Evaluation of the dynamics of electrotensodynamometry indicators during the implementation of the physical therapy program for children aged 5–6 years with the consequences of hip dysplasia

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Abstract

Purpose: to investigate and evaluate the indicators of electrotensiodynamometry in the process of implementing a program of physical therapy for children aged 5–6 years with the consequences of hip dysplasia (HD).

Material & Methods: 131 children were examined, from which two groups were subsequently formed: the HD group (n=68) – a group of children with the consequences of HD; comparison group (n=63) – healthy children. The HD group was divided into control (n=33) and main (n=35). To evaluate the results, the method of electrotension dynamometry of the thigh muscles was used.

Results: there is an asymmetry in the development of the strength capacity of the muscles of the lower limbs (the tone of the adductor muscles exceeds the tone of the hip abductor muscles, there is an asymmetry in the muscle tone of the hip flexors and extensors when compared with an intact limb) in children with HD. A program of physical therapy (basic and variable component) for children 5-6 years old with the consequences of HD on the level of function and activity/participation of the ICF-CY was developed. The effectiveness of the program was confirmed by the dynamics of electrotensiodynamometry indicators, where the strength of the hip abductor muscles of the affected limb did not have statistically significant ($p>0,05$) differences (intact – 86,42±6,63, affected – 83,21±6,34), in contrast to the control group, where the parameters of the affected group were statistically significantly ($p <0,05$) higher (intact – 82,14±7,41, affected – 57,25±7,53).

Conclusions: the dynamics of electrotensiodynamometry indicators of the thigh muscles during the implementation of the physical therapy program for children aged 5-6 years with the consequences of HD shows the advantages of the developed physical therapy program, which was tested in the main group. Positive changes were noted in the control group, which were determined by increasing indicators of the moment of strength of the thigh muscles of the affected limb, but they did not have a confirmed statistically significant ($p>0.05$) positive effect.

Key words: physical therapy, hip dysplasia, children, electrotensodynamometry.

Анотація

Олександр Звіряка, Анна Руденко, Ольга Свєрчкова. Оцінка динаміки показників електротензодинамометрії у процесі реалізації програми фізичної терапії дітей 5–6 років із наслідками дисплазії кульшових суглобів. Мета: дослідити та оцінити показники електротензодинамометрії у процесі реалізації програми фізичної терапії дітей 5–6 років із наслідками дисплазії кульшових суглобів (ДКС). **Матеріал і методи:** проведено обстеження 131 дитини, з яких було в подальшому сформовано дві групи: група ДКС (n=68) – група дітей із наслідками ДКС; група порівняння (n=63) – здорові діти. Групу ДКС розподілили на контрольну (n=33) та основну (n=35). Для оцінки результатів використано метод електротензодинамометрії м'язів стегна. **Результати:** у дітей з ДКС спостерігається асиметрія розвитку силової здатності м'язів нижніх кінцівок (тонус м'язів-аддукторів перевищує тонус м'язів-абдукторів стегна, спостерігається асиметрія м'язового тонусу згиначів та розгиначів стегна при порівнянні з інтактною кінцівкою). Розроблено програму фізичної терапії (базовий та варіативний компонент) дітей 5-6 років із наслідками ДКС на рівні функції та активності / участі МКФ-ДП. Ефективність програми підтверджено динамікою показників електротензодинамометрії, де сила м'язів-абдукторів стегна ураженої кінцівки не мала статистично значущих (p>0,05) відмінностей (інтактна–86,42±6,63,уражена–83,21±6,34), на відміну від контрольної групи, де статистично значуще (p<0,05) перевищували показники ураженої (інтактна – 82,14±7,41 уражена – 57,25±7,53). **Висновки:** динаміка показників електротензодинамометрії м'язів стегна у процесі реалізації програми фізичної терапії дітей 5-6 років із наслідками ДКС свідчить про переваги розробленої програми фізичної терапії, яка була апробована в основній групі. У контрольній групі були відзначені позитивні зрушення, що визначалися у підвищенні показників моменту сили м'язів стегна ураженої кінцівки, проте вони не мали підтвердженого статистично значущого (p>0,05) позитивного ефекту.

