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Research article

The role of physical exercise in the rehabilitation of children with surgically treated unilateral slipped capital femoral epiphysis

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Abstract: Slipped capital femoral epiphysiolysis (SCFE) is a multifactorial pathology; the major predisposing factor is obesity. The main objective of our study is to underline the importance of early rehabilitation in functional recovery of children with operated unilateral SCFE. 30 patients with unilateral SCFE treated by in situ fixation with a percutaneous screw have been evaluated using the Harris Hip Score (HHS) before surgery, 7 days post-op and three months post-operatively. The 30 patients participating were divided into two groups: group 1 (15 patients who followed a physical exercise program: aerobic cycling, strength training, proprioceptive exercises) and group 2 (15 patients who did not undergo rehabilitation). There were no significant differences between the two groups before sur-gery and after one week evaluations. After 3 months, the HHS was significantly higher for group 1. The group that followed a physical exercise program after surgery (group 1) had better functional outcomes after 3 months in comparison to the group without a physical exercise program (group 2) (mean difference of HHS: 49.26 for group 1, 36.17 for group 2). Regarding body mass index (BMI) we noticed that patients in group 1 had statistically significant lower values at 3-month assessment when compared to before surgery (24.26 ± 2.21 vs. 26.03 ± 3.41, p=0.0003). For group 2 patients there were no differences of BMI be-tween the two evaluations (26.83 ± 2.54 vs. 26.95 ± 2.66, p=0.15). There were statistically significant differences between the two groups at 3-month assessment, with patients in group 1 having a decreased BMI. Early postoperative physical therapy after SCFE surgery improves functionality and hip range of motion, reducing pain and having a beneficial ef-fect on weight loss.

Keywords: slipped capital femoral epiphysis, physical exercise, assessement

1. Introduction

Slipped capital femoral epiphysiolysis (SCFE) is one of the most common hip pathologies in adolescents with an incidence that is growing in the last years. Even though the typical patient with SCFE is an obese adolescent who presents with hip pain, this pathology can appear in normoponderal children aswell. This beeing said, SCFE must be included in the differential diagnosis in any scheletaly imature child that presents with hip or knee pain. When the pathology is not diagnosed and early

therapeutic measures are not taken, the disease can lead to long term severe consequences with great negative impact on functionality and quality of life [1].

SCFE implies the displacement of the proximal femoral metaphysis in relation to a fixed intra-articular epyphysis, which usually happens during an episode of rapid growth. Patients with this particular pathology have typical clinical, hystological and radiological caracteristics. Hip pain or knee pain in a patient between 10 and 16 yrs. old is a positive diagnostic indicator [2].

In children with SCFE, the femoral neck slips in an anterior and superior direction along the growth plate while the femoral head remains in the acetabulum. It is a multifactorial disease but the main predisposing factor is obesity [3] associated with the severity of the slippage of the proximal femoral epiphysis in children that develop SCFE [4].

Symptoms that guide the clinician to request imagistic evaluation of the hip include a vicious posture with the affected hip held in external rotation, slight abduction and flexion, with limited weight bearing and pelvic tilt, in a child with obesity, pain located typically in the groin area and/or knee pain with limping.

Obesity in children is strongly associated with the risk of SCFE [5] the magnitude of the association and temporal relationship providing the strongest evidence supporting a causal association [6].

Among the aetiological factors of SCFE both biomechanical and biochemical are implicated, with stable and unstable SCFE occurring more frequently in boys than girls and in certain racial groups, and the majority of children with SCFE are obese [7].

Functionality and quality of life in these children are strongly influenced, and without optimal treatment as early as possible, long term complications can be severe.

There is no standardised protocol for post-surgery rehabilitation in children with operated SCFE, and in the absence of such protocols, the experience of the medical team treating these patients is the basis for the recovery of post-surgery functionality and is the subject of the present study, and we hope that the results obtained will allow us to recommend the integration of structured exercise in post-surgery care guidelines for SCFE.

