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Influence of Lateral Dominance of Sight on the Quality of the Natural Locomotion Performance at the Senior Preschool Age

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Abstract

The article shows age-specific peculiarities of the formation of the asymmetry of visual perception and justifies the mechanisms of participation of the visual sensory system in the implementation of natural motor actions that contribute to the development of concepts of motor systems management, the development of the strategy of the typological approach to training and development of preschool children who demonstrate different types of lateral dominance. Experimental results were obtained using certified hardware. Recording of the surface EMG was performed using the "Neuro-Mvp" multipurpose computer system. Motor tasks under the control of binocular vision in the age of 5-6 years are implemented with the key role of the dominant eye. The narrowing of the visual field by means of closing the dominant eye during performance of a single manual action reduces the bioelectric activity of muscles due to the decrease in the maximum amplitude of the EMG signal, which indicates the reduction in the rate of muscles contraction. At the binocular method of sight, EMG of all studied muscle groups is characterized by the uniform bioelectric activity. When one is holding the "Flamingo" pose with closed eyes, disruption of the stability of the parameters of bioelectric activity takes place, which is manifested as appearing sharp bursts of the bioelectric activity in the EMG patterns. The sight space narrowing at closing the dominant eye leads to disruption of the bioelectric stability of postural muscles of the back and thigh. The sight space narrowing at closing the subdominant eye during holding the "Flamingo" pose leads to disruption of the bioelectric stability of postural muscles of the thigh.

Keywords: Bioelectric Structural Components of Movement, Children of Senior Preschool Age, Lateral Dominance of the Organ of Sight, Maximum Amplitude of the Signal

1. Introduction

It is known that the preschool period is characterized by intense changes of all body systems, due to the influence of biological development program[8], including changes of the functional asymmetry ensuring the development of binocular vision, which determines the nature of the eyes interaction during sighting.

In this age period, the basic foundation of natural locomotion is formed, determining the course of further development of the child's motor function. High quality implementation of voluntary movements, including the main natural movements formed at this age, from the perspective of the N.A. Bernstein's theory of levels of movement control, requires the formation of the mechanism of movements control at the level of the spatial field. Sensory correction at this level provides the coordination of the motor act with the external space with the leading role of visual afferentation[2].

However, sensory correction is performed better if the organ of sight, which mainly identifies and assesses the quality of the space and the extent of conformance

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of the implemented action to the conceived plan, is better adapted to the space assessment. In other words, the quality of the motor action implementation depends on how the eye controls the course and the result of the performed motion.

One of the manifestations of functional asymmetry is the lateral dominance of one of the visual analyzers, which manifests itself in the dominance of one eye over the other in sighting abilities and skills of action space assessment[1,3,4,6,7,9,10]. However, physiology still faces the understudied problem of formation of lateral dominance of the organ of sight and the influence the quality of sight defined by this dominance on the consistency of the components of voluntary movements in children of preschool age. The problem becomes relevant in the senior preschool age, because in this age, the child masters the best ways to implement basic movements that allow him to adapt to the environment effectively in the future.

The theory of the effect of lateral dominance of the organs of sight on the consistency of the components of implementation of natural movements within the 5-6-year segment of ontogeny is based on verifiable data and facts of the sight parameters' age-specific development and motor development[3,4,7]. It is consistent with the general theory of ontogeny, the concepts of asymmetry formation in ontogeny, the theory of interaction of the biological and the social in human development.

1.1 Research Target

To justify the mechanisms of the effect of lateral dominance of the organ of sight on the quality of implementation of major natural locomotion of senior preschool age children.

1.2 Research Objectives

- To define the criteria for physiological evaluation of the quality of implementation of the basic natural movements based on electromyographic methods.
- To identify physiological mechanisms of influence of the sight asymmetry (lateralization of sight) on the change in the bioelectric characteristics of natural motor actions in children aged 5-6 years.

2. Research Methods

The study was conducted at the premises of the Health Center of the Research Institute for Systemic Problems of ASU and the Preschool Educational Institution No. 6 of the City of Maykop in groups of children aged 5-6 years. The main group of the research consisted of 60 children. The survey was carried out on healthy children of the same age and approximately the same body type. The study was conducted with the consent of the parents of preschool children.

