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Original Article

Effect of physical therapy on vertebral artery functional compression syndrome

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Abstract
Background. The article deals with the effect of physical therapy on students with vertebral artery functional compression syndrome. Constant stable flexion of the cervical spine is one of the functional factors that can cause deformation of the vertebral arteries and, as a consequence, to reduce blood flow through these arteries **The purpose of the research** is to define the effect of physical therapy on vertebral artery functional compression syndrome caused by a violation of biomechanics in the cervical spine. **Material and methods.** The research involved 24 students aged 18 to 23 years old. The research used the following methods: theoretical analysis and generalization of reference sources on the topic of scientific research, clinical evaluation of vegetative disorders with a questionnaire for determining signs of vegetative changes by O. M. Vein, comprehensive ultrasound examination of the head and neck blood vessels, goniometry of the cervical spine and mathematical statistics. **Results.** Physical therapy helped to restore the volume of active movements in the cervical spine ($p<0.05$). The disappearance of the main symptoms was noted by an average of 74% of respondents, and the rest noted their decreased character. Peak systolic blood flow velocity in the vertebral arteries when performing functional tests increased ($p <0.05$). **Discussion.** The positive results were achieved, probably due to the normalization of anatomical and functional interconnections in the cervical spine, stimulation of its reparative capabilities via manual therapy, namely post-isometric muscle relaxation. **Conclusions.** The research results show that the use of physical therapy for patients with vertebral artery functional compression syndrome helps to reduce the clinical manifestations of the disease, restore proper spinal biomechanics and improve blood flow in vertebral arteries.
Key words: physical therapy, vertebral artery functional compression syndrome, post-isometric muscle relaxation, biomechanics of the cervical spine, goniometry of the cervical spine, ultrasound examination of the vertebral arteries.

Introduction

Vertebral-neurological diseases are among the most significant problems in the structure of the musculoskeletal system disorders. Economic losses due to the disability of patients with vertebrogenic pathology occupy the first place among all diseases of the nervous system (Dido et al., 2021; Popelianskyi L., 2020).

Ensuring proper body biomechanics is an integral part of the functioning of the whole organism and the most important indicator of health (Kashuba V. et al., 2020). In modern conditions of human life, there have been changes manifested in urbanization, low physical activity, changes in diet and quality of food and the introduction of digital technologies in all spheres of life. Nowadays, with the widespread introduction of gadgets in the learning process, students work for a long time in a forced position of the head and body (Povorozniuk V., 2019). New problems we can see after modernization educational system, passive rest with notebooks, computers, smartphones, online games, play stations and other time with monitors and electronic-calculation machines. These problems is understanding as posture defects in students, diseases of mio-sceletal system in children and young peoples and deviations in healthy development. Flexion of the cervical spine during prolonged work with computers, tablets and smartphones causes mechanical load on the cervical spine and leads to a number of violations of the biomechanics of the spine. In the modern medical literature, this phenomenon is known as “text-neck” (Barrett J.M. et al., 2019). Prolonged flexion of the cervical spine is a significant mechanical risk factor for chronic neck pain and increases compression in the entire cervical spine by 1.6 times compared to the neutral position (Barrett J.M. et al., 2019). Constant stable flexion of the cervical spine is one of the functional factors that can cause deformation of the vertebral arteries and, as a consequence, to reduce blood flow through these arteries (Mitchell J. et al., 2008). The vulnerability of the vertebral artery to distortion with sustained, full-range cervical spine rotation, resulting in compromised blood flow and possible vertebrobasilar

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ischemia, is well recognized. In Jeanette Mitchell researches we saw, that the distortion or compression of the anatomical relationships of the suboccipital vertebral artery demonstrated by the reduction in diameter on ipsilateral cervical spine rotation, particularly, was sufficient to result in compromised blood flow. A significant stretching effect of vertebral artery, on contralateral rotation, was not demonstrated in these subjects. Nevertheless, these findings add evidence to support the recommendation that sustained, full-range cervical spine rotation should be avoided in professional practice. (Mitchell J. et al., 2008). Reflex narrowing, compression of the vertebral arteries and their deformation are manifested as the vertebral artery syndrome, which includes a complex of cerebral, vascular and vegetative syndromes (Mitchell J. et al., 2008). The development of vertebrobasilar insufficiency among young people, which occurs against the background of pathological biomechanical changes of the cervical spine inevitably affects the quality of life, which (according to the WHO) is an integral characteristic of physical, psychological, emotional and social functioning of the patient based on his/her subjective perception (Grygus I. et al., 2019; Morozova O. et al., 2018; Nesterchuk N. et al., 2020).