Early postoperative and sustained medical rehabilitation treatment has an important role in recovering hip function and preventing long-term functional complications in children with operated SCFE.

2. Materials and Methods

2.1.Parcicipants

All subjects included in the study participated voluntarily, their legal guardians signed a written informed consent giving their consent to participate, but also that the data obtained from the assessments and images obtained during the rehabilitation program to be used for scientific purposes only. The Ethics Committee of "Victor Babes" University of Medicine and Pharmacy of Timisoara approved the present study (approval no. 46/02.10.2023), thus complying with the Declaration of Helsinki.

The study was carried out between November 2023 and October 2024, in the Medical Recovery Department, "Louis Turcanu" Children's Emergency Hospital, Timisoara, and included a total of 30 children with unilateral femoral epiphysiolysis operated in the Pediatric Surgery Department of the same hospital. The inclusion criteria were: children with unilateral femoral epiphysiolysis, the type of surgery was ”in situ” percutaneous screw fixation, the affected leg was the dominant leg (affirmative). Exclusion criteria in the study were: febrile/infectious conditions, neuro-psychiatric diseases, avascular necrosis of the femoral head, chondrolysis of the hip joint, lack of compliance of the child and family, other musculoskeletal malformations with impact on stability and gait.

The 30 patients participating in the study were divided into 2 groups: group 1: 15 patients with SCFE who benefited from a physiotherapy program and group 2: 15 patients with SCFE who did not undergo physiotherapy and early recovery. A sample size analysis was performed using the G*Power 3.1.9.7 software (Heinrich-Heine-Universität, Düsseldorf, Germany). For a power of 70%, alpha = 0.05 and an estimated effect size of 0.9, the number of subjects for each group should be at least 13.

Patient distribution across the two groups was made according to the compliance of the children and their relatives. A total of 15 subjects agreed to the 3 evaluations, but refused to be included in a rehabilitation program without specifying the reasons for refusal.

The surgical intervention was performed by the same pediatric surgeon and the same technique was used in all 30 children: in situ percutaneous screw fixation of the SCFE.

For percutaneous "In Situ" screw fixation of Slipped capital femoral epiphysis, the patient is placed supine on the orthopedic table, we position the lower limb in internal rotation with the patella facing anteriorly and the hip in abduction. No reduction maneuvers are made before, during and after positioning the patient on the orthopedic table **(Figure 1-a).** The image intensifier is used in order to obtain good intraoperative frontal and lateral views of the femoral head and neck. First we must identify the desired direction of the screw and we are doing that by placing a k-wire on the surface of the hip and using the image intensifier, we are marking on skin with a surgical skin marker the position of the k-wire in both the AP and lateral views. Under fluoroscopic guidance a k-wire is inserted in the direction of the capital epiphysis centre, perpendicular to the physis, from the anterior cortex of the base of the femoral neck **(Figure 1-b).** We measure the length of the needed screw by inserting a second k-wire against the femoral neck, parallel with the first one, the length of exposed end of the second k-wire will be the length of the screw. Next on the guidewire we drill with the cannulated drill bit, under fluoroscopy in order to avoid accidental penetration of the guidewire in to the joint or pelvis. For fixation, 6.5 mm or 7.0 mm cannulated screws are used. We place the screw on the guidewire and we are inserting it under fluoroscopy to the centre of the femoral head position, at the end we take several intraoperative radiological exposures in standard and different oblique views to detect if a the screw is correctly placed and has not penetrated in to the hip joint **(Figure 1-c).**

(a) **(b)** **(c)**

Figure 1. (a) Positioning on the operating table; (b) Guide wire placement; (c) Screw insertion

Data collected from the study participants included: age, hight and Body Mass Index **(Table 1).** The two groups were homogenous in terms of anthropometrical characteristics. Height, weight and BMI were also recorded after 3 months.

