The Influence of Self-Stretching Based on Postisometrical Relaxation, Static Stretching Combined With Stabilizing Exercises, and Stabilizing Exercises Only on the Flexibility of One-Joint and Two-Joint Hip Flexors

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Key Words: *flexibility of hip flexors; postisometrical relaxation; static stretching; stabilizing exercises.*

Summary. *Background and Objective. The limitations of muscle flexibility are a common dysfunction of the musculoskeletal system. Therefore, various therapeutic techniques are used in rehabilitation programs to increase their flexibility. The aim of this prospective, randomized, single-blind study was to evaluate the changes in the flexibility of hip flexors in children who participated in a 6-week therapeutic program consisting of one physiotherapy session per week with a physiotherapist and daily home exercises.*

Material and Methods. A total of 94 children aged 10–13 years were randomly assigned to 3 experimental groups: postisometrical relaxation group (PIR group), static stretching combined with stabilizing exercise group (SE/SS group), and stabilizing exercise group (SS group). To assess the flexibility of one- and two-joint hip flexors, the modified Thomas test was used. The examination was conducted by blinded observers.

Results. A significant improvement in the flexibility of one-joint hip flexors was documented in all 3 groups (P<0.01). The flexibility of two-joint hip flexors increased significantly only in the SS/SE group (P<0.05). After the program, the highest range of motion of the hip extension (test for one-joint hip flexors) was recorded in the SS/SE group (20.6°±4.5°), and it was significantly greater than in the SE group (16.6°±4.0°, P<0.05). There were no significant differences in the knee flexion (test for two-joint hip flexors) among all 3 groups (P>0.05).

Conclusions. The 6-week therapeutic program regardless of the technique applied (postisometrical muscle relaxation, static stretching with stabilizing exercises, and stabilizing exercises only) resulted in the increased flexibility of one-joint hip flexors. Only static stretching combined with stabilizing exercises led to a significant increase in the flexibility of two-joint hip flexors.

Introduction

The limitations of muscle flexibility are a common dysfunction of the musculoskeletal system among children and adults (1–5). They may lead to a decrease in the joint range of motion (ROM) (1, 6), changes in a body posture (1, 3, 7), spine deformations (8), increased likelihood of back pain (5, 6, 9), and increased risk of tendinosus and muscular injury during physical activity (10). Even a slight reduction in the extension of the hip joint limits peak extension during walking. Therefore, in order to compensate for that, the anterior pelvic tilt is increased and the stride length is shortened (11). However, it is worth noting that hip flexors are not currently referred to as a homogenous group of muscles. According to Kendall et al. (1), it is advisable to examine and, if required, carry out an exercise program for one- and two-joint flexors separately. The modified Thomas test is the test that enables to evaluate the flexibility of both types of hip flexors (1, 12–14).

A variety of methods are employed to improve the flexibility of muscles in the clinical practice. Postisometrical muscle relaxation is one of them (13, 15). It is based on a subsequent reduction in muscle tone after isometric contraction (13, 15). Moreover, static stretching, particularly when combined with exercises that activate stabilizing muscles, is considered effective in increasing the ROM (3, 16). According to Shrier (17), Sewall and Micheli (18), and Siegel et al. (19), the flexibility of muscles might be significantly influenced by performing stabiliz-

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ing exercises only. Although every aforementioned method is regarded as effective, they have not been compared in terms of their effectiveness yet. Due to the fact that each method relies on a different mechanism of affecting the musculoskeletal system, it might be expected that their impact on the changes in muscle flexibility will vary (3, 13, 15–18).

Taking into consideration a negative impact of the decreased flexibility of hip flexors on the musculoskeletal system (1, 3, 11) and the fact that various methods to stretch these muscles are often a component of rehabilitation programs, sports training, and sports classes (1, 3, 11–15, 20), it is essential to verify their effectiveness.

In the literature, studies on the effectiveness of stretching on the change in the flexibility of hip flexors and the ROM of the hip joint are still scarce. Moreover, optimal stretch parameters (duration, frequency, and number of repetitions) are constantly the subject of discussion (11). Therefore, the reliable evaluation of various therapeutic methods is of importance since it might lead to an improvement in the efficiency of therapeutic and sports programs and to lower costs of their realization.

The aim of this study was the prospective randomized single-blinded evaluation of the flexibility of one-joint and two-joint hip flexors among children enrolled into the 6-week therapeutic program consisting of one physiotherapy session per week and daily home exercises.

