

EFFECT OF POSTURAL CHANGES ON LEG MUSCLE TONE AND ARTERIAL BLOOD PRESSURE IN ABLE-BODIED PEOPLE AND PEOPLE AFTER CHRONIC SPINAL CORD INJURY

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ABSTRACT

Research background and hypothesis. Following spinal cord injury part of sympathetic nervous system is disrupted from the brain stem control, which results in cardiovascular system regulation disorders. Impaired cardiovascular regulation may cause orthostatic hypotension or other negative impacts on persons' health. However, there are adaptive mechanisms which may change cardiovascular regulation and compensate these cardiovascular disorders. One of the mechanisms that may affect the occurrence of orthostatic hypotension may be changes in muscle tone after spinal cord injury.

The aim of research was to ascertain the effect of muscle tone changes on blood pressure in persons with spinal cord injury through ortho-clinostatic test.

Research methods. During passive ortho-clinostatic test, non-invasive blood pressure was continuously measured using the vital signs tracking monitor and leg muscle tone measurement was performed using myotonometer.

Research results. In control group muscle tone is characterized as constant wave – it decreases in orthostasis and increases in clinostasis. In paraplegic group muscle tone changes are as similar to those in controls, except that dynamics is not so constant and numeric values are lower. In tetraplegics we can see that muscle tone changes rapidly and tone in thigh muscles has a tendency to decrease through all the test.

Discussion and conclusions:

1. Leg muscle tone changes are important for blood pressure compensating mechanisms when the body position changes: it increases during orthostasis and decreases during clinostasis.

2. Blood pressure varies differently among able-bodied persons and persons with spinal cord injury. The degree of the breach has a significant impact on the occurrence of compensatory peripheral regulation mechanisms. Characteristics of blood pressure fluctuations during body position changes in paraplegics are similar to those of reactions as in the able-bodied controls, while in tetraplegia case, possibilities of homeostatic blood pressure compensation during body posture changes are significantly reduced.

Keywords: blood pressure, muscle tone, paraplegia, tetraplegia.

INTRODUCTION

Following spinal cord injury innervation of muscle and organ below lesion level is disrupted. Regulatory mechanisms of the cardiovascular system (CVS) are disturbed, too. If these mechanisms do not recover fully during acute rehabilitation, problems of the cardiovascular system may persist for life. As a result, persons

with chronic spinal cord injury (CSCI) may have orthostatic hypotension or other sudden, life-threatening health problems as increased heart rate, blood pressure variability, and episodic hypertension and so on. It was also found that among people with spinal cord injuries, due to the relatively passive lifestyle, obesity, diabetes and

other health conditions, morbidity and mortality due to diseases of cardiovascular system are very high.

However, there are various adaptive mechanisms which may change cardiovascular regulation and compensate these cardiovascular disorders (Claydon et al., 2006).

Orthostatic hypotension is a condition when systolic blood pressure decreases by at least 20 mmHg, diastolic – at least 10 mmHg in standing position (Pauza et al., 2002). This condition is characterized by headache, dizziness, fainting and so on.

Research literature includes a number of studies dealing with orthostatic hypotension of individuals with SCI, but the results are rather contradictory. S. Houtman et al. (2000) showed reduced abilities or complete inabilities of persons with SCI to tolerate orthostatic hypotension because of decreased leg and visceral vascular vasoconstriction. Other authors suggest that despite the manifestation of hypotension, orthostatic intolerance in high SCI occurs even less frequently than in able-bodied controls, supposedly due to increased cerebral vasoconstriction opportunities that lead to a sufficient supply of oxygen to the brain during orthostasis (Cariga et al., 2002; Mathias, Frankel, 2002; Wecht et al., 2004). S. Houtman et al. (2000) as the key factor in determining the conscious state in the orthostatic test is not specific cerebral blood flow, but cerebral oxygenation. SCI persons are exposed to greater blood pressure drop in orthostasis than the able-bodied persons, but they showed the same decrease in cerebral oxygenation as the persons in the control group.