Ключові слова: фізична терапія, дисплазія кульшових суглобів, діти, електротензодинамометрія.

Introduction

The prevalence of diseases of the musculoskeletal system among children of different ages does not tend to decrease over the course of a decade. Congenital pathologies of the musculoskeletal system occupy one of the first places among all intrauterine fetal anomalies (Afanasyev, Rokutov, Afanasyeva, & Proskura, 2020; Bilinsky, Urvan, & Guralnik, 2019). The incidence of hip dysplasia (HD) in the world is 1-7 cases per 1000 newborns (International Hip Dysplasia Institute; Golka, Buryanova, & Klymovitskyi, 2019; Harsanyi, Zamborsky, Krajciova, Kokavec, Danisovic, 2020; Swarup, Penny, Dodwell, 2018). This pathology, due to the untimeliness of diagnostic and therapeutic measures in early childhood, progresses and leads to negative consequences that begin to manifest themselves in preschool children.

Recent studies indicate that anatomical, functional and trophic disorders in the hip joint without adequate treatment progress with the growth of the child and lead to complex structural changes in the joint and cause functional disorders of the muscular system of the lower extremities. Weakness of the muscles of the lower limb is noticeable during the Duchenne-Trendelenburg symptom, indicating hypotrophy of the gluteal muscles (Zelenetsky, 2018). Statistical indicators of the Ministry of Health of Ukraine indicate that 12,5-20,5% of preschool children have the consequences of HD in the form of valgus and varus deformity of the lower extremities. X-shaped and O-shaped installations of the lower extremities cause physiological and biomechanical prerequisites for constant hypertonicity of individual muscles, which leads to a decrease in the tone-strength indicators of antagonist muscles and the development of pathological processes at the site of their attachment (Hip dysplasia and congenital hip dislocation in children. Evidence-based clinical guideline, 2016; Korolkov, & Mitelevoy, 2016). With the X-shaped installation, individual muscles of the thigh (extensors, adductors), lower legs (flexors, pronators) and feet (flexors, pronators) are overloaded. At the same time, the tone-strength indicators of individual muscles of the thigh (abductors, flexors), lower legs (arch supports) and feet (arch supports, extensors) decrease (Korolkov, & Mitelevoy, 2016).

Carrying out systematic treatment measures and preventing the development of complications in HD is a priority. At the same time, some programs of preschool physical education involve the use of rehabilitation and correctional measures in the presence of functional disorders of the musculoskeletal system in children. (Afanasyev, 2017; Kashuba, Nosova, & Kozlov, 2017). However, functional methods for diagnosing the condition of the thigh muscles in HD have not yet been defined and the means of physical therapy for the consequences of this pathology in preschool children have not been improved, and the formed approaches are not effective enough.

Purpose of the study is to investigate and evaluate the indicators of electrotensodynamometry in the process of implementing a program of physical therapy for children aged 5-6 years with the consequences of hip dysplasia.

Material and methods of research

Participants

The research was conducted on the basis of Sumy Petalized Preschool Educational Institution (nursery) No. 20 "Smile" and Sumy Preschool (kindergarten) No. 39 "Teremok". In order to study the features of the functional state of the musculoskeletal system of children of preschool institutions with the consequences of hip dysplasia, 131 children were performed, from which two groups were subsequently formed: the first (HD, n=68) – a group of children with the consequences of hip dysplasia (in accordance with stories about diseases, medical records), who visited a specialized group of preschool education institution; The second group (comparison group, CG (n=63)) is healthy children without clinical, radiological and ultrasound-confirmed signs of HD that visited the preschool education institution in the usual group. The implementation and efficiency of the developed rehabilitation program was already evaluated on the basis of a survey of a group of children with HD (n=68), followed by their division into two groups: control (n=33), in which children were engaged in a generally accepted program of preschool institution, and the main (n=35), which was engaged in the author's rehabilitation program. The parents of the children signed the form of informed consent to participate in the study, which was fulfilled in accordance with the ethical standards of the Helsinki Declaration.