Table 1. Patients' characteristics at the beginning of the study (before surgery)

Variables	Group 1 (N=15)	Group 2 (N=15)

Ages (years) *	14.07 ± 2.52	14.07 ± 2.05
Gender		
Male, N (%)	12 (80%)	11 (73.33%)
Female, N (%)	3 (20%)	4 (26.66%)
Height (cm) *	164.2 ± 8.64	164.2 ± 8.98
Weight (kg) *	70.43 ± 12.52	73 ± 11.45
BMI (kg/m²)*	26.03 ± 3.41	26.95 ± 2.66

* Data are presented as mean ± standard deviation (range); N: number of patients; BMI: body mass index.

2.2.Assessment

All 30 patients participating in the study (both groups) were evaluated with the Harris Hip Score (HHS) each receiving three assessments: before surgery, at 7 days postoperatively (in group 1 patients before initiation of rehabilitation treatment) and at 3 months postoperatively (in group 1 patients 11 weeks after initiation of rehabilitation treatment).

The Harris score is the most commonly used tool to measure hip function, various hip disabilities and, in particular, the results of hip surgery [8,9].

The Harris Hip Assessment Score is an easy-to-use tool that requires no pre-application training, requiring only a goniometer to assess range of motion. It comprises 10 questions divided into four domains that assess: pain, functionality, deformity and hip range of motion. The total score can range from 0 to 100 points. A score <70: shows poor hip status; a score of 70 - 79: fair hip status; 80 - 89: good hip status and 90 - 100: excellent hip status [10].

The pain-addressing section of the Harris Pain Score measures the severity of the pain, as well as its impact on activities of daily living and the need for pain-suppressing medication. The functionality section is divided into activities of daily living and walking ability. The first two sections are completed by the patient or caregiver. The section assessing deformity includes hip flexion posture, abduction, abduction, external rotation, and limb length discrepancy, and the movement section assesses active hip movements (flexion, abduction, adduction, and external rotation movements). These last two sections require evaluation by the physiotherapist or physician for correct completion of the evaluated parameters [11].

Patients in both groups had their body mass index (BMI) determined before surgery and at 3 months postoperatively, the formula including anthropometric data: height and weight: BMI = [(weight in kg) / (height in meters x height in meters)] [12].

The same scales were used to determine the weight and the same thalliometer to determine the height of the subjects, the assessments being performed in the morning without walking and at a similar interval for all participants.

2.3.Physical Exercise Program

Postoperatively, after 7 days, 15 patients (group 1) were included in a medical rehabilitation program consisting of specific physical exercises. The initiation and practice of the exercise program was performed in a specialized rehabilitation center under the supervision of a physiotherapist for 3 weeks, 2 sessions of 45 minutes/day, 5 days/week.

During these rehabilitation sessions the subjects practiced and correctly learned an exercise program adapted to be performed at home in the following period. After this stage, the exercise program was performed at home daily by all subjects for 8 weeks, 40-50 minutes/day.

The exercise program applied in the rehabilitation center in the postoperative period had the following objectives: increasing joint mobility at the hip (abduction and adduction movement, internal and external rotation, hip flexion and extension), increasing the strength of the gluteal and thigh muscles on the affected side, progressive re-education of walking with aids (walking frame/carts) with progressive loading and later without aids, proprioceptive re-education and re-education of stability both static and when walking.

The objectives of the exercise program performed at home during the 8 weeks were to increase the strength and endurance of the affected hip and thigh muscles, to increase stability and re-educate gait, but also to reach higher intensity training with increased energy consumption and reduce excess weight, where necessary.

The exercise program applied to the subjects participating in the study was individualized for each case and took into account the age of the participants, their individual physical abilities, pain intensity and functional capacity, as well as their compliance to rehabilitation therapy. The design of the applied exercise program was based on the therapist's personal experience and did not follow a standardized, homologated protocol, but followed the general principles of postoperative hip rehabilitation in order to achieve the proposed objectives **(Table 2).**

The exercise program is detailed in Table 2**,** where the progression of the resistance applied to the movement or loading of the operated lower limb during the 11 weeks of medical rehabilitation is shown:

- in week 1: free active movements were performed 3 sets x 8 repetitions/exercise and walking 5 x 10m/day - with loading of the operated lower limb 10%-3 days and 20%-4 days
- in week 2: active movements with weights of 0.5 kg, 3 sets x 10 repetitions/exercise and walking 5 x 10m/day - with loading of the operated lower limb 30%-3 days and 50%-4 days
- in week 3: active movements with weights of 1-1,5 kg, 3 sets x 12 repetitions/exercise and walking 5 x 20-30m/day - with 70% load on the operated lower limb for 3 days and 100% thereafter
- in week 4-11 (at home): active movements with weights of 1-1,5 kg, 3 sets x 15 repetitions/exercise and walking with 100% loading of the lower limb operated 3-5 sets x 100-200m/day (walking on flat ground, over obstacles, up and down steps)

Post-surgery in the first 2 weeks pain was present in all patients with an intensity ranging between 3-6 on a visual analogue scale in week 1 and between 2-4 in week 2, where 10 represents the maximum pain intensity and 0 represents the absence of pain, this being the consideration that led to the initiation of active physiotherapy programme from day 8 without resistance and only from week 2 exercises with 0.5 kg weights were performed.

From week 3, active movements were performed with weights varying between 1 kg and 1.5 kg, taking into account the age of the participants, which varied between 11.5 and 16.5 years and the individual physical tolerance to effort.

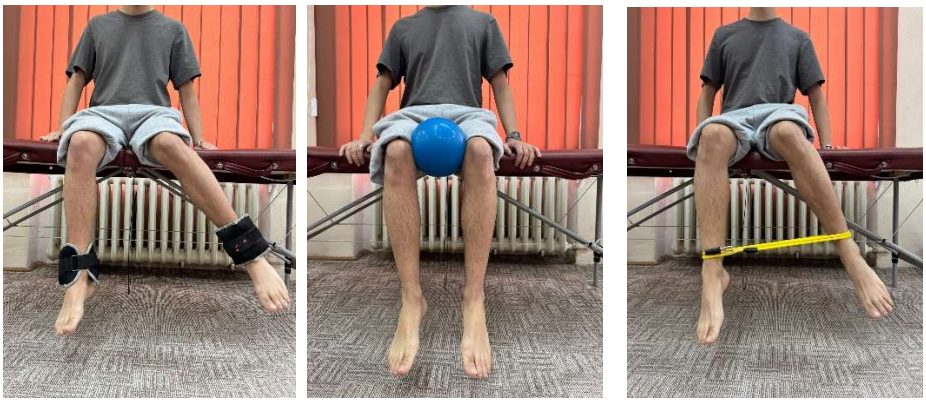
The aerobic training programme was performed for all participants by cycling (ergometric) for 20-30 minutes/day and took into account the subjects' age and maximum heart rate (HRmax) allowed during exercise (HR max = 220-age in years) [13].

Table 2. Exercise programme diagram (executed by group 1)

Rehabilitation center	*Week 1*	Hip mobility exercises -Patient in supine position: -Thigh abduction and adduction with extended knee (3 sets x 8 repetitions)