Material and Methods

Subjects

Initially, a total of 120 children aged 10–13 years were included into the study. The inclusion criteria were as follows: physical activity limited only to school classes (4 times per week) and no pain, injuries, or any disorders of the musculoskeletal system throughout the last year. The children who did not complete the whole study were excluded from the study (2 examinations, 1 weekly session with a physiotherapist for the period of 6 weeks). Finally, the data of 94 children (46 boys and 48 girls) were used in the analysis (Table 1). All the children attended the same school and participated in the same physical education program in school.

Table 1. Characteristics of the Study Population

Parameter	Mean	Minimum	Maximum	SD
Age, years	11.5	10	13	0.5
Height, m	1.53	1.34	1.73	0.07
Weight, kg	44.1	29.0	72.0	10.2
BMI, kg/m^2	18.6	13.2	28.2	3.4

BMI, body mass index.

Procedures

Measurement Protocol. The examination was performed twice by 2 observers who did not participate in the exercise program: directly before the therapeutic program and a week after the last session with the physiotherapist (one day after the last session of home exercises). The first observer carried out the measurement using a digital inclinometer (AMI, OPIW, Poland). Additionally, the first observer was responsible for recording the results. The second observer controlled the examination procedure (a stable and correct position of the pelvis, sacrum, and lumbar spine – flat on the table, correct position of the thigh during the measurement of the knee flexion using a goniometer). The results of only right side were used in the analysis. All the measurements were taken 3 times, and the average was analyzed.

Assessment of Flexibility of Hip Flexors. In order to assess the flexibility of hip flexors, a modified Thomas test was applied. The subjects were wearing unrestricting sports clothes and no shoes.

Modified Thomas Test. In order to assess the flexibility of one- and two-joint hip flexors, the modified Thomas test was used. The test was conducted in accordance with the methodology proposed by Kisner and Colby (12), Chaitow (13), and Aalto et al. (14). The subject was lying in a supine position on a table. The subjects' pelvis was near the edge of the table, and they were asked to hold knees close to the chest with both hands. The range of flexion in the hip that was not examined was correct when the lumbar part of the spine and the sacrum could touch the table. Then the right lower limb was lowered to the point of full relaxation and was kept in this position. The knee joint was loose, too. The second observer stabilized the pelvis and informed the first observer about its correct position. Afterwards, the first observer assessed the flexibility of hip flexors using the digital inclinometer.

For the assessment of one-joint hip flexors, the first observer placed the inclinometer (reset beforehand in a horizontal position) on the right thigh of the subject (Fig. 1). 0° indicated a neutral position of the hip joint. The flexion of the hip joint was marked with a minus sign, and the extension was indicated with no sign.

The range of knee flexion was measured in order to assess the flexibility of two-joint hip flexors. For this reason, the inclinometer was placed just below the tibial tuberosity. The position of the thigh was parallel to the ground. This position was controlled using a goniometer. The center of the goniometer was placed on the greater trochanter of the femur. The stationary arm was placed parallel to the table, and the mobile arm was adjusted to the center of tibiofemoral joint. The correct position was when the goniometer showed 0° (Fig. 2). The right lower leg was in a loose position. After being informed by the second observer that the position of the pelvis and the lower limb is correct, the first observer conducted the measurement.

Pilot Study of Reliability. Before the examination, the reliability of the measurements of the flexibility of one-joint and two-joint hip flexors was assessed (21).

Study Design. After the examination, the children were divided into 3 groups: group 1 comprised 31 children who did self-stretching according to postisometrical relaxation rules (PIR group); group 2, 31 children who performed self-static stretching and stabilizing exercises (SS/SE group); and group 3, 32 children who did stabilizing exercises only (SE group). The subjects were assigned to each group randomly by picking cards with numbers. There were no differences among groups regarding age, height, weight, body mass index (BMI), and the flexibility of one and two-joint hip flexors (Table 2). Fig. 3 displays the flowchart of the study.

Exercises. Each group underwent the 6-week therapeutic program based on one physiotherapy session and immediately following 6 sessions of home exercises done every day.