Methods

Together with the staff of the Laboratory of Biomechanics of the State Institution "Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences of Ukraine", we used the author's original technique of electrotensiodynamometry, which allows us to ensure high accuracy in measuring the strength of the muscles of the lower extremities (Lazarev, Zviriaka, Maksymishyn, & Rudenko, 2017). The manual muscle test method (MMT) was based on the use of a mechanical effort sensor-a PMP-1 strain to measure the magnitude of the child muscles, which converts mechanical deformation into an electrical signal. Depending on the type of study, the physical therapist carried out the force of the MMT on the study segment of the extremity, after which the data was transferred to the monitor of the software and computer complex to the "EXPANDER" software environment through the analog-digital converter.

Procedure

To determine the strength of the studied muscles, the child took the appropriate starting position, taking into account the range of motion in the hip joint. The researcher was on the side of her, holding the MMT with one hand, and through it resisted active movement, holding the distal segment of the patient's limb in a static position. Testing was performed three times, registered the maximum muscle strength by MMT.

During the study, the muscles of both extremities were tested with the subsequent comparison of the affected limb with intact: thigh extension (m. Biceps femoris, m. Semitendinosus, m. Semimbranosus); thigh flexion (m. rec. femoris, m. sartorius); hip abduction (m. gluteus medius, m. gluteus minimus, m. tensor fasciae laratae); hip adduction (m. gracilis, m. adductor longus, m. adductor brevis); external rotation (m. gluteus maximus, m. gluteus medius, m. gluteus minimus); internal rotation of the hip (m. tensor fasciae latae, m. adductor longus). The methodological feature of measuring muscle strength using the technique of manual muscle testing is: the position of the limb and hands of the researcher; fixing segments; rate of movement in the joint; arm length. The latter must correspond to the shortest distance from the axis of rotation to the line of action of the force vector.

Statistical analysis

For mathematical processing of digital data of research materials, the Windows XP operating system and the Statistica 6.0 program were used. The critical level of significance when testing statistical hypotheses was taken α=0,05 ($p<0,05$).

Results of the study

The results of electrotensiodynamometry of the muscles of the lower extremities in children with HD indicated a statistically significant ($p<0,05$) decrease in the strength of the hip abductor muscles. (m. gluteus medius, m. gluteus minimus, m. tensor fasciae latae) of the injured limb relative to the intact one (intact – 85,8±6,8 N*m ($\bar{X}$±S) and affected 54,5±4,9 N*m ($\bar{X}$±S)), and hypertonicity of the adductor muscles of the thigh (m. gracilis, m. adductor longus, m. adductor brevis) from the side of the affected limb relative to the intact limb (intact – 68,2±4,4 N*m ($\bar{X}$±S), affected – 95,8±4,1 N*m ($\bar{X}$±S)).

When comparing the results of electrotensiodynamometry in children with HD and CG, it was found that the indicators of the comparison group corresponded to the average values of the intact limb indicators in HD children and did not differ statistically significantly ($p>0,05$). Thus, the indicators of the strength of the thigh abductor muscles in the CG corresponded to the values (89,2±3,8 and 87,8±5,5 N*m ($\bar{X}$±S)) and had no statistically significant ($p>0,05$) differences from the parameters of the intact limb

in children with HD (85,8±6,8 N*m (X̄±S)). When assessing the strength of the thigh adductor muscles between children with HD and CG, it was found that the indicators on the side of the lesion were higher, which we associate with pathological adductor contracture in children with HD.

According to the results of the assessment of the moment of strength of the hip flexor muscles (m. quadriceps femoris, m. sartorius), it was found that the CG indicators (120,6±6,2 N*m (X̄±S) and 124,3±5,1 N*m (X̄±S)) statistically significant (p<0.05) exceeded the results of indicators in children with HD (intact – 91,2±4,2 N*m (X̄±S), affected 75,9±4,1 N*m (X̄±S). A similar trend was revealed when assessing the strength of the hip extensor muscles (m. biceps femoris, m. semitendinosus, m. semimembranosus) between the children of the HD and the CG. Low indicators of the moment of muscle strength in the HD (affected 65,4±6,2 N*m (X̄±S) and intact 80,2±4,2 N*m (X̄±S) can be caused by asymmetry in muscle development (Table 1).