Studies dealing with the problem of orthostatic hypotension in SCI can be divided into several groups – analyzing cerebral oxygenation problems, muscle pump dysfunction, baroreceptor activity and so on. However, studies dealing with muscle tone and blood pressure relationship in SCI during orthostatic maneuvers were not found.

Muscle tone changes – muscle spasticity or less responsiveness – are shown in all SCI cases, depending on the type of paralysis – central or peripheral. Central paralysis is characterized by widespread paralysis, muscle stiffness, worsening deep physiological reflexes, absent or decreased skin reflexes, joint contractures and pathological synkineses.

Peripheral paralysis is characterized by localized (involving single muscle groups or mono-

type), decreased or extinct muscle tone, decreased or extinct all physiological reflexes, early muscle atrophy, joint contractures likely to occur only after a considerable time after the beginning of paralysis (Adomaitienė et al., 2003).

In case of altered muscle tone, work one of the key mechanisms for ensuring the circulation of blood through the veins – the muscular pump – is disrupted. After standing up, in 10–15 minutes at 10–20% of blood volume (400–600 ml) is accumulated in the legs, deep vein walls stretch and cause a large hydrostatic pressure (about 90 mmHg blood pressure in the veins of the foot). When striated muscles of the legs shrink, they compress the veins and accelerate the flow of blood toward the heart, which is very important in maintaining venous circulation in an upright position (Faghri et al., 2001). A key function here is carried out by three-headed calf muscle. In case of venous valve insufficiency or with impaired peripheral vascular vasoconstriction, the effect of muscle pump weakens.

Persons with spinal cord injury, due to muscle paralysis, have a lack of muscle pump activity. Blood stagnation in the veins of the legs is highly increased in people with chronic SCI, which increase deep vein thrombosis, pulmonary embolism and the risk of orthostatic hypotension. Due to decreased venous flow in a vertical position and therefore decrease of blood pressure, systolic and cardiac output, people with spinal cord injury are prone to circulatory hypokineses (Faghri et al., 2001).

The aim of research was to ascertain the effect of muscle tone changes to blood pressure in persons with spinal cord injury through ortho-clinostatic test.

RESEARCH METHODS

The study included a control group and two groups of people with disabilities (paraplegia and tetraplegia, Table 1). To carry out the investigation agreement from Lithuanian Bioethics Committee was obtained.

Experimental procedure. Blood pressure data is registered in a lying position (duration – 5 minutes) and myotonometric samples are carried out; an orthostatic test is performed – a table is raised up to a 70 degree angle (Harms et al., 1999) and the myotonometric samples are carried out, and the blood pressure data is recorded (duration – 5 minutes); shift to 10 degrees of clinostasis is made

Table 1. Anthropometric data of subjects (means and standard deviations)

Subjects	Gender	Number of subjects	Age, years	Height, cm	Weight, kg	Duration of disability, years
Control group (n = 14)	m	9	44 ± 12.01	182.5	94 ± 2	–
	f	5	36 ± 12.02	162 ± 6	70 ± 20	–
Tetraplegia group (C5 – C6) (n = 7)	m	6	43 ± 5.5	183.5 ± 8.6	82 ± 6.7	21 ± 4.5
	f	1	34	170	50	16
Paraplegia group (Th1 – L5) (n = 14)	m	9	38 ± 12.4	182 ± 2.5	84 ± 6.6	11 ± 1.5
	f	5	42 ± 11.2	164	67	18

Note. Abbreviations: m – male, f – female.

(Harms et al., 1999) and myotonometric samples are carried out, the blood pressure data is recorded (duration – 5 minutes).

Non-invasive blood pressure measurement (NIBPM). Blood pressure is non-invasive, oscillometric, continuously automatically measured during the ortho-clinostatic test, using the monitor of vital signs tracking “Hospitex Diagnostic VS-800”.

Leg muscle tone measurement. Leg muscle tone is measured by myotonometer (*Myotonometer, neurogenic Technologies, Inc.*). The test is carried out by measuring muscle strength of the quadriceps of one thigh and lower leg biceps in basal position and immediately after the postural change.

