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The effect of physiotherapy on the symmetry of passive mechanical properties of muscles of children with and without cerebral palsy

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1. Introduction

The majority of skeletal muscles are located on the left and on the right sides of the human body. All people have usually higher or lower asymmetry of skeletal muscles, because of scoliosis, posture dysfunctions, improper training, some diseases, and cerebral palsy (CP). Thus, asymmetry of muscles can stimulate posture dysfunctions, scoliosis, and spinal pain [1-4].

The symmetry of muscles is usually assessed by measuring muscle force, electromyography, and flexibility of both body sides copulas [5-7]. To our knowledge no method has been propposed to assessment the passive mechanical properties of skeletal muscles symmetry in the literature.

The active and passive mechanical properties of muscles are distinguished. The active properties are characterised by the force developed by affected muscle fibre, length-tension, load-velocity, and force-time relationships of the muscle [8-10]. The passive properties are impacted by parallel muscle's and in series with other elastic components. They are characterised by muscle's stiffness, tone (frequency of the damping oscillations), and elasticity (logarithmic decrement of the damping oscillations). A device myotonometer "MYOTON-3" produced in Estonia allows measuring these mechanical muscle properties [11]. Myotonometry is characterised as a non-invasive method for assessment of muscle's viscoelastic properties [12, 13].

The tone of skeletal muscle denotes the mechanical tension in the muscles which cannot be lessened voluntarily. The tone of the nervous-muscular complex is maintained by the central nervous system and cellular tone [14]. The muscle tone can be assessed in various ways. It can be measured most objectively by using instrumental research methods. By using the myotonometer "MYOTON-3", the muscle tone is assessed as relaxed muscle's oscillation frequency [15].

Stiffness characterises of the muscle ability to resist the changes of its shape caused by external forces. When muscles are stiffer, more force is needed to strain the antagonist muscles. It decreases the energy expenditure economy during movement. Big asymmetry in stiffness of the right and left body side can cause the disturbances in the movement rhythm. In case of decreased stiffness, the resistance of antagonist muscles will be smaller [14, 16].

In adolescence period, motor abilities are being most rapidly developed; due to various factors, posture disorders leading to more serious pathologies occur. Comparison of the parameters characterising the muscle condition for different body sides is particularly informative considering potential pathologies; a great difference may indicate a heightened risk of pathological states [14].

The aim of this work is to investigate whether physiotherapy exercises can decrease asymmetry of passive mechanical properties of skeletal pair muscles in control children who had no physical or motor impairments and those with CP.

2. Subjects and methods

The evaluation was carried out on 17 children (10 boys and 7 girls) between the ages of 8-16 years (the average age was 12.2 ± 0.72 years) . Seven children (5 boys and 2 girls) with cerebral palsy were treated during 10 sessions of physiotherapy on the therapeutic ball that simulates three-dimensional movements. During one session, the subjects performed pelvic in all directions for 10 minutes. The duration of the session was 30 minutes. There were 10 children (5 boys and 5 girls) without any physical and movement impairments as a control group. The local ethics committee approved the study (No. 158200-11-069-31).

Stiffness and tone (frequency of muscle oscillations) of the both left and right sides of the lumbar erector spinae (ER) and gluteus medius (GM) muscles were investigated.

Measurements were carried out after the subjects relaxed their muscles while lying on stomach and standing. Before measurement the required points were marked and measurement was performed for 10 times in the same place, used index averages for calculations. Mechanical properties of the muscles were investigated before starting the physiotherapy session (pre-test 1), after the first session (post-test 1), before the last session (pre-test 2) and after the last session (post-test 2).

Passive mechanical properties of the muscles were measured by using MYOTON-3 device designed in University of Tartu, Estonia [11]. It using of acceleration probe to record the reaction of the peripheral skeletal muscle or its part to the mechanical impact and the following analysis of the resulting signal with the aid of the personal computer. Myoton exerts a local impact on the biological tissue by means of a brief impulse which is shortly followed by a quick release. The tissue responded to the mechanical impact with damped oscillations. The oscillations were recorded by the acceleration transducer at the testing

end of the device. The oscillation frequency *f*, the logarithmic decrement of damping *d*, and stiffness *K* were estimated. Functioning of the device is described in detail in articles [11, 12].