The main pathogenetic mechanism of vertebral artery functional compression syndrome is the compression of the trunk of the artery, vegetative plexus and narrowing of the lumen of the vessel due to a reflex spasm, which reduces blood flow to the posterior parts of the brain with the subsequent development of cerebral insufficiency. The topic of the research is relevant due to the fact that vertebral-neurological diseases cause great harm to the economy, and their treatment is of great medical and social and economic importance. Medicament treatment of vertebral artery functional compression syndrome gives an incomplete and short-term effect. In the modern science, there is insufficient research on efficiency of physical therapy application among patients with vertebral artery functional compression syndrome (Lazarieva O. et al., 2015). The search for new tools and methods of physical therapy for patients with vertebral artery functional compression syndrome and evaluation of their effectiveness is an important and urgent medical and social problem.

Material and methods

Participants. The research involved 24 students aged 18 to 23 years old with vertebral artery functional compression syndrome. Informed consent to physical therapy was obtained from all research participants.

Procedure / Test protocol / Skill test trial / Measure / Instruments. To achieve the purpose of the research, a research plan was developed. It allowed obtaining sufficiently complete and reliable information about each task, as well as their consecutive implementation. An objective examination of the students included determining the amount of active movement in the cervical spine. Goniometry allows estimating the volume of movements in the cervical spine, determining flexion, extension, bending to the left and right and rotation in the cervical spine. A special tool – goniometer – was used during the assessment of movements in the cervical spine used a tool.

Head movements in two planes depend on the degree of mobility in the atlanto-occipital joint and joints of the cervical spine, so the examination of patients was performed in a vertical position (sitting). The points of application of the goniometer legs for measuring mobility in the sagittal plane are as follows: the most protruding point between the superciliary arches and the point of the occiput. The pointer of the goniometer in the vertical position should be at zero. The angles of inclination of the head (amplitude of movements) at maximum flexion (tilt forward) (normal 45^0) and maximum extension (tilt backward) (normal 85^0) are measured.

To measure the amplitudes of head movements in the frontal plane (tilt to the right and left), the legs of the goniometer are placed symmetrically on both sides of the head (on the scales of the temporal bones). The pointer of the goniometer should show zero. The angles of inclination of the head to the right and left of the vertical position are measured. Normally, these indicators make 40^0.

Along with neurological and general clinical examination, assessment of vegetative disorders included "Questionnaire to determine the signs of vegetative changes" by O. M. Vein (completed by students independently). A score greater than 15 indicated the presence of vegetative dysfunction.

All subjects underwent a comprehensive ultrasound examination of the head and neck blood vessels, which included a standard ultrasound examination and duplex scanning of these vessels using functional tests with rotation of the head. Duplex vascular scanning was performed according to standard methods using functional tests with rotation of the head in all subjects before and after the application of a comprehensive program of physical therapy. The speed parameters of blood flow, namely the peak blood flow rate, were evaluated. The research also involved functional tests, which included tilting the head forward and backward and turn of the head to the right and to the left.

The physical therapy program included therapeutic gymnastics, therapeutic exercise, post-isometric muscle relaxation and mild mobilization techniques to unlock functional blocks in the intervertebral motor segments of the cervical spine. Physical therapy was performed three times a week in the form of symmetrical, asymmetrical and distortion exercises, developed individually for each student, taking into account the peculiarities of posture and, accordingly, the biomechanics of the spine. Therapeutic sessions usually lasted up to 30 minutes and included exercises to strengthen the muscles of the neck, trapezius, etc., in a sitting, standing and lying position with gradual muscle tension. Therapeutic gymnastics was prescribed after the reduction of acute pain. Rotational movements in the cervical spine, as well as throwing the head with flexion of the spine were

performed very carefully under the control of muscle tension to avoid the possible development of vertebral hypermobility. The course of physical therapy lasted for 4 weeks.

Before post-isometric muscle relaxation, a short massage of the neck and collar area was performed to warm up the paravertebral muscles to reduce muscle spasm. Due to its mild, gentle effect, post-isometric muscle relaxation, in contrast to manipulation, is allowed in the case of vertebral artery functional compression syndrome. A total of 5 post-isometric muscle relaxation procedures were performed during the course of treatment.