Ortho-clinostatic test. Ortho-clinostatic cardiovascular function is tested by using the orthostatic test (head-up tilt table test [Rating Form for Physical and Biological Constructus (Pathology and Impairment) and Their Implications for Diagnosis, Health, Function, and QOL. “Tilt-Table Testing” for the Evaluation of Cardiovascular Autonomic Function after Spinal Cord Injury (SCI)]. This test includes a passive postural change from horizontal to vertical and from vertical to clinostatic position. Orthostatic test is performed using a tilt-table, “Veronese” (Italy).

The study was carried out in the Lithuanian Academy of Physical Education, in the laboratory of Physical Activity in Adapted Physical Activity Science and Study and in the Lithuanian Association of Paraplegics’ Landscape Therapy and Recreation Center.

The subjects were asked not to use stimulant drinks, alcohol and drugs to reduce spasticity 12 hours prior to the test. Individuals with a medically approved cardiovascular dysfunction were not enrolled in the research.

Upon arrival at the laboratory, subjects were introduced with the purpose and protocol of the study. The subjects completed a questionnaire,

giving information on their health status, personal and other data.

After is lying on the orthostatic table, the person was fixed with the straps to the table in order to ensure the safety after the changes in the body position occur. All subjects were asked not to talk, sleep or make any movements.

The data were processed using *Microsoft Excel* program. The arithmetic mean and standard deviation were calculated; comparisons between groups were tested by Student’s t-test (significance level $p < 0.05$); correlations between changes of muscle tone and blood pressure in the three groups were determined by Pearson’s correlation coefficient.

RESEARCH RESULTS

During the study, after moving from a lying to a standing position, two subjects (tetraplegics) experienced orthostatic hypotension (OH) symptoms – dizziness, nausea, and so on. They stayed in the standing position for 2–3 minutes. Because of increased OH symptoms they were returned to the position of rest. These results confirmed the results obtained by other authors for tetraplegics intolerance of orthostatic hypotension (Claydon et al., 2006).

Analysing systolic blood pressure (SBP) data (Figure 1) we can see that in the control group the rates were stable and within the normal range – 110 to 120 mmHg, the dynamics of blood pressure was even.

Results differed markedly in the disabled groups: in paraplegics group systolic BP was slightly elevated – 115–130 mmHg, but within the normal range. Analyzing its dynamics we can see that it can be characterized as uneven. In response to postural change, the shift from a lying position to standing, systolic BP increased to 130 mmHg and remained the same for some time, then it declined

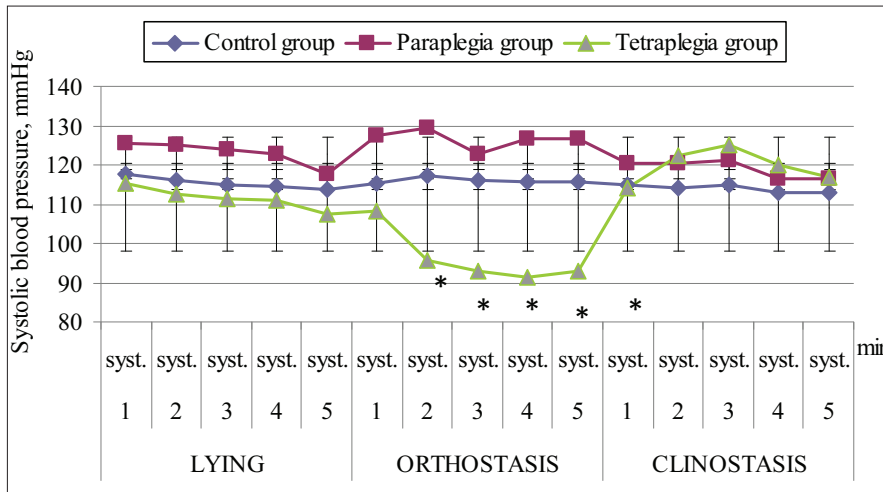


Figure 1. Mean systolic blood pressure (mmHg) in ortho-clinostatic test

Note. * – statistically significant difference between all three groups (p < 0.05).

and rose again in a minute. These changes were statistically significantly different from the ones in the control group.

