistance Level (SRL) and one leg standing balance in healthy subjects. Sixty eight voluntary students from the University of Dumlupinar Physical Therapy and Rehabilitation school were participated to the study. One leg standing balance tests were measured on dominant and non-dominant leg in three positions; eyes open (60 sec), eyes closed (30 sec) and eyes open with head rotation (30 sec) with arms held comfortably at the side. SRLs were recorded with two surface electrodes by the Digital Multimeter (DT-9923B) tool during standing on one leg. Carbon electrodes were placed over the 5 metatarsus heads and heel with conductive gel. No statistically differences were between male and female groups in static and dynamic one leg standing test results ($p>0.05$). The final SRL values were statistically higher in non-dominant leg than dominant in both male and female subjects ($p<0.05$). The dynamic tests on dominant and non-dominant leg with eyes closed results were found statistically lower in subject's foot base SRL higher than 100 kΩ than subject's foot base lower than 100 kΩ ($p<0.05$). We concluded that the SRL is inversely proportion with dynamic balance and the non-dominant foot plantar SRL is higher than dominant foot. Subjects who have higher than 100 kΩ foot plantar SRL have lower one leg standing dynamic balance with eyes closed. Further studied should be investigated the relationships of the SRL and one leg standing balance in age decades and different pathologies.

Key words: Balance, proprioception, skin resistance

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INTRODUCTION

The inhibitory component of the skin against given electrical current, is called as the electrical skin resistance (Cho and Chun, 1994). Skin Resistance Level (SRL) is related with skin conductance, which changes in the presence of sweat, a fluid composed of water and ions. It is determined by passing a weak current through the measuring changes in electricity flow or by measuring the current generated by the body itself. It has been correlated with emotion, attention and stress. Correlations between SRL and attitude, empathy and social interactions, especially when associated with small group interactions, (Clariana, 1992). Liao *et al.* (1998) studied skin resistance respond, SRL and skin blood flow decrease and that perspiration increases transiently at the deh-chi stage (described as a kind of soreness, numbness, or heavy swelling in deep tissues during manual acupuncture). Kyle *et al.* (2004)evaluated differences in body mass index, Body Fat Mass Index (BFMI) and Fat-free Mass Index (FFMI) in physically active and sedentary subjects younger and older than 60 years and determined the association between physical activity, age and body composition parameters in a healthy white population between ages 18 and 98 years. A clear association was found between low physical activity or age and height-normalized body composition parameters (BFMI and FFMI) derived from bioelectrical impedance analysis (Clariana, 1992). Vernet-Maury *et al.* (1995) show that the Ohmic Perturbation Duration (OPD), skin resistance respond durations, could be an appropriate measure of Electrodermal Response (EDA) allowing any stimulus to be temporarily quantified towards sympathetic activation induced response. Generally skin resistance level evaluated on the hand fingers in these studies.

Direct current measurements do not provide information about the capacitative properties of the tissue that is discussed in almost any electrical model of the skin. Such an electrical model is shown in Fig. 1. The capacitor C represents the insulating layers of the stratum corneum, and the parallel resistor R1 corresponds to the current path through the sweat gland ducts. R2 represents the resistance of the deeper skin layers and is relatively small (Schaefer and Boucsein, 2000)

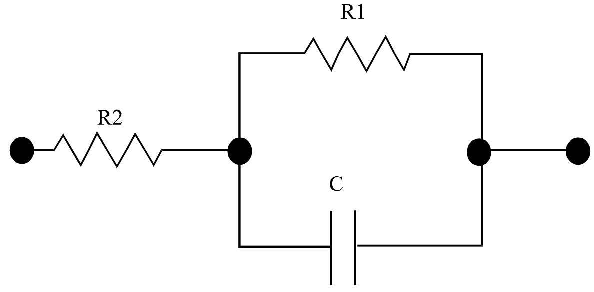

Fig. 1: Simplified electrical model of the skin

Skins of foot plantar area has many mechanoreceptors (Pacinian, Meissner, Merkel and Ruffini) are sensitive to joint pressure and tension. In addition, blood vessels, sweat gland activity and interstitial fluid are generated normal physiological conditions for foot. In literature studies especially about diabetic patients show that the foot plantar fascia stiffened (Gefen, 2003) impaired the skin blood flow (Vinik *et al.*, 2001) and sensation (Resnick *et al.*, 2002) or absence in sweating (Boulton *et al.*, 1983) are affected the standing balance and becomes important for risk of falling. No more studies have been evaluating the relationships of the skin resistance level and standing balance in healthy subjects and patients. The aim of this study was to evaluate relationship between skin resistance levels and one leg standing balance in healthy subjects.