(specialized supervision)		-Thigh flexion on the pelvis with knee extended and return (3 series x 8 repetitions) -Thigh flexion on pelvis with knee flexion and return (3 sets x 8 repetitions) -Hip internal rotation and external rotation (3 sets x 8 repetitions) -Heterolateral decubitus: -Same exercises as in supine (3 sets x 8 repetitions) Exercises to increase muscle strength -Isometric contractions of the flexor, extensor, abductor, adductor, adductor and rotator muscles of the hip - performed with the physiotherapist's help (isometric contractions of 6 seconds x 8 repetitions x 3 series/muscle group) Proprioceptive stimulation exercises -From sitting on the chair: -Roll the sole on a proprioceptive roll (3 sets x 12 anterior-posterior rolls) -With the hands resting on a walking frame or the back of a chair, progressive lifting is performed, with a maximum of 10% of the weight on the operated limb (3 series x 8 repetitions) Orthostatic and gait re-education exercises -In the gait frame: orthostasis with 10% support on the operated lower limb (3 days)- maintain orthostasis for 90 seconds, then 20% (4 days)- maintain orthostasis for 180 seconds; 3-5 series/session -With gait frame: gait with 10% load on the operated lower limb- 5 sets x 10 m (3 days), then 20% on the operated lower limb- 5 sets x 10 m (4 days)
	Week2	Exercises for hip mobility and increasing muscle strength and endurance -Patient in supine position: -Thigh abduction and adduction- performed with sandbag/weight of 0.5 kg attached at ankle (3 sets x 10 repetitions) -Thigh flexion on the pelvis with the knee extended and return performed with sandbag/weight of 0.5 kg attached at the ankle (3 sets x 10 repetitions) - Hip internal rotation and external rotation performed with a 0.5 kg sandbag attached to the ankle or with an elastic band attached to the ankle (3 sets x 10 repetitions) -Heterolateral decubitus: -The same exercises as in supine position (3 sets x 10 repetitions) -From sitting on the chair: -With an elastic band fastened above the knees perform thigh abduction (3 series x 10 repetitions) - Hip internal rotation and external rotation performed with a 0.5 kg sandbag attached to the ankle **(Figure 2-a)** or with an elastic band attached to the ankle **(Figure 2-c)** (3 sets x 10 repetitions) -With a ball between the knees contract the adductors (3 sets x 10 repetitions) **(Figure 2-b)** Exercises to increase muscle strength: continue the isometric contractions performed in the first week Proprioceptive stimulation exercises: Continue proprioceptive stimulation also performed in the first week Orthostatic and gait retraining exercises -With 2 Canadian / axillary crutches: orthostasis with 30% loading on the operated lower limb (3 days)- maintain orthostasis 180 seconds, then 50% loading (4 days)- maintain orthostasis 360 seconds; 3-5 series/session -With 2 Canadian crutches/axillary: gait with 30% loading on the operated lower limb - 5 sets x 10 m (3 days), then with 50% loading on the operated lower limb
	Week3	Exercises for hip mobility and increasing muscle strength and endurance -Patient in supine position: -Thigh abduction and adduction- performed with sandbag/ 1-1.5 kg weight 1-1.5 kg sandbag/weight clamped at ankle (3 sets x 12 repetitions)

		-Thigh flexion on the pelvis with the knee extended and return performed with sandbag/weight of 1-1.5 kg attached at the ankle (3 sets x 12 repetitions) -Internal hip rotation and return (to midline) with 1-1.5 kg sand bag/weight 1-1.5 kg at ankle level (3 sets x 12 repetitions) -From heterolateral decubitus: -The same exercises as in supine position (3 sets x 12 repetitions) -From sitting on the chair: -With an elastic band fastened above the knees perform thigh abduction (3 sets x 12 repetitions) Exercises to increase muscle strength: Continue the isometric contractions performed in the first 2 weeks (3 sets x 12 repetitions), but without the therapist's help. Proproiceptive stimulation exercises: Continue proprioceptive stimulation also executed in the first 2 weeks (3 series x 12 repetitions) Orthostatic and gait re-education exercises: -With 1 Canadian/axillary crutch: orthostasis with 70% support on the operated lower limb (3 days)- maintain orthostasis 180 seconds, then 90% (2 days)- maintain orthostasis 360 seconds; 3-5 series/session -With 1 Canadian/axillary crutch: gait with 70% load on the operated lower limb - 5 sets x 10 m (3 days), then 90% on the operated lower limb - -Walking without support with 100% weight bearing on the operated limb (3 series x 20-30 m), practicing walking over obstacles and on uneven terrain, walking up and down steps (2 days, 3 series) -Stability exercises on balance board (2 days, 3 series x 12 repetitions)
At home	*Week 4-11*	-Exercises for hip mobility and to increase muscle strength and endurance in the hip and thigh muscles performed in week 3 continue daily, 8 weeks: 3 sets x 15 repetitions -Genoflexions: 3 sets x 15 repetitions -Flat terrain walking (3 -5 sets x 100-200 m), over obstacles, up and down steps, lateral walking (with operated lower limb) -Progressive aerobic training: cycling in order to increase energy consumption and reduce excess weight - 20-30 minutes/session