To perform exercises correctly, the children were taught how to attain and maintain the neutral position of the lumbo-pelvic (LP) area (12, 22). Each exercise session with a physiotherapist was preceded by a 5-minute exercise session aimed at increasing the ability to control the neutral position of the LP complex. The whole set of exercises took about 10 minutes (5-minute exercises to control the LP complex and 5 minutes for the main exercises). Each child received a card with instructions for home exercises (the same as the ones performed with a therapist). Therapeutic programs were conducted by physiotherapists with a minimum of 2-year experience in applying PIR, static stretching and stabilizing exercises for children. During the sessions with a physiotherapist, the presence of parents was required so that they could control exercises at home and ensure that they are performed in a proper way.

Postisometrical Muscle Relaxation Group (PIR Group). The program of postisometrical relaxation was conducted according the guidelines by Chaitow (13) and Lewit (15). In order to increase the elasticity of one-joint hip flexors, each child performed an exercise in a one-leg kneeling position (Fig. 4). In this position, the child slightly pushed the right knee to the ground. The contraction was maintained for 10 seconds and was followed by the relaxation phase with a gradual increase in the extension of the right hip joint. There were 5 sets of exercises with 10-second relaxation intervals.

Table 2. Characteristics of the PIR, SS/SE, and SE Groups

Parameter	PIR Group	SS/SE Group	SE Group	*P*
Age, years	11.4 (0.6)	11.5 (0.6)	11.5 (0.5)	0.84
Height, m	1.53 (0.07)	1.52 (0.07)	1.54 (0.09)	0.83
Weight, kg	43.5 (9.2)	45.4 (11.1)	43.3 (10.4)	0.67
BMI, kg/m^2	18.4 (3.2)	19.3 (3.6)	18.2 (3.4)	0.4
One-joint hip flexors, °	11.9 (10.6)	14.2 (9.7)	12.6 (9.6)	0.65
Two-joint hip flexors, °	68.6 (13.5)	66.0 (9.6)	66.7 (15.2)	0.71

Values are mean (standard deviation).
PIR group, postisometrical relaxation group;
SS/SE group, static stretching with stabilizing exercise group;
SE group, stabilizing exercise group.

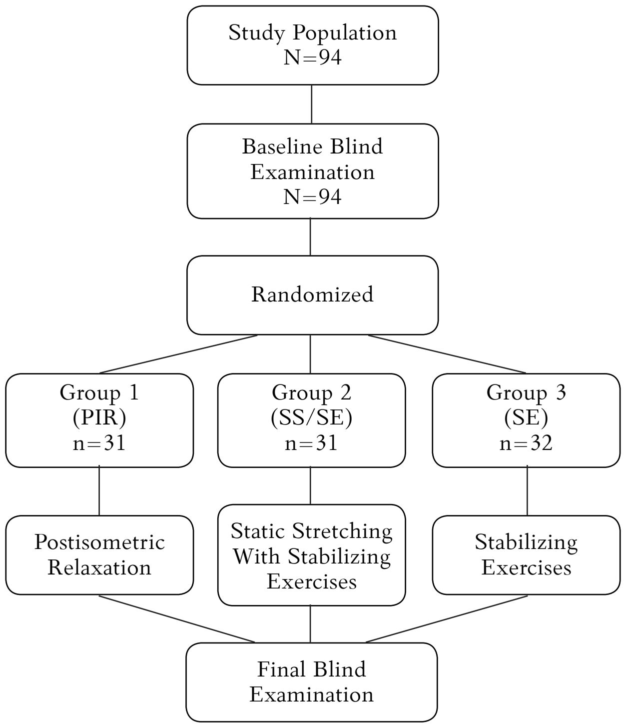

Fig. 3. The diagram of study design

In order to increase the flexibility of two-joint hip flexors, the exercise was performed in a one-leg kneeling position with the right knee flexed. The subject held the lower leg just above the foot. During the contraction phase, slight pressure was put on the right hand, but without any movement (Fig. 5). The duration of contraction and relaxation phases as well as the number of repetitions was the same as in the exercise for one-joint hip flexors.