A battery of modern methods for collecting and processing information was used, which allowed to study the bioelectric activity of muscles. The findings are based on more than 1,320 units of observation.

In order to study the duration of the motor program formation and change in the bioelectric activity of the skeletal muscles due to external features of its implementation, we chose natural locomotion. The most effective natural movements to identify the space-time characteristics of movement, taking into account the tested age, are the catching of an object and the maintaining of a pose, which allow estimating spatial orientation. Each tested person carried out a motion with eyes open, eyes closed, with the closed right and closed left eye.

The experimental results were obtained using certified equipment of domestic firms. Surface EMG was recorded using the "Neuro-MEP" multipurpose computer system (LLC "Neurosoft", Ivanovo). Electromyography allows exploring displays of the integrated bioelectric activity of muscles, reflecting their functional state and activities, the form of contraction of muscle groups, their coordination in time and the degree of synchronization of movements.

3. Discussion of the Research Results

Performing motor tasks require involvement of a large number of muscle groups, while the potentials of their actions are summarized, which when recording EMG is manifested in the emergence of a complex integrative curve characterizing the bioelectric activity. The EMG shape (pattern) reflects the nature of muscle contraction: the higher the speed of muscle contraction, the higher the EMG amplitude. The study of patterns of the bioelectric activity of muscles in the process of catching a falling object allows defining that EMG of the deltoid muscle is an interference curve characterized by a sharp burst of the bioelectric activity; EMG of the biceps — by an intense increase and decrease of the bioelectric activity; EMG of the forearm muscle — by gradual increase and decrease (Figure 1).

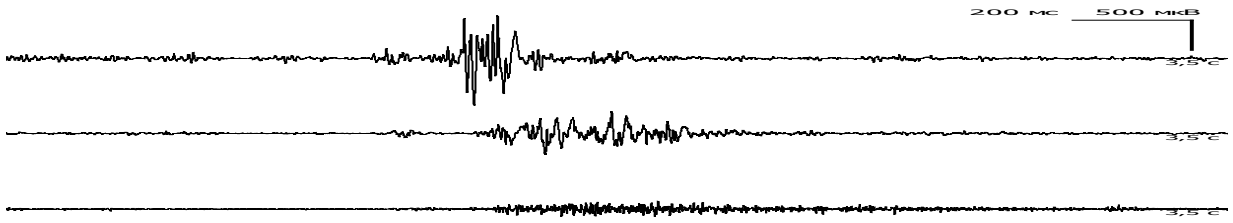

Figure 1. Typical EMG of the deltoid, biceps, and forearm muscles in children aged 5-6 years while catching a falling object.

It was found that in a group of children aged 5-6 years with the leading right eye when it is closed while catching a falling object, there is significant reduction in the maximum amplitude of the EMG signal of the deltoid muscle from 772±87.7 μV to 402.1±48.2 μV (P <0.01) and in a group of children with the leading left eye, the maximum amplitude of the EMG signal of the deltoid muscle decreased from 802±91.2 μV to 511.6±61.0 μV (P <0.01) (Table 1).

There was smoothing of the burst waveform of the bioelectric activity at the initial moment of the movement in the EMG pattern of the deltoid muscle, a significant increase in catching time, an unsuccessful first attempt for more than 40% of the tested persons, a change in the head position in the starting position. As a result of closing the leading eye, the space of action becomes wider than the space of sight. In these conditions, it is impossible to solve movement tasks quickly and accurately at the same time. Therefore, to make catching of a falling object precise, the child sacrifices the speed of its implementation, which is manifested in the increase in the catching time along with the reducing maximum amplitude of the EMG signal of the deltoid muscle.

Thus, motor tasks controlled by binocular vision in the age of 5-6 years are implemented with the key role of the dominant eye. The sight space narrowing by closing the dominant eye during performance of a single manual action reduces the bioelectric activity of muscles due to the decrease in the maximum amplitude of the EMG signal, which indicates the reduction in the rate of muscles contraction.