We did not find any significant changes in clinostasis. As these changes were statistically insignificant, we cannot say that they were different from the physiological norms of the human body.

In tetraplegia group, systolic blood pressure changes were most significant, especially during orthostatics. We can see clearly that after the shift in the standing position, systolic blood pressure rapidly and significantly reduced to 90 mmHg and remained like this all the time during orthostasis. This suggests that compensatory mechanisms responsible for blood pressure regulation are very weak. Given that two subjects experienced orthostatic hypotension phenomena we can suppose that the tetraplegics are at risk for experience OH.

From the analysis of diastolic blood pressure results (Figure 2) shows that obtained data are substantially similar to the ones of systolic blood pressure. The most remarkable case of changes observed in tetraplegia was the decrease in BP up to 60 mmHg in orthostasis and remained like this all the time in the standing position. In clinostasis indicators increased very sharply and suddenly, indicating that even a short time in upside-down position affected blood pressure significantly, much more than in the control group or in paraplegia group.

After the performance of the myotonometric test of the leg muscle during ortho-clinostatic test, we see that in the control group the calf muscles were more relaxed than in the other experimental groups – sensor penetration reached 11.5 mm, while in the disabled groups the maximum penetration of the sensor was up to 8.2 mm (Figure 3). It is

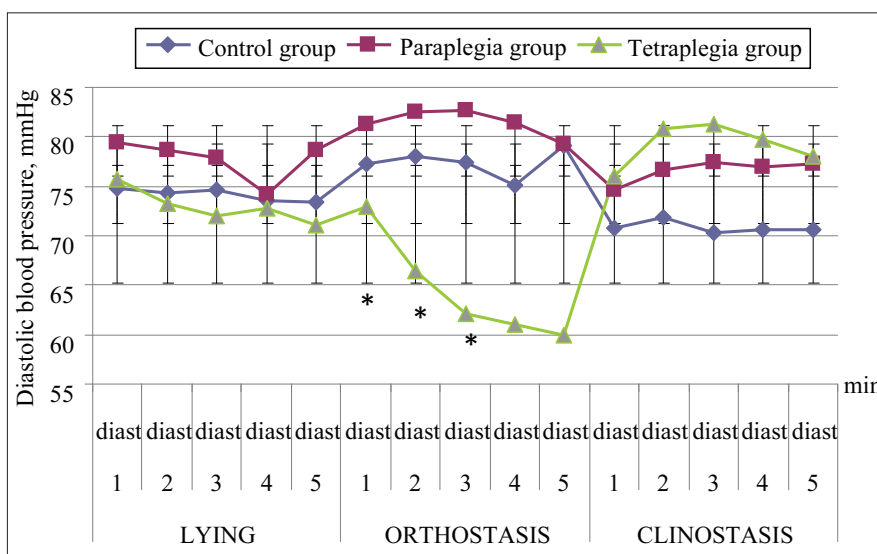


Figure 2. Mean diastolic blood pressure (mmHg) in ortho-clinostatic test

Note. * – Statistically significant difference between all three groups (p < 0.05).

Figure 3. Calf myotonometric test results in ortho-clinostatic test (averages)