Asymmetry of mechanical properties (oscillation frequency and stiffness) of the muscles by conditional values were assessed according to the formula

$$A = \left| \frac{R}{L} - 1 \right| \ 100\%$$

where *R* is the value of the right muscle's mechanical properties and *L* is the value of the left muscle's mechanical properties.

For data analysis, the software package MS Office EXCEL 2003 was employed. The arithmetical average ± standard deviation was assessed. Reliability of difference of the results was assessed by applying Student's t criterion. The level of significance *p* was preset at $p < 0.05$.

3. Results

Both control and CP children have asymmetry of muscle mechanical properties to a certain extent. Table 1 presents the data obtained at the beginning of the research when still no physiotherapy measures were being applied. While investigating all children, no statistically significant difference was observed between control children and those with CP. Additional, no significant difference was observed between asymmetry of mechanical properties before and after physiotherapy on the therapeutic ball.

Table 1

Asymmetry of mechanical properties of muscles of the investigated children

		Lying on stomach		Standing	
		Tone, %	Stiffness, %	Tone, %	Stiffness, %
Gluteus medius muscles	HT	19.6 ± 6.3	14.4 ± 4.3	26.1 ± 8.1	14.3 ± 5.6
	CP	18.2 ± 5.2	13.6 ± 7.0	14.1 ± 4.8	7.3 ± 1.8
Lumbar erector spinae muscles	HT	7.1 ± 2.2	11.4 ± 3.9	27.7 ± 9.5	20.2 ± 4.6
	CP	12.8 ± 5.8	13.8 ± 6.1	13.2 ± 4.9	14.1 ± 2.2

Note:
HT — healthy children,
CP — children with cerebral palsy,
the average ± standard deviation is presented.

Symmetry testing is particularly informative considering potential pathologies; a great difference may indicate a heightened risk of injury. The best scores are symmetrical, i.e. the parameters are as similar as possible in the corresponding muscles of both body sides and the difference should not exceed 5% (a presupposition for correct movement) [17].

That is why only those investigated children whose initial asymmetry was higher than 0.15 (15%) were chosen for further analysis. Thus, the number of the selected subjects is presented in Table 2. Similar sampling is performed by other authors, too [7].

Table 2

The number of the investigated children whose asymmetry of muscle passive mechanical properties was higher than 15%. The number in brackets indicates percentage out of the number of the investigated children

Measurement conditions	Measured value	Gluteus medius muscles	Lumbar erector spinae muscles
Lying on stomach	Tone	9 (53%)	5 (29%)
	Stiffness	6 (35%)	6 (35%)
Standing	Tone	8 (47%)	8 (47%)
	Stiffness	6 (35%)	9 (53%)

Before applying physiotherapy, asymmetry of stiffness of gluteus medius muscles was the following: 31.6 ± 5.0% while lying and 24.3 ± 7.1% while standing. After the first physiotherapy session, asymmetry statistically significantly decreased as follows: down to 7.8 ± 3.6% and 9.3 ± 3.3% ($p < 0.01$). After the last physiotherapy session, asymmetry of stiffness of gluteus medius muscles was as follows: 4.5 ± 1.2% and 4.8 ± 1.1%. The dynamics of asymmetry of stiffness of gluteus medius muscles under the impact of physiotherapy is shown in Fig. 1.