The physiological mechanism of maintaining the vertical posture is the system of postural control. Postural control is performed by the antigravity muscles (the extensor muscles of the spine, the hip and knee joints), as well as by the reflexes of stretching the muscles of the front and back of the shank (Demin[5]). The trigger afferent system in this case are the proprioceptive somatosensory signals, as well as the supporting sensory afferentation caused by superficial and deep touch receptors of the plantar surface of feet, i.e. information about the contact of the foot with the foot support.

Table 1. The parameters of the maximum amplitude (μV) of the EMG signal of muscles of children aged 5-6 years at catching a falling object

The dominant organ at sight	Character of sight								
	With open eyes			With the right eye closed			With the left eye closed		
	Deltoid muscle	Biceps muscle	Forearm muscles	Deltoid muscle	Biceps muscle	Forearm muscles	Deltoid muscle	Biceps muscle	Forearm Muscles
Right	772± 87.7*	98± 18.2	65± 14.5	402.1± 48.2*	107± 19.8	71± 4.8	652± 71.9	72± 15.6	51± 15.9
Left	802± 91.2*	78± 15.3	59± 12.4	724± 75.7	64± 17.2	62± 20.1	511.6± 61*	59± 16.2	68± 19.1
Ambidexter	642± 65.6	108± 17.6	64± 15.8	590± 57.9	94± 19.9	51± 17.4	701± 95.6	53± 21.5	56±1 9.2

Remark: ** - manifestation of significant differences of the deltoid muscle values between groups of children with the leading right and left eye, P<0.01*

In the implementation of the equilibrium function, the important data are visual information and information from proprioceptors of tendons of the eye muscles. But proprioception and impulses from the vestibular apparatus receptors are the most important (the proof of this is their earlier appearance in phylogeny). It is known that visual representation of the gravitational vertical is formed in ontogeny based on the information from the otolith receptors. Regulation of postural equilibrium is limited to the motor centers of the brain stem (the vestibular nuclei and the reticular formation), which are directly affected downwards by the medial segments (worm) of the cerebellum, which, in turn, receive afferent information from the somatosensory system. At this level, there is regulation of the tone of the postural muscles and coordination of the muscle synergies, providing equilibrium. In this regard, the study of bioelectric activity of postural muscles will allow defining the importance of the lateral dominance of the sight organ in the mechanism of maintaining postural stability.

Maintaining the vertical position of the body, which is formed as a result of the child's counteract to the forces of gravity, is mainly implemented due to the tone of the postural extensor muscles of the back, thighs and shanks. The study of the patterns of the EMG of the back, thigh and shank muscles in the process of maintaining equilibrium in the "Flamingo" pose allows us to conclude that the method of binocular sight typically causes uniform expression of bioelectric activity at EMG of all studied muscle groups (Figure 2). The parameters of the maximum amplitude of the signal in the groups of children with the leading right eye, left eye and ambidexterity had no significant differences (P>0.05) (Table 2). Thus, the maximum amplitude of the signal of the back muscles in children with the leading right eye is 87.0±21 μV, and the thigh and shank muscles — 193.0±46 μV and 107.0±28 μV, accordingly.

When one is holding the "Flamingo" pose with closed eyes, disruption of the stability of the parameters of bioelectric activity takes place, which is manifested as appearing sharp bursts of the bioelectric activity in the EMG patterns (Figure 3).

A significant increase in the maximum amplitude of the signal of all muscle groups under study was determined.

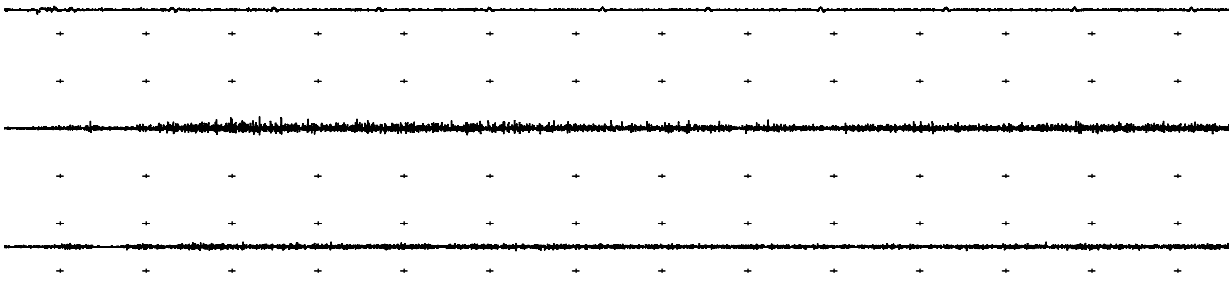

Figure 2. Typical EMG of the back, thigh, and shank (in order from top to bottom) in the process of holding the «Flamingo» pose at the binocular sight method in children aged 5-6 years.