(a) **(b)** **(c)**

Figure 2. (a–c) Exercises for hip mobility and increasing muscle strength and endurance

2.4. Statistical analysis

All statistical analyses were done using GraphPad Prism 5.0 for Windows. Descriptive statistics were computed for all variables (mean and standard deviation). Before

statistical applications, the normal distribution of values in this study was verified by the D'Agostino-Pearson normality test. The intragroup data (Harris Hip Scores and BMI) were compared with the paired t-test. The intergroup data (differences of the Harris Hip Scores and BMI between the two groups) were compared with the unpaired t-test. A p-value of less than 0.05 was considered as statistically significant [14].

3. Results

The Harris Hip Scores of the two groups before surgery, one week after surgery and 3 months after surgery are presented in **Table 3.** For both groups there were statistically significant differences at one week assessment and 3-month assessment, respectively. The Harris Hip Scores improved after surgery, with better functional results after 3 months.

Table 3. The intragroup comparisons of the Harris Hip Scores

	HHS before surgery	HHS 1 week after surgery	HHS 3 months after surgery	p^a	p^b
Group 1 (N=15)	45.89 ± 11.59	80.52 ± 8.48	95.15 ± 3.49	**<0.0001**	**<0.0001**
Group 2 (N=15)	48.15 ± 11.16	79.22 ± 6.78	84.38 ± 3.33	**<0.0001**	**0.0007**

N: number of patients; HHS: Harris Hip Score; p^a relates to the difference between before surgery and 1 month assessments; p^b relates to the difference between 1 month and 3 months assessments. The bolded p-values indicate significant differences.

The intergroup comparisons of the Harris Hip Scores are included in **Table 4**. There were no significant differences between the two groups before surgery and after one week evaluations. After 3 months, the Harris Hip Score was significantly higher for group 1. The group that followed a physical exercise program after surgery (group 1) had better functional outcomes after 3 months in comparison to the group without a physical exercise program (group 2). The effect size for this analysis (d = 3.16) was found to exceed Cohen's (1988) convention [15] for a large effect (d =0.8).

Table 4. The intergroup comparisons of the Harris Hip Scores

	Group 1 (N=15)	Group 2 (N=15)	P
HHS before surgery	45.89 ± 11.59	48.15 ± 11.16	0.59
HHS 1 week after surgery	80.52 ± 8.48	79.22 ± 6.78	0.64
HHS 3 months after surgery	95.15 ± 3.49	84.38 ± 3.33	**<0.0001**

N: number of patients; HHS: Harris Hip Score. The bolded p-value indicates significant differences.

Analyzing the results of BMI we noticed that patients in group 1 had statistically significant lower values at 3-month assessment when compared to before surgery (p=0.0003). For group 2 patients there were no differences of BMI between the two evaluations (p=0.15). At 3-month evaluation the mean BMI decreased with 1.77 for group 1 (physical exercise group) and with only 0.12 for group 2 (group that did not attend the physical exercise program).

There were statistically significant differences between the two groups at 3-month assessment, with patients in group 1 having a decreased BMI **(Table 5).** The effect size for this analysis (d = 1.08) was found to exceed Cohen's (1988) convention [15] for a large effect (d =0.8).

Table 5. The intergroup comparisons of BMI before and 3 months after surgery

	Group 1 (N=15)	Group 2 (N=15)	P
BMI before surgery	26.03 ± 3.41	26.95 ± 2.66	0.41
BMI 3 months after surgery	24.26 ± 2.21	26.83 ± 2.54	**0.006**

N: number of patients; BMI: body mass index. The bolded p-value indicates significant differences.