Thus, it was found that in children with hip dysplasia, there is an asymmetry in the development of the power capacity of the muscles of the lower extremities (the tone of the adductor muscles exceeds the tone of the abductor muscles of the thigh, there is an asymmetry in the muscle tone of the flexors and extensors in comparison with the intact limb) and a pronounced drive contracture in affected hip joint.

Taking into account the above principles of the study, the planning of interventions and the preparation of a physical therapy program based on the International Classification of Functioning, Disabilities and Health of Children and Youth (ICF-CY) were carried out. The planning of rehabilitation interventions was carried out in accordance with the identified problems and needs of children with the consequences of HD at the level of the function and activity/participation domains of the ICF-CY (Table 2).

The developed program of physical therapy is aimed at eliminating the consequences of corticosteroids, improving the functionality of the musculoskeletal system, strengthening the articular-ligamentous apparatus, correcting the imbalance of soft tissue components and preventing further complications in preschool children. In order to fully take into account, the features of the functional state of the musculoskeletal system, the developed program consisted of basic and variable components.

Among the differences between the two groups (CG and MG) of children with HD consequences, it should be noted that the proposed rehabilitation intervention in the MG was developed taking into account the individual functional needs of the child, filled with differentiated means and methodological features of building classes. The PT program for children from the CG included

Table 1. Results of electrotensiodynamometry of the muscles of the lower limb in children of the HD (n=68) and CG (n=63) groups at the stage of the ascertaining experiment

Indicators	Limb	Group HD affected / intact (X̄±S)	CG dex/ sin (X̄±S)	Comparison of indicators between HD and CG t-cr. Student
Moment of strength of the thigh muscles during abduction, (N m) (*muscles-abductors of the thigh*)	affected	54,5±4,9*	89,2±3,8	p≤0,05
	intact	85,8±6,8	87,8±5,5	p>0,05
t-cr. Student		p≤0,05	p>0,05	
Moment of strength of the thigh muscles during adduction, (N m) *(muscles-adductors of the thigh)*	affected	95,8±4,1*	70,5±4,8	p≤0,05
	intact	68,2±4,4	72,4±3,6	p>0,05
t-cr. Student		p≤0,05	p>0,05	
Moment of strength of the thigh muscles during flexion at the hip joint, (N·m)	affected	75,9±4,1*	120,6±6,2	p≤0,05
	intact	91,2±4,2	124,3±5,1	p≤0,05
t-cr. Student		p≤0,05	p>0,05	
Moment of strength of the thigh muscles during extension in the hip joint, (N·m)	affected	65,4±6,2*	99,3±4,7	p≤0,05
	intact	80,2±4,2	101,4±5,1	p≤0,05
t-cr. Student		p≤0,05	p>0,05	

Note: **– differences are statistically significant at p < 0,05*

Table 2. Rehabilitation interventions for children with HD consequences at the level of function and activity/participation of the ICF-CY

ICF-CY category	Problem / disorder	Intervention
b 7300	Strength of the muscles surrounding the hip joint	Exercises to increase muscle strength: with overcoming resistance (Thera-band elastic loop), with weights (balls 2 kg)
b 7603	Support function of the limb (lower limb)	Exercises for balance, coordination of movements and training of the support function of the lower limbs
d 4106	Moving the body's center of gravity in a standing position	Exercises / games for balance in a standing position
d 4154	Maintaining a standing position on different surfaces for the required time	Standing balance exercises/games on different surfaces (BOSU hemisphere, balance discs)
d 435 d 4350 d 435	Coordinated actions for moving objects with the lower limbs: Pushing an object Kick	Exercises / games with balls of different weights and diameters. Outdoor games with elements of football and floorball
d 450-469 d 4500 d 4501 d 4502 d 4503	Walking and moving: Walking for short distances Walking for long distances Walking on different surfaces Walking around obstacles	Walk-focused training

therapeutic exercises and dosed walking according to standard methods.