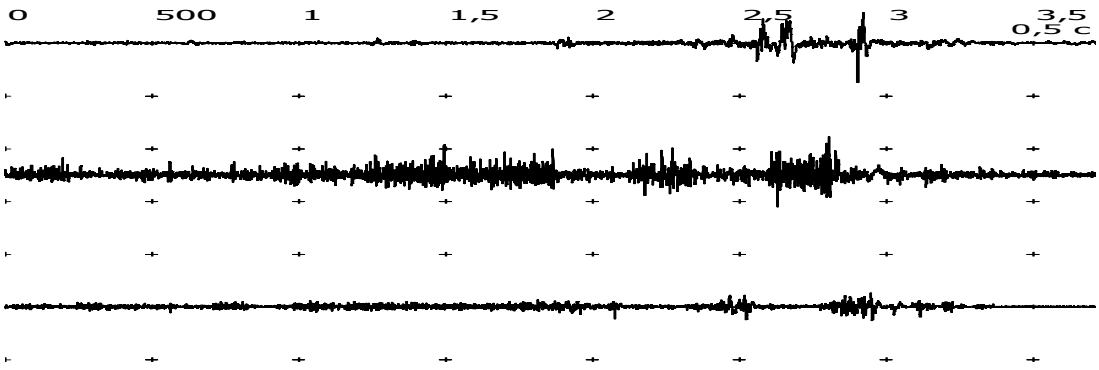

Figure 3. Typical EMG of the back, thigh, and shank (in order from top to bottom) in the process of holding the «Flamingo» pose in the absence of sight in children aged 5-6 years.

For example, in children with the leading right eye, this indicator's value for the back muscles increased from 87.0±21 μV to 663.0±121 μV (P<0.001), for the thigh muscles — from 193.0±46 μV to 682.0±145 μV and for the shank muscles — from 107.0±28 μV to 260.0±52 μV (P<0.001) (Table 2).

Lack of sight leads to disruption of the bioelectric stability of skeletal muscles performing the function of postural control.

The narrowing of the sight space at closing the dominant eye leads to disruption of the bioelectric stability of the postural muscles of the back and thigh, which is characterized by a change of the uniform EMG waveform of the back muscles for the burst waveform and an increase in the amplitude of the undulating bursts on the pattern of EMG of the thigh muscles (Figure 4).

The sight space narrowing at closing the subdominant eye during holding the "Flamingo" pose (Figure 5) leads to disruption of the bioelectric stability of the postural thigh muscles, which is characterized by the change of the uniform waveform of EMG for the undulating waveform and a significant increase in the maximum amplitude of EMG of the back and thigh extensor muscles.

Studying the bioelectric stability of the back and thigh muscles in the mechanism of maintaining postural

Table 2. The parameters of the maximum amplitude (μV) of the EMG signal of muscles of children aged 5-6 years at maintaining equilibrium

The dominant organ at sight	Character of sight											
	With open eyes			With closed eyes			With the right eye closed			With the left eye closed		
	Back muscles	Thigh muscles	Shank muscles	Back muscles	Thigh muscles	Shank muscles	Back muscles	Thigh muscles	Shank muscles	Back muscles	Thigh muscles	Shank muscles
Right	87.0±21*	193.0±46	107.0±28	663.0±9*	682.0±115	260.0±52	227.0±35*	625.0±111	110.0 ±25	286.0±42*	484.0±62	153.0±34
Left	101.0±19**	202.0±31**	94.0±27**	597.0±92**	697.0±87**	320.0±48**	245.0±37	450.0±69	105.0 ±21	221.0±35	651.0±107**	121.0±23**
Ambi-dexter	98.0±24***	175.0±18***	120.0±20	672.0±120***	591.0±70***	251.0±29	175.0±27***	421.0±37***	125.0 ±15	201.0±44***	390.0±51***	117.0±19

