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DYNAMICS OF THERMOGRAPHIC AND NEUROLOGICAL DATA IN ASSESSING THE EFFECTIVENESS OF REHABILITATION OF CHILDREN 5-8 YEARS OLD WITH SPASTIC FORMS OF CEREBRAL PALSY

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Introduction

Spasticity is one of the leading clinical symptoms of spastic forms of cerebral palsy (CP), which can also lead to the development of secondary musculoskeletal problems. Thermal imaging has indisputable advantages allowing this technique to occupy its own place among the methods for motor disorders objectifying [1]. Search and analysis of thermal imaging signs of normalization of peripheral thermoregulation - a promising area of research on the effectiveness of rehabilitation of children with CP.

Hypothesis

comparison of the initial status and response to standard motor load before and 1 year after treatment shows the direction of changes and may indicate the effectiveness / ineffectiveness of therapy.

The aim was to search for predictors of a positive rehabilitation prognosis for children with cerebral palsy based on a dynamic study of their thermal imaging characteristics in comparison with a neurological assessment.

Methods

20 children aged 5-8 years with spastic forms of cerebral palsy and functioning at Gross Motor Function Classification System (GMFCS) levels I or II participated in the study. CP was identified using ICD-10 codes G80.1 - diplegia (10 children) and G80.2 - hemiplegia (10 children). The research had first been approved by the local ethics committee of the PIMU (protocol No.4 from 29.03.2017). Informed consent was obtained from parents and/or the legal guardians. Rehabilitation measures were carried out on the basis of the University Clinic of the Federal State Budgetary Educational Institution of Higher Education "PIMU" of the Ministry of Health of Russia in accordance with the Standards for the provision of specialized medical care to children with cerebral palsy of the Russian Federation (rehabilitation phase) [2]. Rehabilitation course included two planned hospitalizations for inpatient treatment per year, as well as outpatient observation of patients. The average duration of hospital stay was 14 days (±4). The average time of outpatient follow-up of patients between hospitalizations is 6 months (±7 days). Treatment included pharmacotherapy (muscle relaxants, botulinum therapy, neurotropic drugs, cholinomimetics, general tonic drugs), physical (exercise) therapy, mechanotherapy, physiotherapy, massage, reflexology. Orthopedic shoes were recommended for 12 patients. A neurologist, a pediatrician, a child psychologist, a physiotherapist, a reflexologist and a massage therapist participated in the rehabilitation process. Consultations of doctors of other specialties were carried out as necessary. Parents were consulted to improve their compliance. Continuous scheduled exercise therapy and massage courses were mandatory for patients between hospitalizations.

To objectify the evaluation points of the determinants, specialized questionnaires and scales were used: GMFCS, MAS (Modified Ashworth Scale for Grading Spasticity), GMFM-88 (Gross Motor Function Measure-88), MACS (Manual Ability Classification System), visual analogue scale (VAS). The thermal image was observed by a thermo-tracer (NEC TH-9100). The measurements were carried out before and 1 year after the start of rehabilitation in accordance with the protocols of thermal imaging studies [3], with our modification of positions. Our own method of active infrared mapping was applied [4]. The technique involves recording thermograms of 67 regions of interest (ROI) on the torso, upper and lower limbs before and after motor load. The standard motor load for all groups of children was biomechanical testing of 4 tasks: 1. Holding a vertical pose on the ST-150 stability platform, the test duration is 60 s. 2. 2 passes along the path of the Tekscan Walkway podographic system, duration 2-5 min. 3. 2 passes of 3 m on the left and right sides on the Simi Reality Motion Systems GmbH motion capture system (2D video analysis of movements), test duration 10-15 min. 4. Performing the Nine-hole Peg Test with dominant and non-dominant hands, test duration 5-15 min. Tests 2-4 varied depending on the child's abilities, the total time was 30-45 min. The condition was the mandatory completion of each task and a clear sequence of tests.

MS Excel 2010, Statistica 12 software, and the RStudio integrated development environment were used for data processing and analysis. The type of distribution of the studied parameters was determined using the Shapiro-Wilk test. The level of significance of differences for indicators with

a nonparametric distribution was estimated by the Mann-Whitney test (w), for indicators with a normal distribution - by the Student's t-test for unrelated samples (t). A statistically significant p value was established as $p \leq 0.05$.

Results and discussion

The neurologist criteria for classifying improvement/no improvement in the evaluation were developed by us based on [5]. The rehabilitation effect was determined based on the dynamics of domain ratings for the components "functions", "activity and participation" 12 months after the start of rehabilitation activities. The criterion for improvement was considered to be the positive dynamics of the child's condition in at least 3 domains with a change in the score by at least 1 point. 12 months after the rehabilitation measures, according to our proposed criterion for evaluating the effectiveness of medical rehabilitation, improvement was observed in 14 patients with CP.

Thermal imaging assessment. The normal distal-proximal gradient (DPG) on the extremities in children is within the following limits: hip/foot ≥0,5≤3°C with thermal asymmetry (TA) on all three segments of the lower extremities ≤0.8°C; forearm / hand ≥0,5≤2,5°C (TA on all three segments of the upper extremities ≤0.5°C) [6, 7]. Improving the symmetry of the temperature distribution on the extremities is positively correlated with improving the functional characteristics of the body, in particular, the balance function, and is a useful indicator of the effectiveness of rehabilitation interventions [1, 8].

Table 1 demonstrates the comparison of treatment results according to clinical questionnaires and thermal imaging.