Static Stretching and Stabilizing Exercises Group (SS/SE). The SS/SE group performed static stretching to achieve the inhibition of hip joint mobilizers in a standing position. In the first phase, the pelvis and the lumbar spine were in a neutral position (3, 16, 23). Then, the right hip and knee were

Fig. 1. Test of one-joint hip flexors

Fig. 2. Test of two-joint hip flexors

Fig. 4. Postisometrical relaxation of one-joint hip flexors

Fig. 5. Postisometrical relaxation of two-joint hip flexors

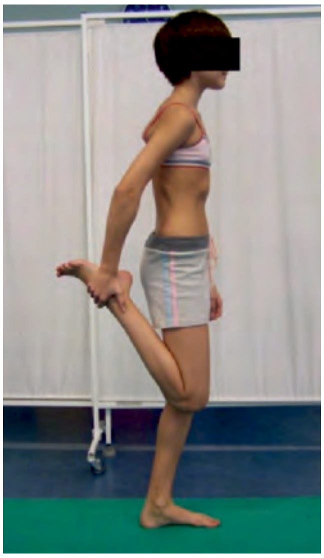

Fig. 6. Static stretching to achieve the inhibition of hip joint mobilizers

Fig. 7. Activation of the iliopsoas muscle in a sitting position

flexed. The lower leg was held with the right hand just above the foot. The pelvis and the lumbar spine were held in a neutral position, and then the hip was extended until the stretching of the hip flexors could be felt. This position was held for 30 seconds and followed by a 30-second break. The procedure was repeated 4 times (Fig. 6). To activate muscles that stabilize the right hip joint (iliopsoas muscle), 2 exercises were performed in this group (3, 16, 23). The first one was performed in a sitting position. The hip

Fig. 8. Activation of the iliopsoas muscle in a supine position (the arrow indicates the direction of motion made in order to achieve the shortening of the hip)

was actively flexed through the full ROM. During the exercise, the lumbopelvic complex was maintained in the neutral position. To avoid the activation of two-joint hip flexors (musculus rectus femoris, tensor fascie latae, and sartorius), the hip joint had to be in a neutral position in the transversal plane, and the lower leg was flexed. In case of a rotation in the hip joint and/or knee extension, the ROM of the hip flexion was reduced. The position with isometric activation was kept for 10 seconds and repeated 10 times. There was a 10-second break between repetitions (Fig. 7). The second exercise was performed in a supine lying position (Fig. 8). "The shortening of the hip" was performed in the first phase. The motion involves the elevation of the right pelvis, leading to the apparent shortening of the right lower limb. In the second phase, the heel actively slid up toward the buttocks to the level of the contralateral knee. The heel should slide only as far as the subject confidently feels that the hip is still "shortened." The duration of activation and a break as well as the number of repetitions were the same as in the first exercise. The eccentric return movement was controlled and performed at the same slow pace as the concentric component. The subjects were informed that tibial external rotation and hip rotation, abduction, and adduction should be avoided.

Stabilizing Exercises Group (SE Group). The SE group performed stabilizing exercises, which were the same exercises as in the SS/SE group, but without the inhibition phase (Figs. 6 and 7).

Before the study, all the parents gave written informed consent, which allowed their children to participate in the program. The Ethics Committee of Józef Rusiecki University College also granted permission to conduct this study.

Statistical Analysis. Statistical analysis was performed with Statistica 7.1 (StatSoft, Poland). The Shapiro-Wilk test was applied to analyze normally distributed data. Additionally, the Levene, Kruskal-Wallis, ANOVA, Tukey, and Wilcoxon tests were used. To assess the reliability level, the Cronbach α was used (21). The level of significance was set at $P<0.05$.

Results

The reliability level of the tests assessing the flexibility of one- and two-joint hip flexors was 0.98 and 0.94, respectively.

Table 3. Comparison of the Range of Motion During the First (1) and Second (2) Examinations by the Groups

Test		PIR Group	SS/SE Group	SE Group
One-joint hip flexors, °	1	11.9 (10.6)	14.2 (9.7)	12.6 (9.6)
	2	19.1 (4.8)‡	20.6 (4.5)†	16.6 (4.0)‡
Two-joint hip flexors, °	1	63.5 (8.6)	63.2 (9.4)	66.3 (9.1)
	2	68.6 (13.5)	66.0 (9.6)*	66.7 (15.2)

Values are mean (standard deviation).
PIR group, postisometrical relaxation group;
SS/SE group, static stretching with stabilizing exercise group;
SE group, stabilizing exercise group.
*$P<0.05$, †$P<0.01$, ‡$P<0.001$, the first examination vs. the second examination.

A significant improvement in the flexibility of one-joint hip flexors was observed in all 3 groups ($P<0.01$). In turn, a significant increase in the knee flexion was documented only in the group performing static stretching combined with stabilizing exercises ($P<0.05$) (Table 3).