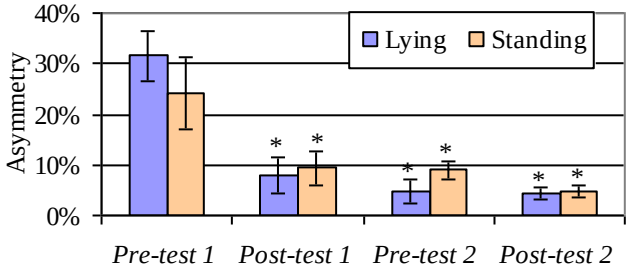

Fig. 1 The dynamics of gluteus medius muscles' stiffness asymmetry under the impact of physiotherapy. *Pre-test 1* – before physiotherapy, *Post-test 1* – after the first session of physiotherapy, *Pre-test 2* – before the last session of physiotherapy, *Post-test 2* – after the last session of physiotherapy. * – $p < 0.05$ as compared with *Pre-test 1*

At the beginning of the research, asymmetry of lumbar erector spinae was the following: 27.2 ± 5.0% while lying and 25.7 ± 3.5% while standing. After the first session of physiotherapy, the asymmetry statistically significantly decreased as follows: down to 13.2 ± 4.1% and 15.0 ± 2.3% ($p < 0.05$). After the last session of physiotherapy, asymmetry of lumbar erector spinae was as follows: 14.9 ± 3.4% and 11.8 ± 3.1%. The dynamics of asymmetry of lumbar erector spinae under the impact of physiotherapy is shown in Fig. 2.

At the beginning of the research, asymmetry of tone of gluteus medius muscles (oscillation frequency of a

muscle) was 30.9 ± 5.0% while lying and 37.2 ± 7.8% while standing. After the first session of physiotherapy, the asymmetry statistically significantly decreased as follows: down to 12.7 ± 3.1% and 19.5 ± 7.5% ($p < 0.05$). After the last session of physiotherapy, asymmetry of tone of gluteus medius muscles was as follows: 6.1 ± 1.2% and 9.6 ± 2.3%. The dynamics of asymmetry of tone of gluteus medius muscles under the impact of physiotherapy is shown in Fig. 3.

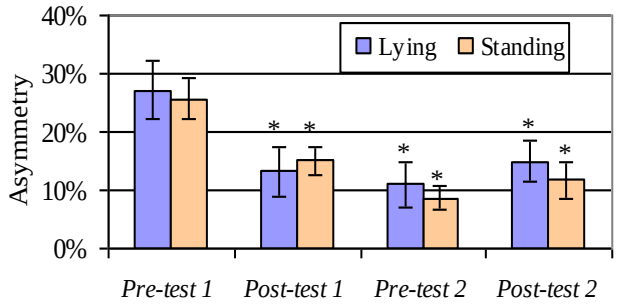

Fig. 2 The dynamics of stiffness asymmetry of lumbar erector spinae under the impact of physiotherapy (marked in the same way as in Fig. 1)

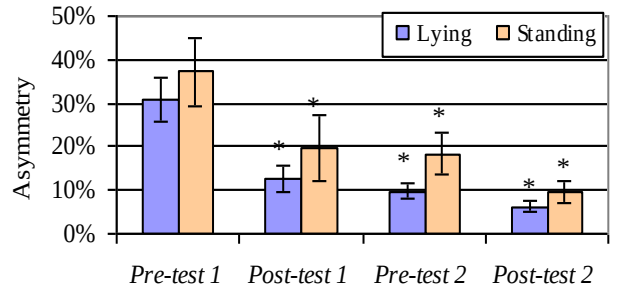

Fig. 3 The dynamics of asymmetry of tone of gluteus medius muscles under the impact of physiotherapy. Marked in the same way as in Fig. 1

Before applying physiotherapy, asymmetry of tone of lumbar erector spinae was as follows: 26.8 ± 4.8% while lying – and 26.1 ± 3.2% while standing. After the first session of physiotherapy, the asymmetry statistically significantly decreased as follows: down to 8.2 ± 3.8% and 15.8 ± 3.5% ($p < 0.05$). After the last session of physiotherapy, asymmetry of tone of lumbar erector spinae was as follows: 11.1 ± 2.8% and 9.3 ± 2.2%. The dynamics of asymmetry of tone of lumbar erector spinae under the impact of physiotherapy is shown in Fig. 4.