MATERIALS AND METHODS

Sixty eight voluntary students from the University of Dumlupinar Physical Therapy and Rehabilitation School were participated to the study during the fall semester of the 2004-2005 education years in Kutahya-Turkey. The exclusion criteria; age over 30, plantar ulcers at the moment of the evaluation, vision or hearing impairment, peripheral vascular disease, vestibulopathy history, or any neurological, muscular or rheumatic disease, history of abusive alcohol intake, partial or total amputation. The study had local research and ethics committee approval and all the subjects given written consents.

One leg standing tests were measured on dominant and non-dominant leg in three position; eyes open (60 sec), eyes closed (30 sec) and eyes open with head rotation (30 sec) with arms held comfortably at the side. Subjects were tested on level tile flooring with athletic-type rubber-soled shoes. Subjects were allowed one practice trial for each of the balance tests. In standing on one leg test, stable platform for static balance and trampoline for dynamic balance were used. The position of the non-weight bearing leg was chosen by the subject. Test was accepted failure

Fig. 2: Skin resistance levels were recorded by the Digital Multimeer (DT-9923B) tool during standing on one leg

when the stance foot shifted in any way or the nonstance foot touched the ground. Each subject performed three trials and the best result of the three trials was recorded (Huroyuki *et al*., 2003; Ozdirenc *et al*., 2003)

Measurement of plantar foot skin resistance level (SRL): SRLs were recorded with two surface electrodes by the Digital Multimeter (DT-9923B) tool during standing on one leg (Fig. 2). Carbon electrodes were placed over the 5 metatarsus heads and heel with conductive gel. First recorded the initial levels and after fixing the skin resistance values were recorded the finals levels.

Statistical analysis: SPSS 10.0 for Windows statistical program was used for all statistical analyses. Results were presented as mean±SD. Statistical evaluation of the data was performed with independent t test for comparison between the two groups, (dominant versus non-dominant). Findings with an error probability value of less than 0.05 were considered as statistically significant.

RESULTS

No statistically differences were found between gender's age, dominant and non-dominant leg SRL ($p>0.05$). Male subjects were found statistically heavier and taller than female subjects ($p<0.01$) (Table 1). Right leg is dominant in most of the subjects in both groups.

No statistically differences were found between male and female groups in static and dynamic one leg standing test results ($p>0.05$). Static test results were better than dynamic tests in both genders. The subjects performed better with the eyes open than with eyes closed. One leg standing balance results are shown in Table 2.

Table 1: Demographic data of subjects

	Male (n = 32)	Female (n = 36)
Age (year)	20.4±1.5 (18-23)	20.1±1.3 (18-24)
Height (m)	1.77±0.1 (1.7-1.9)*	1.65±0.04 (1.54-1.73)
Weight (kg)	69.3±7.9 (50-87)*	59.4±9.3 (47-85)
SRL (kΩ)		
Dominant leg	63.9±19.8 (35.1-113.2)	69.6±21.6 (39.3-147.9)
Non dominant leg	72.9±26.4 (374-170.0)	82.2±32.1 (40.7-189.8)

*p<0.001, SRL: Skin Resistance Level, Data are listed means±SD (min – max)

Table 2: Comparison of one-leg standing test *

	Group	Independent sample t-test
	Male (n = 32)	Female (n = 36)
Static		
Dominant leg		
EO	56.4±8.4	56.3±10.3
EC	21.1±10.4	22.8±9.0
With head rotation	21.9±9.3	22.6±8.3
Non dominant leg		
EO	57.8±7.9	56.2±10.5
EC	20.1±10.6	21.3±9.6
With head rotation	21.9±9.6	19.8±9.6
Dynamic		
Dominant leg		
EO	53.0±13.2	49.6±18.0
EC	10.2±8.6	7.1±4.9
With head rotation	14.2±9.1	11.2±8.6
Non dominant leg		
EO	53.5±11.2	48.8±17.9
EC	7.9±6.9	5.9±3.7
With head rotation	12.2±8.4	9.9±7.9