Remark: * - validity of the results in the group of children with the leading right eye, P<0.05; ** - validity of results in the group of children with the leading left eye, P<0.01; *** - validity of the results in the ambidexter group, P<0.001

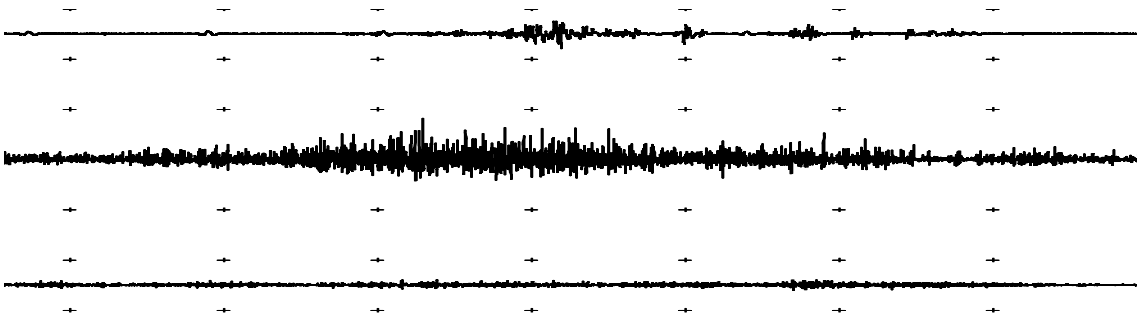

Figure 4. Typical EMG of the back, thigh, and shank (in order from top to bottom) of children aged 5-6 years while holding the «Flamingo» pose with the dominant eye closed.

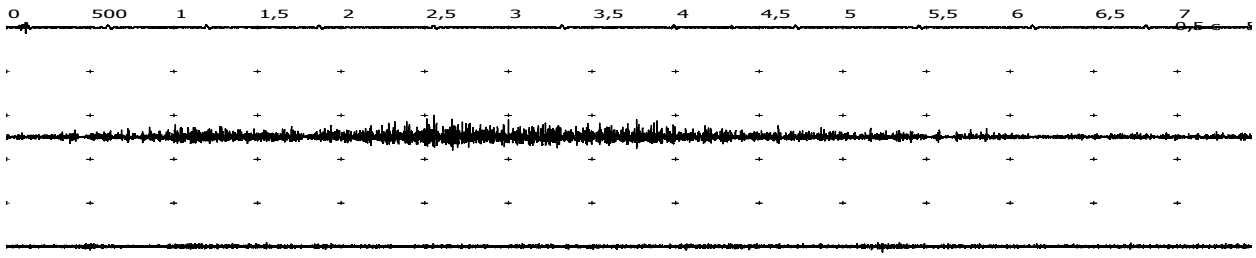

Figure 5. Typical EMG of the back, thigh and shank (in order from top to bottom) of children aged 5-6 years while holding the «Flamingo» pose with the subdominant eye closed.

stability allows us to conclude that the greatest resistance to the narrowing of the sight space is typical of the shank muscles, where the uniform type of pattern is maintained for all modes of sight and the maximum amplitude of the EMG signal increases only when the dominant eye is closed.

The lowest resistance to the narrowing of the sight space is typical for the thigh muscles, in which disruption of the uniform type of EMG and a significant increase in the maximum amplitude of the signal are observed in the implementation of all methods of monocular sight.

Studying the set out above changes of the bioelectric activity of postural muscles at changing the sight methods enables us to classify three types of the obtained EMG: the stable type — characterized by a uniform display of amplitude fluctuations of the bioelectric activity of the postural muscles; the undulating type — characterized by irregular undulating amplitude fluctuations of the bioelectric activity of the postural muscles; and the burst type — characterized by sharp bursts of the bioelectric activity of the postural muscles.