The criteria for improving the functional state (group "improvement", 4 patients) were considered the following changes for the second period of the study ("after 1 year of treatment") compared to the first period ("before treatment"): 1) reduction of thermal asymmetry (TA) in the projection of muscles and muscle groups at least at one stage - initially or after exercise (in the hemiparesis group - G80.2), 2) a decrease in the inversion of the DPG on the extremities at least at one stage (in the diplegia group - G80.1).

The group "no tendency" (9 patients) included cases where thermal imaging registered indicators that did not have significant differences from the first stage.

The group "without improvement" (7 patients) included cases of deterioration (registration of an increase in TA and DPG and/or the phenomenon of "multiplication" of pathological signs: the appearance of signs of TA in the group with diplegia, and violation of DPG - in the group with hemiparesis).

Intra-group comparison before and after treatment revealed trends in a number of characteristics, but significant differences in the pre-load stage were found only in two characteristics (Fig. 1 A, B) and in the post-load stage - in one characteristic (Fig. 1 C).

The discrepancy between the results of clinical and thermal imaging analyses can be explained by the use of a large number of rating scales taking into account subjective assessment of contextual parameters of life. The observed temperature dynamics trends before the rehabilitation and after one year of treatment provide objective ground for their proof in subsequent studies.

Table 1
Comparison of treatment results according to clinical questionnaires and thermal imaging.

Patient ID	Diagnosis	Side / Paresis Level *	Improvement (●) / Without improvement (■) / No Tendency (●/■)			
			MAS	GMFCS	Neurologist Report	Thermal Imaging
101	G80.2	Right	■	■	■	■
102	G80.2	Right	■	■	■	■
105	G80.2	Right	●	■	●	●
106	G80.2	Left	■	■	●	●/■
108	G80.2	Right	●	●	●	■
109	G80.2	Right	■	■	■	■
113	G80.2	Right	●	■	●	●/■
118	G80.2	Right	■	■	■	■
120	G80.2	Left	●	■	●	●
124	G80.2	Left	■	■	●	●/■
110	G80.1	Lower limbs	■	■	●	■
111	G80.1	Lower limbs	■	●	●	●/■
115	G80.1	Lower limbs	●	■	●	●
116	G80.1	Lower limbs	●	■	●	●/■
119	G80.1	Upper limbs	■	■	■	●
122	G80.1	Lower limbs	●	■	●	●/■
125	G80.1	Lower limbs	●	●	●	●/■
126	G80.1	Upper limbs	■	■	●	●/■
127	G80.1	Lower limbs	■	■	■	■
128	G80.1	Lower limbs	■	■	●	●/■

*a child with G80.1 (diplegia) can have spasticity in both the lower and the upper limbs. Here the diagnosis was established in limbs where spasticity prevailed before the treatment.
Note: for thermal imaging evaluations, 'without improvement' rather means worsening of metrics.

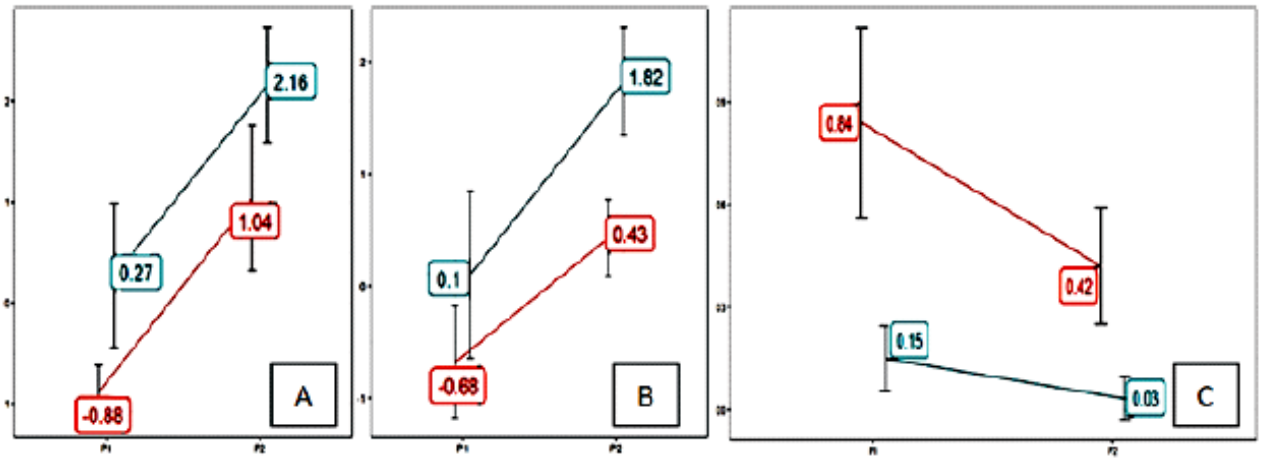

Figure 1.
Dynamics of indicators (deltas - the difference between the stages before and after treatment) by groups and visits with the significance of intra-group differences $p<0.05$: A - hip/foot PDG (left/pathology) before load,
B - hip / foot PDG (right/norm) before load, C - TA (wrist joint, outer surface) after load.
Blue color - diagrams for the group with diplegia, red color-with hemiparesis.
P1 - visit before treatment, P2 - visit after 1 year of treatment.

Conclusion: The possibilities of thermal imaging as a method for assessing motor disorders in children with spastic forms of cerebral palsy, which has the potential to create a reliable, convenient, non-invasive and high-precision method for monitoring the course of rehabilitation, are demonstrated. Increasing the sample size and further data analysis open up prospects for clarifying the objectification of neurological practice and improving the accuracy of the prognosis of the disease, as well as correcting complex rehabilitation programs for this pathology.

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