* p>0.05 (No statistically differences were found between male and female subjects) EO: Eyes Open EC: Eyes Closed, Data is listed Means±SD

Table 3: Comparison of SRL in subjects

	Male (n = 32)		Female (n = 36)	
SRL (kΩ)	Dominant	Non dominant	Dominant	Non dominant
Initial	48.1±12.9	55.1±13.2*	51.7±10.4	60.3±11.7**
Final	63.9±19.8	72.9±26.4	69.6±21.6	82.2±32.1*

* p<0.05 (Non dominant foot base SRL statistically higher then dominant foot base SRL) ** p<0.001 (Non dominant foot initial foot base SRL statistically higher than dominant foot in female subjects), Data are listed means±SD, SRL: Skin Resistance Level

The initial SRL values were observed statistically higher in non-dominant foot than dominant foot in female subjects ($p<0.01$), but no statistically differences were found in male subject's initial SRL values between foots. The final SRL values were statistically higher in non-dominant foot than dominant foot in both male and female subjects ($p<0.05$) (Table 3).

No statistically differences were found in static balance results between subject's plantar foot SRL higher than 100 kΩ and lower 100 kΩ ($p>0.05$). When compared the subjects had higher and lower 100 kΩ plantar SRL, the dynamic tests on dominant and non-dominat leg with eyes closed results were found statistically lower in subject's

Table 4: Comparing balance results depending SRL in subjects

	Group(Independent sample t-test)	
	SRL higher than 100 kΩ (n =13)	SRL lower than 100 kΩ (n = 55)
Static		
Dominant leg		
EO	56.2±10.6	56.4±9.1
EC	21.1±10.4	22.2±9.5
With head rotation	21.2±9.8	22.5±8.5
Non dominant leg		
EO	58.3±4.4	56.6±10.2
EC	19.9±11.7	20.6±9.7
With head rotation	21.5±9.6	20.6±9.7
Dynamic		
Dominant leg		
EO	53.3±14.0	50.7±16.4
EC*	4.6±2.0	9.5±7.5
With head rotation	14.1±10.9	12.3±8.4
Non dominant leg		
EO	50.9±12.9	51.0±15.8
EC*	4.4±1.2	8.4±5.9
With head rotation	13.5±10.1	10.4±7.6

*$p<0.05$, EO: Eyes Open, EC: Eyes Closed, Data are listed means±SD, SRL: Skin Resistance Level

plantar foot SRL higher than 100 kΩ ($p<0.05$) (Table 4). No statistically differences were found in balance results under 100 kΩ groups (0 – 49 kΩ, 50 – 74 kΩ, 75- 100 kΩ) ($p>0.05$).

DISCUSSION

Human beings keep their balance when nerve signals from three different systems are accurately sent to and processed by the brain. The three different systems are the eyes (vision), pressure sensors in the legs and torso (proprioception) and inner ear balance organs (vestibular system). Humans seem to rely primarily on signals from the pressure sensors in the legs and torso (proprioceptors) to maintain good balance. The cerebrum selects the most accurate signals from the three balance systems and sends messages back to the muscles of the limbs, torso and neck to keep us stable and to keep our view of the world upright. The more signals the brain receives and sends, the better the balance (Bernier and Perin, 1998; Huroyuki *et al.*, 2003; Resnick *et al.*, 2002; Vander-maury *et al.*, 1994; Vinik *et al.*, 2001)

Skin receptors, usually with little or no myelin, have free nerve terminals not related to any apparent receptor structures. These terminals are sensitive to stimuli that give rise to pain and temperature. Thicker, myelinated axons, on the other hand, end in receptors that can be quite complex, for example, Pacinian corpuscle, Meissner's and Merkel's corpuscles and corpuscle of Ruffini. These are all mechanoreceptors (Vander-maury *et al.*, 1994). Mechanoreceptors are sensitive to joint pressure and tension caused by dynamic movement and static position (Bernier and Perin, 1998). This disturbance of the afferent input from mechanoreceptors would affect not only a sense of movement and position but also the subsequent proprioceptive reflex to control posture and coordination (Bernier and Perin, 1998; Feuerbach *et al.*, 1994).