Data collection and analysis / Statistical analysis.

Computer processing of the research results was performed using MS Excel 2007 and a statistical program SPSS 11.5. All data of the research results were processed using mathematical statistics, which included characteristics of the central trend (arithmetic mean) and characteristics of variation (variance, standard deviation, arithmetic mean error). Differences at $p < 0.05$ were considered significant.

Results.

All subjects underwent a clinical examination, goniometry of the cervical spine, comprehensive ultrasound examination of the head and neck blood vessels. The vegetative status was determined with "Questionnaire to determine the signs of vegetative changes" by O. M. Vein. Hemodynamic abnormalities in the vertebral arteries of varying severity were found in subjects. All examinations were performed before the beginning of the course of physical therapy, and after the course of physical therapy, which lasted for 4 weeks.

Among the research participants, the leading complaints include weakness (87.5%), vertigo (83.3%), headaches that are localized in the cervical and occipital parts and spread forward and intensify with head movements (75%), pain in the neck, radiating to the shoulder and arm (79.2%), dizziness (54.2%). In addition, students complain of fatigue (58.3%), photopsia (54.2%), weather sensitivity (41.6%) and tinnitus (29.2%) (Table 1). After a course of physical therapy, complaints of dizziness disappeared in 92% of subjects, weakness in 90%, neck pain in 84%, photopsia in 84%, vertigo in 75% and headache in 67%. The same trend was observed with disappearance of such complaints as tinnitus – 57% and meteorological sensitivity – 40%. Among the rest of the subjects, symptoms became less pronounced (Table 1).

The dynamics of the frequency of subjective symptoms among the research participants *Table 1*

Symptoms	Before physical therapy		After physical therapy	
	n=24	%	n=24	%
Vertigo	20	83.3	5	20.8
Headache	18	75	6	25
Neck ache	19	79.2	3	12.5
Weakness	21	87.5	2	8.3
Dizziness	13	54.2	1	4.2
Fatigue	14	58.3	4	16.7
Tinnitus	7	29.2	3	12.5
Weather sensitivity	10	41.6	6	25
Photopsia	13	54.2	2	8.3

All subjects were found to have biomechanical disorders in the cervical spine in the form of limited amount of active and/or passive movements in the cervical spine and signs of instability of the vertebral motor segments. According to the data of goniometry, which was performed before the course of physical therapy, students noted a decrease in flexion, extension and inclination compared to the normal values (Table 2). In particular, the rate of flexion was 39.583±3.855 (m = ±0.787) at the norm of 45^0, extension – 49.208±7.621 (m = ±1.556) at the norm of 60^0, right tilt – 35.458±2.621 (m = ±0.535) at the norm of 40^0 and left tilt – 35.750±2.674 (m = ±0.546) at the norm of 40^0.

As Table 2 and Figure 1 show, after the course of physical therapy, the volume of movements in the cervical spine significantly improved and/or restored. The indicators of flexion were 43.625±1.861 (m = ±0.380), extension – 54.583±4.393 (m = ±0.897), right tilt – 38.958±1.517 (m = ±0.310) and left tilt – 38.958±1.517 (m = ±0.310), which corresponds to the normal reference values. The indicators are statistically significant.

Volume of movement in the cervical spine *Table 2*

Type of movement (norm)		Before physical therapy (n=24)	After physical therapy (n=24)
Flexion ^{0} (45^0)		39.583±3.855 (m = ±0.787)	43.625±1.861 (m = ±0.380)
Extension ^{0} ($50\text{-}60^0$)		49.208±7.621 (m = ±1.556)	54.583±4.393 (m = ±0.897)
Tilt ^{0} (40^0)	right	35.458±2.621 (m = ±0.535)	38.958±1.517 (m = ±0.310)
	left	35.750±2.674 (m = ±0.546)	39.042±1.459 (m = ±0.298)