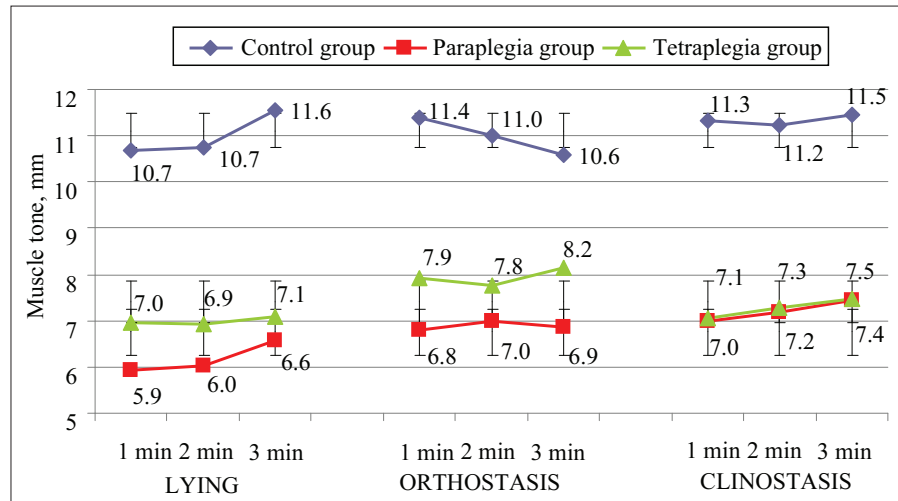
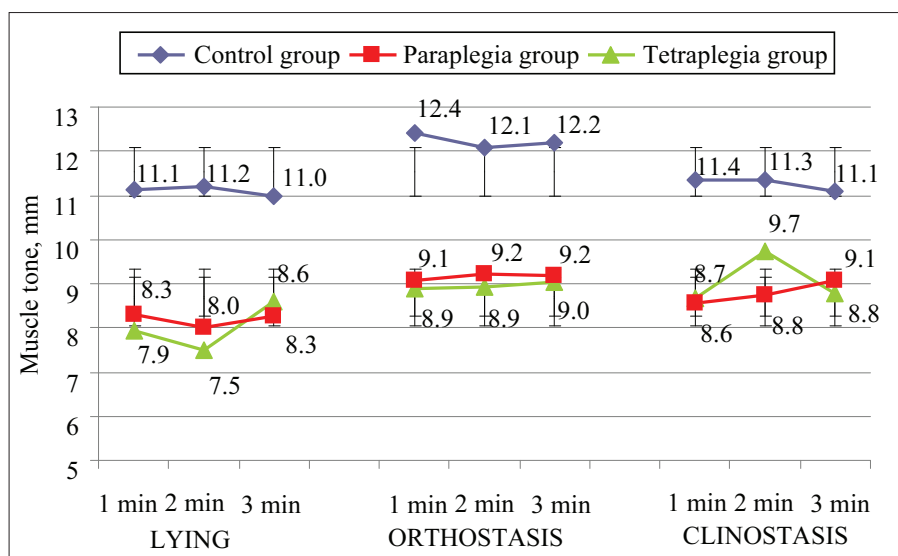


Figure 4. Thigh myotonometric test results in ortho-clinostatic test (averages)



worth noting that muscles in tetraplegia subjects are more relaxed than in paraplegia, although most of tetraplegics have increased muscle tone (spasticity).

The differences between the control group and two disabled groups were statistically significant ($p < 0.05$) in all three body positions. The differences between paraplegia and tetraplegia groups were statistically insignificant.

When monitoring the dynamics of muscle tone, we observe that the initial reaction to the orthostatic test in all groups led to the loss of muscle tone. During orthostasis changes in group dynamics were different: if the control group could be characterized by the tendency of muscular tension, tetraplegia in this case was the opposite – after standing muscles were relaxed.

The transition from orthostatic to clinostatic position in the control group was characterized by a stable state of muscle tone – the tone was reduced and remained such all the time. Paraplegia group

dynamics was almost the same. Tetraplegia group could be characterized by the opposite reaction – muscle tone increased and then slightly decreased.

The analysis of the femoral myotonometry (Figure 4) results shows that the control group was characterized by a relatively strong muscle relaxation, in response to the standing position. These rates were maintained all the time in orthostasis, and after the transition to clinostatic position muscle tone slightly increased.

In both disabled groups muscle tone and dynamics were quite similar – in lying position muscles were more tense compared to the ones in able-bodied group and in response to orthostatic position we observe relaxation persisting all the time in standing position.

In clinostasis, paraplegia group subjects experienced loss of thigh muscle tone, while the control group was in the reverse process – the tone increased. Tetraplegia group changes were very sharp and abrupt.

The differences between the control group and two disabled groups were statistically significant ($p < 0.05$) in all three body positions. The differences between paraplegia and tetraplegia groups were statistically insignificant.