After the program, the highest ROM of the hip extension (test for one-joint hip flexors) was documented in the group that performed static stretching with stabilizing exercises (20.6° [SD, 4.5°]), and it was significantly higher as compared with the group performing stabilizing exercises only ($P<0.05$). In turn, in the test for two-joint hip flexors (range of knee flexion), the greatest improvement was achieved in the group that performed postisometrical relaxation. However, there were no significant differences in the ROM of the knee flexion among all 3 groups (Table 4).

The greatest improvement in the hip extension was recorded in the postisometrical relaxation group (7.2° [SD, 11.2°]), but there were no significant differences comparing all the groups ($P=0.38$). The improvement in the knee flexion was greatest in the postisometrical relaxation group, too (5.1° [SD, 13.4°]), but the difference among the groups was also not significant ($P=0.28$) (Table 5).

Discussion

The aim of the present study was to determine how the flexibility of one- and two-joint hip flexors changed after the 6-week therapeutic program based on 3 methods: postisometrical relaxation, static stretching with the activation of stabilizing muscles, and stabilizing exercises exclusively, performed by

Table 4. Comparison of the Range of Motion During the Second Examination by the Groups

Test	PIR Group	SS/SE Group	SE Group	P	Tukey Test
One-joint hip flexors, °	19.1 (4.8)	20.6 (4.5)	16.6 (4.0)	0.001	SS/SE > SE
Two-joint hip flexors, °	68.6 (13.5)	66.0 (9.6)	66.7 (15.2)	0.15	–

Values are mean (standard deviation).
PIR group, postisometrical relaxation group; SS/SE group, static stretching with stabilizing exercise group;
SE group, stabilizing exercise group.

Table 5. Comparison of Differences in the Range of Motion Between the First and Second Examinations by the Groups

	PIR Group	SS/SE Group	SE Group	*P*
One-joint hip flexors, °	7.2 (11.2)	6.4 (9.9)	4.0 (8.2)	0.38
Two-joint hip flexors, °	5.1 (13.4)	2.8 (9.9)	0.4 (12.5)	0.28

Values are mean (standard deviation).
PIR group, postisometrical relaxation group; SS/SE group, static stretching with stabilizing exercise group; SE group, stabilizing exercise group.

children under their parents' supervision and once a week under the supervision of a physiotherapist.

The obtained results indicate that regardless of the method applied, the ROM of the hip joint extension increased during the analyzed period (from 11.9° [SD, 10.6°] to 19.1° [SD, 4.8°], $P<0.001$; from 14.2° [SD, 9.7°] to 20.6° [SD, 4.5°], $P<0.01$; from 12.6° [SD, 9.6°] to 16.6° [SD, 4.0°], $P<0.001$, for PIR, SS/SE, and SE groups, respectively). It is also worth noting that there were no significant differences regarding an improvement in the hip extension between the first and second examinations comparing all 3 groups (7.2° [SD, 11.2°], 6.4° [SD, 9.9°], and 4.0° [SD, 8.2°] for the PIR, SS/SE, and SE groups, respectively; $P=0.38$). However, a significantly greater angle of the hip extension after the program was recorded in the children who performed static stretching combined with stabilizing exercises compared with the children who performed only stabilizing exercises (20.6° [SD, 4.5°] vs. 16.6° [SD, 4.0°], $P<0.05$).

It worth noting that before the program, the average ROM of the hip joint extension exceeded 11° in all the groups (11.9° [SD, 10.6°], 14.2° [SD, 9.7°], and 12.6° [SD, 9.6°] for the PIR, SS/SE, and SE groups, respectively). This may indicate that the iliopsoas muscle was not shortened. It is in accordance with assumptions put forward by Sahrmann (3) as well as Comerford and Mottram (16, 23), who reported that this muscle, fulfilling a stabilizing function, was more prone to be weakened than shortened. According to these authors, the two-joint hip flexors, which can also affect the knee joint, are often shortened and, therefore, are more responsible for the limitation in the ROM of the hip (3, 16). It may be due to the fact that two-joint muscles, which function as joint mobilizers, are global muscles unrelated to the stabilizing system (3, 16, 24). The reduction or lack of stimulation of stabilizing muscles (one-joint) may create an incorrect, hyperactive pattern of two-joint muscle activity and the limitation in the ROM (3, 24). Therefore, the aim of the exercises should be to inhibit hyperactive muscles, which can be achieved when the nervous system reacts to the elongation of these muscles, and to activate the inhibited muscles (3, 16). The connection of these exercises may be more effective in increasing the ROM due to the correction of muscles activity pattern (3, 16).