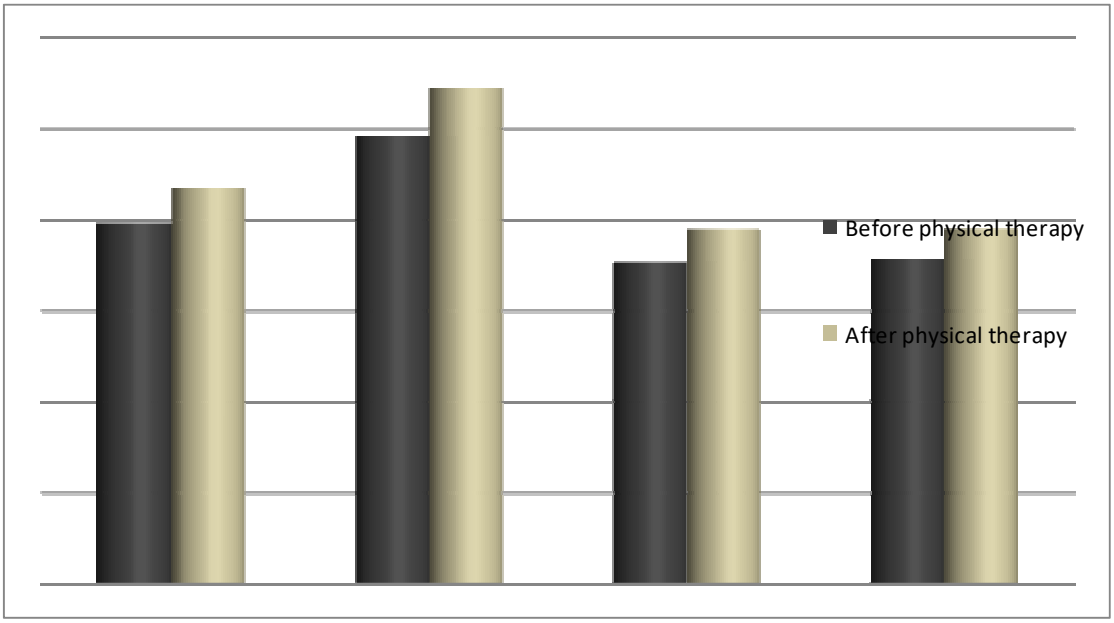

Figure 1. Dynamics of changes in the volume of movements in the cervical spine before the course of physical therapy and after the course of physical therapy

The results of the survey of patients according to the questionnaire for determining the signs of vegetative changes by O. M. Vein show significant changes in the initial vegetative status (Table 3). In particular, the most common clinical signs were headache (91.6%), decreased ability to work and fatigue (87.5%), sleep disturbances (83.3%), palpitation (75%), shortness of breath (66.6%) and others. After the course of physical therapy, the vegetative status was re-evaluated using O. M. Vein's questionnaire (Table 3). As it can be seen from the table, the number of patients with complaints significantly decreased after the course of physical therapy.

The statistical processing of the survey showed the following results: the average value of points before the course of physical therapy was 37.708±13.861 (m = ±2.829), and after the course of physical therapy – 8.833±7.487 (m = ±1.528). Student's coefficient (t) was 2.069 at $p \leq 0.05$, which indicates the statistical reliability of the results.

The research involved analysis of ultrasound examination of students with vertebral artery functional compression syndrome before and after physical therapy. All subjects underwent a comprehensive ultrasound examination of the head and neck blood vessels, which included a standard ultrasound examination and duplex scanning of these vessels using functional tests with rotation of the head. According to the results of many studies, the diagnostic value of using ultrasound examination in cases of vertebral artery disorders makes 85-98% (Uchino A. Et al., 2012). The data of ultrasound examination (Table 4) indicate a violation of blood flow in the vertebral arteries when performing functional tests.

Vegetative status according to the "Questionnaire to determine the signs of vegetative changes" by O. M. Vein before and after a course of physical therapy *Table 3*

Clinical signs	Initial values (n-24)		Values after the course of physical therapy (n-24)	
	n	%	n	%
Predisposition to redness or whitening of the face	15	62.5	6	25
Numbness or coldness of the fingers or toes	15	62.5	6	25
Discoloration of the fingers or toes	8	33.3	3	12.5
Feeling of palpitation or cardiac arrest	18	75	2	8.3
Increased sweating	8	33.3	1	4.2
Shortness of breath	16	66.6	5	20.8
Fainting in a stuffy room or due to the stress	5	20.8	0	0
Dyspepsia (predisposition to constipation, diarrhea, bloating)	8	33.3	1	4.2
Headache	22	91.6	5	20.8
Decreased ability to work and fatigue	21	87.5	6	25
Sleep disturbances	20	83.3	3	12.5