Presented correlations between muscle tone and blood pressure changes shows that the correlation in strength was from weak to strong. This relationship always had a negative value (it was reverse).

DISCUSSION

Typically normal response to postural changes consists of gradually decreasing blood pressure, the heart rate gradually increases during the first 2–3 minutes. After a brief period hemodynamic response reaches a stable level. Recovery is rapid and reaches a similar rate as it was before the change of body position (Claydon et al., 2006).

In our study group the systolic blood pressure response to orthostatic stress in tetraplegia group decreased significantly compared to the control group. These results confirm the findings of other authors: J. M. Legramante et al. (2001) found that tetraplegics' systolic blood pressure decreased significantly ($p < 0.05$) during orthostasis. Other foreign authors (Houtman et al., 2000; Ditor et al. 2005) reported on the reduction of SBP, too. As two of our study participants (tetraplegics) experienced orthostatic hypotension, this confirmed other authors' data (Legramante et al., 2001; Ditor et al., 2005). In paraplegia group, the mean systolic blood pressure was higher than in the control group, but

the dynamics of BP was almost the same. Diastolic blood pressure changes and the dynamics of systolic differed slightly.

Analyzing the relationship between blood pressure and changes in muscle tone we found differences between the disabled groups and the control group reactions. The control group received a strong inverse correlation (-0.7) between muscle tone and blood pressure changes in the transition from orthostasis to clinostasis while in tetraplegia group there was no correlation. This suggests that changes in body position from vertical to horizontal for people without a spinal trauma blood pressure decreases with increasing muscle tone. In our study ortho-clinostatic test was passive, but even passive changes in postural and muscle tone responded influencing other body functions including blood pressure. The fact that after the transition to clinostasis, tetraplegics' blood pressure returned to normal and even rose above the starting line, shows that there are mechanisms responsible for these changes.

Changes in muscle tone in tetraplegia group affected blood pressure during the transition from lying to standing position (correlation coefficient -0.52 and -0.041). Although these relationships were not strong, they implied that the muscle pump activity was very important in case of tetraplegia to maintain a constant BP in the standing position (Houtman et al., 2000). However, the fact that tetraplegics' blood pressure decreased rapidly and significantly in orthostasis suggests that passive standing positive did not have effect on blood pressure control.

Subjects	Blood pressure	Dynamics	Muscle tone	
			$\Delta m1 - m2$	$\Delta m2 - m3$
Control group	Systolic BP	$\Delta m1 - m2$	$-0,09$	
		$\Delta m2 - m3$		$-0,68^*$
	Diastolic BP	$\Delta m1 - m2$	$-0,25$	
		$\Delta m2 - m3$		$-0,70^*$
Tetraplegia group	Systolic BP	$\Delta m1 - m2$	$-0,52^*$	
		$\Delta m2 - m3$		$-0,04$
	Diastolic BP	$\Delta m1 - m2$	$-0,41^*$	
		$\Delta m2 - m3$		$-0,04$
Paraplegia group	Systolic BP	$\Delta m1 - m2$	$-0,37^*$	
		$\Delta m2 - m3$		$-0,13$
	Diastolic BP	$\Delta m1 - m2$	$-0,61^*$	
		$\Delta m2 - m3$		$-0,58^*$

Table 2. Correlations between changes of muscle tone and blood pressure during the ortho-clinostatic test

Note. Abbreviations: m1 – lying position, m2 – orthostasis, m3 – clinostasis. * – statistically significant differences.

Changes in muscle tone in case of tetraplegia affected blood pressure during the transition from lying to standing position (correlation coefficient -0.52 and -0.041). Although these relationships were not strong, they implied that the muscle pump activity was very important for the case of tetraplegia to maintain a constant AC standstill. However, the fact that tetraplegics' blood pressure orthostasis decreased rapidly and significantly suggests that passive standing positive by a effected blood pressure control.