Lack of volume of the information flow in the circumstances of the sight space narrowing reduces the quality of the mechanism of maintaining postural stability, the structural units of which are categorized into two groups:

- Information-dependent elements (on the narrowing of the sight space) of the mechanism of maintaining postural stability, which includes the postural thigh and back muscles. The information flow narrowing at closing the subdominant eye destabilizes the bioelectric activity of the thigh muscles and the dominant eye closing destabilizes the bioelectric activity of the back muscles on top of that;

- An information-independent element (from the sight space narrowing) of the mechanism of maintaining postural stability are the shank muscles. The information flow narrowing at the subdominant eye closing does not affect the bioelectric stability of the shank muscles and the dominant eye closing only leads to an increase in the amplitude parameters of the bioelectric activity while maintaining the shape of the pattern.

4. Conclusion

The increase in the single movement implementation time is caused by the reduction of the bioelectric activity of the muscle involved in its implementation. The reduction in the bioelectric activity is characterized by significant reduction in the maximum amplitude of the EMG signal and smoothing of the burst waveform of the bioelectric activity in the EMG pattern at the time of the movement implementation. In addition, the sight space narrowing results in the unsuccessful first attempt for more than 40% of the tested persons, the change in the initial and final position of the body when implementing the motor action. Thus, the quality of the implementation of a single movement in the age of five is determined by the binocular sight under the leadership of the dominant eye. By the age of six years, this dependence is eliminated. The sight space narrowing when closing any eye does not affect the duration of catching a falling object. These results confirm the plasticity of the monocular sight systems in the conditions of spatial vision, the staged and heterochronic nature of the formation of mono- and binocular sight, and the functional nature of the monocular vision asymmetry.

When the subdominant eye is closed (dominant eye sight), disruption of the bioelectric stability of the postural thigh muscles is observed, which is characterized by the change of the uniform EMG waveform for the undulating one. At closing the dominant eye (subdominant eye sight), disruption of the bioelectric stability

along with the thigh muscles is typical of the postural back muscles, as well, which is manifested in the change of the uniform EMG waveform for the burst one. Thus, within the same time frame of holding the "Flamingo" pose, the quality of the mechanism for maintaining the postural stability remains different. Deterioration of the postural stability quality is determined by the decrease in the volume of visual information for all methods of monocular sight.

5. Summary

- At the binocular sight method, the largest increase in the bioelectric activity at catching a falling object appears in the deltoid muscle's work, in which the amplitude of the EMG signal equals to 742.0±57.7 μV; the amplitude of the EMG of the biceps is 106.0±26.5 μV; and the forearm muscles' amplitude is equal to 70.8±18.0 μV.
- With the dominant eye closed, a falling object catching is characterized by: a decrease in the bioelectric activity of the deltoid muscle due to the reducing average value of the maximum amplitude of the EMG signal from 742.0±57.7 μV to 402.0±48.2 μV in children who had the leading right eye and from 802.0±91.2 μV to 511.6±61.0 μV in children who had the leading left eye; smoothing of the burst waveform of the bioelectric activity at the initial moment of movement in the deltoid muscle EMG pattern; a significant increase in the catching time; an unsuccessful first attempt for more than 40% of the tested persons; a change in the direction of the head in the initial position; a posture change at the time of capturing the falling object. When the subdominant eye is closed, no significant changes in the characteristics of the falling object catching are observed. The sight space narrowing at closing the subdominant eye during holding the "Flamingo" pose leads to disruption of the bioelectric stability of the postural thigh muscles, characterized by the change of the uniform EMG waveform for the undulating one and a significant increase in the maximum amplitude of the EMG of the back and thigh extensor muscles. This sight space narrowing by closing the subdominant eye is not reflected in the bioelectric activity of the shank muscles, EMG of which has no significant differences from EMG obtained at holding the "Flamingo" pose in the conditions of binocular sight. The sight space narrowing when the dominant eye is closed leads to disruption of the bioelectric stability of the postural back and thigh muscles, which is characterized by the change of the uniform EMG waveform of the back muscles for the burst waveform and an increase in the amplitude of the undulating bursts on the EMG pattern of the thigh muscles. Herewith, closing the dominant eye does not affect the EMG pattern of the shank muscles, which is characterized by the uniform type of the bioelectric activity, manifesting itself at the binocular sight and at the subdominant eye sight.

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