The results of the analysis of the dynamics of the average strength indicators of the muscles of the lower extremities using the method of electrotensiodynamometry showed that in children from the MG and the CG at the stage of the initial examination, a statistically significant ($p<0.05$) decrease in the strength of the hip flexor muscles of the affected limb relative to the healthy one was observed: in MG (intact – 91,74±6,55 N*m, affected – 73,36±7,21 N*m), ($\bar{X}$±S)), in CG (intact – 95,41±5,37 N*m, affected 75,92±7,45 N*m), ($\bar{X}$±S)) (Table 3).

In MG children who were engaged according to the developed PT program, the average statistical indicators of the strength of the flexor muscles of the intact and affected limbs did not have statistically significant differences (intact – 101,92±5,77 N*m, affected – 98,89±6,65 N*m), ($\bar{X}$±S), ($p>0,05$)). In children from the CG, who studied according to the standard program of a preschool institution, the asymmetry of the strength of the hip flexor muscles was preserved (intact – 97,58±6,21 N*m, affected – 80,12±4,26 N*m ($\bar{X}$±S), ($p<0,05$)).

Similar results were obtained during a re-examination of the hip extensor muscles of the

Table 3. Dynamics of strength indicators of thigh muscles according to electrotensodynamometry data in children of the main (n=35) and control groups (n=33) with HD before and after the physical therapy program

Researched characteristics	Limb	Before PT		p	After PT		p
		MG	CG		MG	CG	
		($\bar{X}$±S)			($\bar{X}$±S)		
Moment of strength of the thigh muscles during abduction, (N*m)	intact	85,7±6,12	83,17±8,25	p>0,05	86,42±6,63	82,14±7,41	p>0,05
	affected	54,97±4,9	55,82±7,34	p>0,05	83,21±6,34	57,25±7,53	p<0,05
Level of statistical significance		p<0,05	p<0,05		p>0,05	p<0,05	
Moment of strength of the thigh muscles during adduction, (N*m)	intact	66,89±7,98	69,92±7,16	p>0,05	75,71±7,89	73,59±8,34	p>0,05
	affected	95,83±4,72	90,18±8,04	p>0,05	80,99±3,14	91,98±6,83	p<0,05
Level of statistical significance		p<0,05	p<0,05		p>0,05	p<0,05	
Strength of the thigh muscles during flexion at the hip joint, (N*m)	intact	91,74±6,55	95,41±5,37	p>0,05	101,92±5,77	97,58±6,21	p>0,05
	affected	73,36±7,21	75,92±7,45	p>0,05	98,89±6,65	80,12±4,26	p<0,05
Level of statistical significance		p<0,05	p<0,05		p>0,05	p<0,05	
Moment of strength of the thigh muscles during extension in the hip joint, (N*m)	intact	81,12±7,62	83,24±6,43	p>0,05	90,75±8,54	89,63±6,43	p>0,05
	affected	64,52±7,82	65,01±6,57	p>0,05	88,34±8,29	75,23±5,17	p<0,05
Level of statistical significance		p<0,05	p<0,05		p>0,05	p<0,05	

Notes: *– differences are statistically significant at p<0,05

affected limb in a relatively healthy one: in MG (intact – 90,75±8,54 N*m, affected – 88,34±8,29 N*m), ($\bar{X}$±S), (p>0,05) in CG (intact – 89,63±6,43 N*m, affected – 75,23±5,17 N*m), ($\bar{X}$±S)), (p<0,05)).

In both groups of children with HD, a pronounced hypotonicity of the thigh abductor muscles was observed on the side of the affected limb (correlation coefficient between the strength of the thigh abductor muscles and the amplitude of abduction r=0,7 (strong statistically significant relationship, (p<0,05), with At the same time, the indicators between the groups at the stage of the ascertaining experiment did not differ statistically significantly (p>0,05): in the MG (intact – 85,7±6,12 N*m, affected - 54,97±4,9 N*m)), in CG (intact – 83,17±8,25 N*m, affected – 55,82±7,34 N*m)).