The analysis of paraplegia group data suggests that the test results of this group were intermediate between the control and tetraplegia groups. In paraplegia group we observe medium and strong (-0.37 , -0.61 and -0.58) inverse relationship between muscle tone and blood pressure. These relationships were observed in all body positions – move from lying to orthostasis and then to the clinostasis. These results were specific to this group of subjects. The data suggest that in case of paraplegia blood pressure reacts to changes in body muscle tone in all body positions.

CONCLUSIONS AND PERSPECTIVES

1. Leg muscle tone changes are important for blood pressure compensating mechanisms when the body position changes: it increases during orthostasis and decreases during clinostasis.

2. Blood pressure varies differently among able-bodied persons and persons with spinal cord injury. The degree of the breach has a significant impact on the occurrence of compensatory peripheral regulation mechanisms. Characteristics of blood pressure fluctuations during body position changes in paraplegics are similar to those of reactions as in the able-bodied controls, while in tetraplegia case, i. e. when the degree of infringement is greater, possibilities of homeostatic blood pressure compensation during body posture changes are significantly reduced.

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KŪNO PADĖTIES KEITIMO POVEIKIS ĮGALIŲJŲ IR NUGAROS SMEGENŲ PAŽEIDIMĄ TURINČIŲ ASMENŲ KOJŲ RAUMENŲ TONUSUI IR ARTERINIAM KRAUJO SPAUDIMUI

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Pažeidus nugaros smegenis, dalis simpatinės nervų sistemos atsiskiria nuo smegenų kamieno kontrolės. Dėl to asmenims po nugaros smegenų pažeidimo sutrinka širdies ir kraujagyslių sistemos (ŠKS) reguliacijos mechanizmai. Šie sutrikimai gali sukelti ortostatinę hipotenziją ir neigiamai veikti sveikatą. Tačiau pradėjus veikti įvairiems organizmo adaptaciniams mechanizmom, ŠKS reguliacija gali pakisti ir sudaryti sąlygas kompensacinėms galimybėms atsirasti. Vienas iš mechanizmų, galinčių sukelti ortostatinę hipotenziją, raumenų tonuso pokyčiai po nugaros smegenų pažeidimo.

Tikslas – įvertinti, kaip asmenų, turinčių nugaros smegenų pažeidimą, raumenų tonuso pokyčiai veikia kraujo spaudimą ortoklinostatinio poveikio metu.

Metodai. Pasyvaus ortoklinostatinio poveikio metu kraujo spaudimas matuojamas automatiškai, neinvaziškai, naudojant gyvybinių funkcijų sekimo ekraną; kojų raumenų tonuso pokyčiai matuojami naudojant miotonometrą.

Rezultatai. Kontrolinės grupės raumenų tonusas matomas kaip pastovi banga, kuri mažėja ortostazės metu, o klinostazės metu didėja. Paraplegikų grupėje raumenų tonuso pokyčiai yra panašūs, tačiau jie nėra pastovūs ir skaitinės reikšmės mažesnės. Tetraplegikų grupėje pastebimas staigus raumenų tonuso kitimas, o blauzdos raumenų tonusas turi tendenciją mažėti viso testo metu.

Aptarimas ir išvados:

1. Kintant kūno padėčiai, AKS kitimą kompensuojančių mechanizmų grandinėje svarbūs yra kojų raumenų tonuso pokyčiai: padidėjimas – ortostatinio poveikio metu ir sumažėjimas – klinostatinio poveikio metu.

2. Kraujo spaudimas kinta nevienodai sveikųjų ir nugaros smegenų pažeidimą turinčių asmenų grupėse. Pažeidos laipsnis lemia kompensacinių periferinių reguliacinių mechanizmų pasireiškimą. Paraplegijos atveju AKS kaitos ypatybės, kintant kūno padėčiai, yra panašios į sveikų asmenų reakcijas, o tetraplegijos atveju, t. y. esant didesnio laipsnio pažeidimams, AKS homeostatinio kompensavimo galimybės, kintant kūno pozai, yra reikšmingai sumažėjusios.

Raktažodžiai: kraujospūdis, raumenų tonusas, paraplegija, tetraplegija.

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