Indicators of ultrasound examination *Table 4*

		Before physical therapy (n=24)	After physical therapy (n-24)
Right vertebral artery	Diameter (mm)	3.55	3.55
	Peak systolic velocity (cm/sec)	57.21	58.08
	Peak systolic velocity at functional tests (cm/sec)	38.91	44.25*
Left vertebral artery	Diameter (mm)	3.48	3.49
	Peak systolic velocity (cm/sec)	54.21	55.46
	Peak systolic velocity at functional tests (cm/sec)	36.86	44.25*

Note * statistically significant result

As Table 4 shows, the diameter and peak systolic blood flow velocity in the right and left vertebral arteries did not actually change after the course of physical therapy. Peak systolic blood flow velocity at functional tests increased in the right vertebral artery by 12% and in the left vertebral artery by 16%, which are statistically significant results.

After the course of physical therapy, the subjects observed an improvement in general condition, reduction of subjective complaints (Table 1), improvement of vegetative status (Table 3), restoration of normal range of movement in the cervical spine (Table 2, Fig. 1) and improvement of hemodynamics of vertebral arteries according to ultrasound examination of extracranial vessels (Table 4).

Discussion

Cervical part of vertebra is a main vulnerable for exogenous negative influences. Cervical vertebras is more movable in compared with other vertebral parts, that make addition amount of work and traumatization moments. The paucity of studies of vertebral artery emphasises the need for research based on informed understanding of the anatomy and biomechanics of this area. This view on mechanical deformation of vertebral artery associated with cervical spine rotation as a possible cause of compromised blood flow to the hindbrain and vertebrobasilar insufficiency or ischemia provides further argument for avoiding full-range or sustained cervical spine rotation in clinical practice. (Mitchell J., 2008)

The positive results were achieved, probably due to the normalization of anatomical and functional interconnections in the cervical spine, stimulation of its reparative capabilities via manual therapy, namely post-isometric muscle relaxation (Frank S., 2019; Lewit K., 1999). Physical therapy operates at the level of soft tissues and performs the following tasks: accelerates reparative processes, restores physical and mechanical characteristics of tissue structures, including spasmodic or overstretched tissues, and normalizes the circulation of physiological fluids in tissues. Physical therapy also affects proprioceptive mechanisms by stimulating different groups of mechanoreceptors in the affected area and around it. Neurophysiological effects of physical therapy include hypoalgesia, which develops due to post-isometric muscle relaxation, correction of spinal biomechanics due to exercise, psychosomatic and psychophysiological response of the whole body manifested by changes in muscle tone, increased tolerance to pain, and improvement of self-regulation processes. By influencing the cervical spine with physical therapy, it is possible to combat the main cause of the development and progression of blood flow disorders in the vertebrobasilar zone.

Disorders of cervical spine biomechanics need diligent investigation of mobility and patterns for actual treat and correct vertebral artery functional compression syndrome. Non research questions lead to study different factors that can influence to progress vertebral artery functional compression syndrome.

Conclusions

The results of the analysis and generalization of scientific and methodological literature give grounds to establish that among young people who actively use gadgets, mechanical load on the cervical spine leads to a number of disorders of its biomechanics, which are manifested by vertebral artery functional compression syndrome. Reflex narrowing, compression of the vertebral arteries and their deformation are manifested as the vertebral artery syndrome, which includes a complex of cerebral, vascular and vegetative syndromes

Physical therapy in cases of vertebral artery functional compression syndrome gives a positive result, as evidenced by the disappearance or reduction of clinical manifestations of this pathology, confirmed by ultrasound, goniometry and examination of vegetative functions. The physical therapy program included therapeutic gymnastics, therapeutic exercise, post-isometric muscle relaxation and mild mobilization techniques to unlock functional blocks in the intervertebral motor segments of the cervical spine.

Disorders of cervical spine biomechanics need diligent investigation of mobility and patterns for actual treat and correct vertebral artery functional compression syndrome.

The prospect for further research is to conduct the follow-up analysis using other research methods.

Compliance with Ethical Standards

Conflict of Interest. The authors declare that there is no conflict of interest that could be perceived as interfering with publication of the article.

Competing Interests. The authors declare that they have no competing interests.

Ethical Approval. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent. Informed consent was obtained from all individual participants included in the study. All subjects of the institutional survey gave consent for anonymized data to be used for publication purposes. Funding sources. This study has not received any financial support from any government, community or commercial organization.

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