The outcome of the present study that the flexibility of two-joint hip flexors significantly increased only in the children performing static stretching and stabilizing exercises (the change from 63.2° [SD, 9.4°] to 66.0° [SD, 9.6°], $P<0.05$) confirm the suggestions by Sahrmann (3) as well as Mottram and Comerford (16). However, there was no significant difference in the change in the flexibility of two-joint hip flexors between the first and second examinations comparing all 3 groups (5.1° [SD, 13.4°], 2.8° [SD, 9.9°], and 0.4° [SD, 12.5°] for the PIR, SS/SE, and SE groups, respectively; $P=0.28$). Therefore, it seems that further research concerning the influence of static stretching with stabilizing exercises on a change in the muscle flexibility is needed.

The third method applied in this study involved stabilizing exercises only. These exercises are usually used to increase muscle activity. However, some studies have shown that this training may also have a positive influence on muscle flexibility (17–19, 25). The results of the present study showed that a daily activation of the iliopsoas muscle led to a significant increase in the ROM of the hip joint extension. On the other hand, no significant increase in the flexibility of two-joint hip flexors was found. According to the authors this might be due to the lack of techniques concerning the elongation of contracted muscles, and consequently stabilizing exercises may not be as efficient in increasing muscle flexibility as the exercises involving stretching techniques.

It is also worth noting that although the observers used the same instructions and followed the same guidelines, some children needed more detailed instructions and assistance to perform the exercises correctly. However, in our opinion, it did not change the results considerably because the likelihood of the presence of children who need more assistance was the same in each of the groups. A similar conclusion was drawn by Schuback et al. (2). For the same reason, the different levels of engagement in performing home exercises might also be insignificant. Schuback et al. reported that there was no difference in the efficiency between exercises performed at home and those done with a therapist (2).

The assessment of efficiency of stretching exercises is usually based on changes in the ROM. To assess the flexibility of hip flexors, the measurement of hip extension and knee flexion is commonly used (14, 26, 27). Particularly, a modified Thomas test gives such a possibility (1, 12, 13, 28–31). This test represents not only the ROM of the hip joint but also of other joints (e.g., knee joint) (14). As the knee flexion may be limited by various muscles (rectus femoris, tensor fasciae latae, and sartorius), we used the terms *one- and two-joint hip flexors* in the present study as suggested in the literature (1) instead of referring to particular muscles. The evaluation of measurement reliability of the flexibility of one- and two-joint hip flexors revealed that the reliability level was higher than 0.9. According to Bland and Altman (21), this signifies an excellent reliability.

The decreased flexibility of hip flexors has a negative influence on the musculoskeletal system and may lead to the following: 1) body posture disorders, 2) the increase of lumbar lordosis, and 3) increased risk of low back pain (1, 3, 5, 6, 9, 11–13, 20). Shortening of hip flexors is also typical of children with Scheuermann's disease (8). Additionally, even a small reduction in the ROM of the hip extension leads to an increase in the anterior pelvic tilt and the shortened stride length (1, 11). Therefore, rehabilitation programs involve a great variety of different techniques in order to increase the flexibility of hip flexors (11, 12, 14). Postisometrical relaxation and static stretching is one of the most commonly used technique (3, 13, 15, 16). Recently, it has been suggested that the static stretching technique should be combined with stabilizing exercises in order to enhance the effectiveness of the former (3, 16). However, to our knowledge, no studies comparing the efficiency of exercise programs employing the abovementioned exercises in order to change the flexibility of one- and two-joint hip flexors among children have been conducted. Therefore, the present study fills this gap in the literature. However, it makes it impossible to relate the obtained results to those of other publications. Therefore, it seems to be vital to carry out further research assessing the influence of various stretching exercises on the change in the flexibility of hip flexors in children.

Conclusions

The 6-week therapeutic program consisting of one session per week with a physiotherapist and daily home exercises regardless of the technique applied (postisometrical muscle relaxation, static stretching with stabilizing exercises, and stabilizing exercises only) resulted in the increased flexibility of one-joint hip flexors. Only static stretching combined with stabilizing exercises led to a significant increase in the flexibility of two-joint hip flexors.

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Statement of Conflict of Interest

The authors state no conflict of interest.

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