Plantar area is the first to touch the floor during standing and plays an extremely important role in supplying the nervous system with pressure and proprioception information. The motor system will generate motor responses according to the mechanical load received by the foot in order to attenuate the load (Gutierrez *et al.*, 2001; Richardson, 2002). Loss of pressure sensitivity, a measure of peripheral neuropathy, accounted for 3-6% of the association between diabetes and risk of falling (Gutierrez *et al.*, 2001; Richardson, 2002).

A direct correlation was found between the skin sympathetic firing rate in the innervating nerves and the increased sweat response located in the sweat glands in the palms of the hands and soles of the feet (Lindbeg and Wallin, 1981; Macefield and Wallin, 1996). Foot plantar fascia skin resistance is normally recorded by the use of direct current. Skin resistance is related with dermal ion concentrations and sweet gland activity. Thus skin resistance is inversely proportion to ion (Tranel and Damasio, 2000). Skin with high blood vessels, sweet gland activity and interstitial fluid in the normal physiological conditions, mechanoreceptors can be adequate normal proprioceptive and sensory inputs from the plantar fascia of the foot. In this situation, the balance regulation from the foot may also relate with SRL. In our study the non-dominant plantar foot SRL was found higher than dominant side. However, dominant and non-dominat one leg standing balance test results were observed similar in both genders. Because of our subjects constituted from the healthy young groups, we did not find statistically significance between legs. In standing position and in daily living activities dominant leg may used more than non-dominant leg. Thus, gland activity, blood vessels and electrolyte concentration may be higher in dominant leg. On the other hand static balance results were better than dynamic in both genders. Because dynamic balance measurements were doing on trampoline device, these results are normal and expected.

In addition dynamic balance with eyes closed was decreased only in subject's SRL had higher than 100 kΩ. During dynamic one leg standing with eyes closed balance is adequate by proprioceptive sense especially coming from plantar foot fascia. In healthy subjects have plantar foot SRL higher than 100 kΩ proprioceptive balance is decreased in dominant leg 51.6 % and on non-dominant leg 47.6%. No differences were found in age, height and weight between groups SRL higher and lower than 100 kΩ. The number of female subject were higher than male but not significant (F: 8, M: 5). In subjects with higher SRL peripheral sympathetic nervous system may affect the balance. Gladman (2003) claimed that SRLs increase is dependent on the innervating sympathetic nervous system and on the properties of the sweat glands and the skin itself (Tranel and Damasio, 2000). Caldana and Ortolani (1976). loss of sweat secretion can be demonstrated by electrical skin resistance tests in the newborn. This method of investigating sympathetic nerve function has been used to clarify the location of the neurological damage and therefore it is of some value for the prognosis in obstetrical paralysis of the newborn (Caldana and Ortolani, 1976). Lundin *et al.* (1989) reported that sympathetic blockade was accompanied by increase in foot skin blood flow as well as loss of skin resistance responses to arousal method. These results indicate that the peripheral sympathetic nervous system may be a contributing factor in subjects with higher SRL and had bad balance.

Diabetes mellitus (type 2) is major cause pathological changes in plantar soft tissue, which stiffen its structure and diminish its ability to effectively distribute foot-ground contact loads (Vinik *et al.*, 2001). Macleod *et al.* (1991) investigated that the small unmyelinated fibres, responsible for pain and temperature sense and autonomic function, are involved early, particularly in subjects with painful symptoms and may be important in foot ulceration. The sympathetic skin response has been used to investigate the function of small unmyelinated sympathetic fibres in the limbs of diabetic subjects. Changes in skin resistance at the fingers and toes have been measured simultaneously after a sound stimulus (Anderson, 1998).

Measurement of SRLs in plantar foot fascia is clinically very important as diabetes mellitus, geriatric populations, impaired sympathetic systems and neurological diseases. SRL measurement is easy, non-invasive technic and gives reliable results in non-symptomatic healthy subjects. Further studies should be investigated the SRL in age decades, diabetic and neuropathic patients.

In conclusion, results confirmed the measurement of SRL in foot gives clinically important results for evaluation of standing balance.

Following results were found from the present study:

- SRL is inversely proportion with dynamic balance.
- The non-dominant foot plantar SRL is higher than dominant foot.
- Subjects who have higher than 100 kΩ foot plantar SRL have lower one leg standing dynamic balance with eyes closed..
- Further studied should be investigated the relationships of the SRL and one leg standing balance in age decades and different pathologies.

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