4.Discussions

In the study we conducted, we aimed to highlight the importance of early physiotherapy (7 days postoperatively in a medical rehabilitation center with a specialized physiotherapist for 3 weeks) and sustained exercise programme (at home for a further 8 weeks) in the functional recovery of children with stable operated unilateral proximal femoral epiphysis.

Adapted, individualized programs of physiotherapy with specific equipment were carried out, taking into account parameters such as the age of the participants, their individual physical abilities, pain intensity and functional capacity, but also their compliance to rehabilitation therapy.

The exercise program applied to the patients in group 1 did not follow a standardized, homologated protocol, but the general principles of postoperative hip rehabilitation were followed in order to achieve the proposed objectives and were based exclusively on the authors' personal experience.

The patients participating in the study were evaluated using the Harris Hip Score (HHS) and the body mass index (BMI) was determined, in order to establish the objectives of the medical rehabilitation program and to design the appropriate exercises for each individual case, as well as to evaluate the effectiveness of the implemented programs. Treatment compliance, with respect to the applied programs and their duration, is very important to obtain the best results for the participants of this study, taking into account their age, the family having an important role and being an integral part of the team treating these children.

An exercise program was applied to a total of 15 patients for 3 weeks, 2 sessions of 45 minutes/day, 5 days/week, in a specialized rehabilitation center under the supervision of a physiokinetotherapist, and then it was performed at home daily by all subjects for 8 weeks, 40-50 minutes/day.

The exercise program applied in this study in the rehabilitation center in the postoperative period had as objectives: Increasing joint mobility in the hip, increasing the strength of the gluteal and thigh muscles on the affected side, progressive re-education of walking with aids (walking frame/carts) for 4 weeks, with progressive loading and then without aids, proprioceptive re-education and re-education of static and gait stability. The objectives of the exercise program carried out at home during the following 8 weeks had an aditional objective: training with increased energy consumption and reduction of excess weight, where necessary.

There are few studies on exercise, medical rehabilitation treatment and resumption of physical and sports activity in patients with operated stable proximal femoral epiphyseolysis, being a topic for future research and currently based on the personal experience of the team treating this pathology.

In the study by Ashish Anand et al. [16] It is claimed that patients with proximal femoral epiphyseolysis (PFE) are often instructed to use crutches and restrict their activities after surgery. Their study determined the actual duration of crutch use and activity restriction in 43 patients with SCFE treated with in situ fixation, mean age 14.1 years. Of the 43 patients in the aforementioned study 9% never used crutches,

and 67% used crutches for 4 weeks or less, 7% never restricted their activity, and 67% resumed full activities, including sports, by 6 months None of the patients had postoperative complications. The results of their study suggest that early resumption of physical activity is beneficial for SCFE patients with obese child type and is possible without harmful effects, however, the authors suggest that further investigation is needed before an algorithm for postoperative rehabilitation can be presented.

The use of assistive devices (walking frame/carriages) in the 15 patients in our study for 4 weeks with progressive loading of the operated hip is with beneficial effects on stability, pain and functionality, the results of the HHS score are suggestive in this regard and no complications were recorded in any participant.

Thus, we also observed that the HHS score results were similar in all participants, with no significant differences before surgery and 7 days postoperatively, but significant differences were recorded at 3 months postoperatively, with superior results in participants who followed a rehabilitation program and who also performed an aerobic training program for 8 weeks.

Vasileios Giovanoulis et al. in their study suggest that there is a potential correlation between sports participation and the occurrence of SCFE, but few studies have examined return to previous physical activity in these patients [17].

Their analysis showed that patients with operated SCFE were able to resume non-professional physical activities. The same idea is also supported by Trisolino et al. who reported in their analysis that 11 patients were able to return to low to moderate impact sports activity (cycling, swimming, aerobics, running) and another eight participants resumed high impact sports activities (soccer) after surgical treatment of SCFE [18].