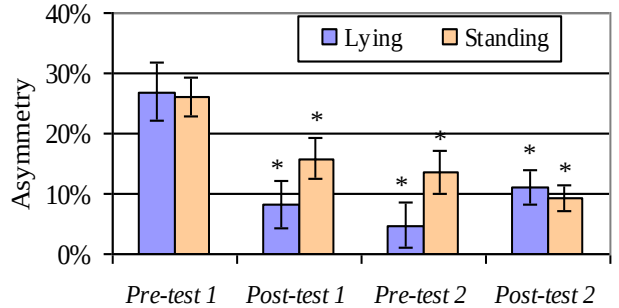

Fig. 4 The dynamics of asymmetry of tone of lumbar erector spinae under the impact of physiotherapy. Marked in the same way as in Fig. 1

4. Discussion

As hippotherapy (treatment by horse-riding) is often being applied to children with CP, the subjects performed the exercises of physiotherapy on the therapeutic ball which imitated three-dimensional movements of a horseman. It is considered that horseman's side bend and stretching with a rotation decrease spasticity of muscles. Spasticity decreases when hips are being bent, pulled back, and rotated outwards at the same time. Such rhythmic movements influence the tone of a hip and trunk muscles [18]. Three-dimensional movements obtained while moving on a therapeutic ball are identical to movements of a healthy walking man; they are transferred to legs, trunk, hip, shoulders, and arms.

A systematic review of literature on horseback riding therapy as an intervention for children with cerebral palsy showed that hippotherapy is effective for treating muscle symmetry in the trunk and hip and therapeutic horseback riding is effective for improved gross motor function when compared with regular therapy or time on a waiting list [19]. Benda et al. [7] compared the impact of electromyography on a barrel and hippotherapy on symmetric muscle activities of children with CP. The average of symmetry changes after 8 minutes of hippotherapy was 65% and after exercises on a barrel 12.8% only. McGibbon et al. [20] also proved that 10 minutes of hippotherapy significantly improved adductor muscle asymmetry ($p < 0.001$; $d = 1.32$). The effects of barrel-sitting were not significant ($p > 0.05$).

Diamano and Abel [21] determined clinical effectiveness of strength training in children with spastic cerebral palsy prospective before and after the trial in which subjects participated in a 6-week strength training programme. Asymmetry in strength improved in hemiplegia with no change in asymmetry in support times or joint motion across extremities. This study reinforced the relationship of strength to motor function in cerebral palsy and further demonstrated the effectiveness of strengthening in this population.

However, no research studies analysing whether muscles of children with CP function symmetrically and, if not, is physiotherapy on a therapeutic ball effective in decreasing asymmetry of passive mechanical properties (tone and stiffness) of children with CP. Passive mechanical properties of lumbar erector spinae and gluteus medius muscles were investigated in this study. The lumbar erector spinae extends, bends the spine sideways, and keeps proper spinal flexures. The gluteus medius muscle is important in controlling the hip's lean in frontal plane. Weakness of this muscle usually predetermines wrong or pathological walking related to increased knee bend during the support phase.

Our research results show that there was no statistically significant difference between children with and without CP; also, no significant difference was observed between asymmetry of mechanical properties at the beginning of the research and after physiotherapy on the therapeutic ball. Asymmetry of stiffness of gluteus medius muscles decreased after physiotherapy exercises to 85% while lying and 80% while standing. After the last exercises of physiotherapy, asymmetry of stiffness of gluteus medius muscles was only 4.5 ± 1.2% while lying and 4.8 ± 1.1% while standing. Insignificant difference between asym-

metry of muscle stiffness in both body sides after the last physiotherapy exercises revealed that the chosen exercises on the therapeutic ball were effective in decreasing asymmetry of stiffness of gluteus medius muscles. After muscle stiffness decreases, more force is needed for exertion of antagonists. This decreases energy expenditure while performing movements [14, 16].

Asymmetry of stiffness of lumbar erector spinae after physiotherapy exercises decreased as well 45% while lying and 54% while standing; however, it was lesser than that of gluteus medius muscles. After the last exercises of physiotherapy, asymmetry of stiffness of lumbar erector spinae was $14.9 \pm 3.4\%$ while lying and $11.8 \pm 3.1\%$ while standing. The obtained results showed that exercises on the therapeutic ball, which were applied during the experiment, only partly decreased asymmetry of stiffness of lumbar erector spinae.