After the PT program, the average statistical strength of the hip abductor muscles of the intact limb in children from the CG was statistically significantly (p<0,05) higher than that of the affected one (intact – 82,14±7,41 N*m; affected – 57,25±7,53 N*m, ($\bar{X}$±S), (p<0,05)); in contrast to the results of MG, where, during abduction, the parameters of the thigh abductor muscles of the affected limb did not have statistically significant differences (intact – 86,42±6,63 N*m, affected – 83,21±6,34 N*m), ($\bar{X}$±S), (p>0,05)).

As a result of rehabilitation interventions, the average statistical indicators of muscle strength in MG children during adduction of the intact and affected limbs did not have a statistically significant (p>0,05) difference: in MG (intact – 75,71±7,89 N*m, affected – 80,99±3,14 N*m), ($\bar{X}$±S), (p>0,05)). In CG children, the parameters of the moment of strength of the adductor muscles of the affected limb compared to the healthy one was statistically significantly different (intact – 73,59±8,34 N*m; affected – 91,98±6,83 N*m, (p<0,05)).

Discussion

The study conducted at the stage of ascertaining experiment made it possible to establish the main consequences caused by early hip dysplasia in children and to identify differences in the state of the musculoskeletal system compared to healthy children. The results of the study confirmed and supplemented the data of the authors (Afanasyev, 2020; Zelenetsky, 2018; Korolkov, & Miteleva, 2016; Nosova, 2020; Yang et al., 2019) regarding the decrease in muscle strength of quadriceps femoris, m. sartorius, m. biceps femoris, m. semitendinosus, m. semimembranosus, which occurs against the background of structural changes in the osteochondral components of the joint. So, electrotensiodynamic indicators m. quadriceps femoris, m. sartorius comparison group (120,6±6,2 N*m and 124,3±5,1 N*m), ($\bar{X}$±S) statistically significant (p<0.05) exceeded the results of indicators in children with HD (intact – 91,2±4,2 N*m, affected – 75,9±4,1 N*m ($\bar{X}$±S)). A similar trend was revealed when assessing the strength of the hip extensor muscles (m. biceps femoris, m. semitendinosus, m. semimembranosus) between the children of the HD and the CG. Low indicators of the moment of muscle strength in children with HD (affected 65,4±6,2 N*m and intact 80,2±4,2 N*m) may be caused by the asymmetry of muscle development and, as a result, a violation of the gait pattern and, accordingly, less activity in children with HD. At the same time, in children with HD, a pronounced adductor contracture in the hip joint is observed, which is associated with hypotonicity of the thigh abductor muscles on the side of the affected limb (correlation coefficient between the strength of the thigh abductor muscles and the amplitude of abduction r=0,7 (strong statistically significant relationship, p<0,05).

The data (Afanasyev, 2020; Nosova, 2020; Judd, Clarke, 2014; Piechocka et al., 2018) on the positive effect of therapeutic exercises have been confirmed. Thus, under the influence of the components of the developed comprehensive PT program for children aged 5-6 years with the consequences of HD, which included, in addition to traditional activities, various special therapeutic exercises using equipment, more pronounced positive quantitative changes in the functional state of the muscles were recorded compared to the effect of generally accepted programs.

The data (Maksymenko, 2018; Cherednichenko, 2016) on the positive effect of outdoor games with elements of football and floorball on the muscles of the lower extremities of children with HD have been supplemented.

Conclusion

A comparative analysis of the dynamics of the parameters of electrotensiodynamometry of the thigh muscles in the process of implementing a program of physical therapy for children aged 5–6 years with the consequences of HD showed the advantage of the developed PT program, which was tested in the MG. The average statistical indicators of electrotensodynamometry showed that the strength of the thigh abductor muscles of the affected limb had no statistically significant (p>0,05) differences (intact – 86,42±6,63, affected – 83,21±6,34), in contrast to the CG, where statistically significant (p<0.05) exceeded the parameters of the affected (intact – 82,14±7,41 affected – 57,25±7,53). At the same time, positive changes were noted in the CG, which were determined by an increase in the moment of strength of the thigh muscles of the affected limb, but they did not have a confirmed statistically significant

(p>0,05) positive effect.

Conflict of interests

The authors declare that there is no conflict of interest that could be perceived as capable of prejudicing the impartiality of the article.

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