Excess weight is a risk factor in the development of SCFE, so in our study we also determined the body mass index (BMI) and how exercise can influence its evolution. Jun-Hyuk Lim et al. [19] in their study, state that they found no relationship between the severity of slippage and the degree of obesity, and Randall T Loder et al. [20] in their study they showed that those involved in sport had a slightly lower body mass index (BMI) and that there were differences between those involved and those not involved in sport for duration of symptoms, severity of SCFE, gender, race or SCFE stable/unstable type.

Thus we found that subjects who performed the recommended exercise program for 11 weeks had a significant decrease in BMI at the end of the study period, compared to those who did not perform the exercise program and in whom there were no differences between the initial and final values of this parameter. These observations are suggestive for the role of sustained physical exercise, including in addition to an exercise program to increase muscle strength and endurance and progressive aerobic training, on BMI reduction and implicitly on the reduction of complications and recovery of hip function in SCFE.

Junga Lee et al. [21] claims that aerobic exercise may be beneficial for reducing body fat, fasting insulin and inflammatory markers, as well as increasing physical fitness and reducing overweight and obesity in childhood and adolescence. The authors suggest that aerobic exercise combined with resistance exercise may help prevent muscle loss in overweight and obese children and adolescents.

BMI reductions were observed in overweight and obese children and adolescents who combined aerobic exercise and strength training and in a study by George Kelley et al. [22] and also by Tianhoo et al. [23] who also noted that this also reduces the percentage of body fat, VO2peak, TG, LDL, TC, while not HDL in obese or overweight school-age children.

Guangwei Chen et al. [24] assessed the relationship between BMI and fitness in a large sample of children and adolescents in Xinjiang, China. The results of their study showed that children and adolescents with a BMI above or below normal ranges have

lower fitness than those with normal BMI. Thus, they suggest that to improve physical fitness, one should conduct a fitness program to counteract the BMI-related effects in children and adolescents.

In their study, Blundell et al. showed that an exercise programme can be considered as one of the most valuable behavioural components with a role in obesity management, which can influence body weight [25] and Andrew P Hills et al. [26] have observed that obesity is increasingly present among children and physical activity plays an important role in preventing overweight in childhood and adolescence and thus reducing the risk of obesity in future adulthood. These conclusions are also supported by the results of our study, which showed a reduction in BMI in study participants with sustained exercise alone for 11 weeks and no diet. A healthy diet, along with regular physical activity and lifestyle modification, to prevent or treat obesity in the paediatric population, is the recommendation of specialists in the field [27], which is also in our agreement. These ideas are also supported by Seema Kumar et al. in their study, where they conclude that the most common cause of obesity in children is a positive energy balance due to caloric intake in excess of caloric expenditure, and that family lifestyle interventions, including dietary modifications and increased physical activity, are the cornerstone of weight management in children [28].

The participants of our study were divided according to their compliance to the exercise program, not by randomization; this is a limitation of the current research. The 3-month follow up can be considered another limitation of our study. We aim to continue the follow up of our patients for one year, with the exercise program group continuing to perform a home-based exercise program.

A limitation of our study is the lack of diet control, although nutritional counselling and an individualised diet were recommended, none of the participants had any change in dietary habits compared to the pre-surgery period and no additional caloric intake.

5. Conclusions

Exercise performed early after surgery in children with SCFE improves functionality, and hip range of motion, relieves pain and increases quality of life. The long-term daily association of a long-term exercise program including joint mobility and muscular endurance exercises with progressive aerobic training, also has a beneficial effect on reducing body mass index, as overweight is known to be a factor involved in the etiology of SCFE.

In children with SCFE, structured physical exercise applied early after surgery has a dual role, both in functional recovery of the hip and in body weight management.

The results of this study recommend the integration of structured physical exercise into postoperative care guidelines for SCFE.

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Institutional Review Board Statement: This study has been carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the "Victor Babes" University of Medicine and Pharmacy Timisoara (reference no. 46/02.10.2023, approved on 2nd October 2023).

Informed Consent Statement: Written informed consent was obtained from all participants' parents.

Data Availability Statement: The data presented in this study are available on request from the corresponding author (L.C) due to privacy.

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