Oscillation frequency depends on muscle tension (muscle tension?): the more the muscle is tightened, the higher the frequency of its oscillations is. By employing the myotonometer "MYOTON-3", the tone of a muscle is assessed as relaxed muscle's oscillation frequency [15]. Asymmetry of tone of gluteus medius muscles under the impact of physiotherapy decreased to 80% in a lying position and 74% while standing. The results obtained after the last physiotherapy exercises ($6.1 \pm 1.2\%$ while lying and $9.6 \pm 2.3\%$ while standing) showed that applied exercises decreased asymmetry of tension (tone) of gluteus medius muscles.

Asymmetry of tone of lumbar erector spinae under the impact of physical training also decreased to 58% while lying and 64% while standing. The asymmetry results obtained after the last exercises of physiotherapy ($11.1 \pm 2.8\%$ while lying and $9.3 \pm 2.2\%$ while standing) revealed that exercises on the therapeutic ball only partly decreased asymmetry of the tone of lumbar erector spinae. Increase in muscle tone disturbs the muscle's blood supply conditions, as the blood vessels of the muscle are more contracted and less blood reaches the muscle.

5. Conclusion

Exercises of physiotherapy on the therapeutic ball imitating horseman's movements decrease asymmetry of stiffness and tone of gluteus medius muscles in children with and without CP and only partially decrease asymmetry of stiffness and tone of their lumbar erector spinae.

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KINEZITERAPIJOS POVEIKIS SVEIKŲ VAIKŲ IR SU CEREBRINIU PARALYŽIUMI RAUMENŲ PASYVIŲJŲ MECHANINIŲ SAVYBIŲ SIMETRIŠKUMUI

R e z i u m ė

Darbo tikslas – ištirti, ar kineziterapijos pratimai gali sumažinti griaučių porinių raumenų pasyviųjų mechaninių savybių asimetriškumą. Tyrime dalyvavo 17 moksleivių nuo 8 iki 16 metų amžiaus. Pirmąją grupę sudarė 7 vaikai, sergantys cerebriniu paralyžiumi, antrąją grupę sudarė vaikai, neturintys fizinių ir judėjimo sutrikimų. Tiriamiesiems taikėme po 10 kineziterapijos pratimų ant terapinio kamuolio, imituojančių trimačius judesius. Raumenų mechanines savybes vertinome naudojant prietaisą MYOTON-3, kurio veikimas paremtas sukeltų gęstančių raumens virpesių matavimu ir analize. Nenustatytas statistiškai reikšmingas pasyviųjų mechaninių savybių skirtumas tarp sveikų vaikų ir vaikų su cerebriniu paralyžiumi. Parodyta, kad kineziterapijos užsiėmimai ant terapinio kamuolio, imituojantys raitelio judesius, sumažina sveikų ir vaikų su cerebriniu paralyžiumi sėdmenų vidurinių raumenų standumo ir tonuso asimetriją, o nugaros tiesiamųjų raumenų tik iš dalies.

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THE EFFECT OF PHYSIOTHERAPY ON THE SYMMETRY OF PASSIVE MECHANICAL PROPERTIES OF MUSCLES OF CHILDREN WITH AND WITHOUT CEREBRAL PALSY

S u m m a r y

The aim of the research is to investigate whether physiotherapy exercises can decrease asymmetry of passive mechanical properties of skeletal pair muscles. In this research, 17 schoolchildren from 8 to 16 years of age participated. In the first group, 7 children had cerebral palsy. In the second group, there were 10 children without physical and movement impairments. The subjects were treated with 10 sessions of physiotherapy on the therapeutic ball. Passive mechanical properties of the muscles were measence between children with and without CP was observed. The research showed that exercises of physiotherapy on the therapeutic ball imitating horseman's movements decreased asymmetry of stiffness and tone of gluteus medius muscles of children with and without CP and only partially decreased asymmetry of stiffness and tone of their lumbar erector spinae.

Keywords: cerebral palsy, passive mechanical properties, muscle symmetry.

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