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ORIGINAL ARTICLE

The effects of close kinetic chain exercises on proprioception and physical activity level in pediatric patients with hemophilia

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Abstract

Introduction: Knee joint proprioception is affected, and lower extremity functioning declines over time in patients with hemophilia A.

Aim: To investigate the effects of a structured exercise programme consisting of the close kinetic chain (CKC) exercises on proprioception and physical activity level in pediatric patients with hemophilia.

Methods: A total of 21 patients with hemophilia A who had at least one target knee joint were randomized into three groups: Study Group (SG, $n = 7$), Conventional Treatment Group (CTG, $n = 7$) and Control Group (CG, $n = 7$). The SG received a structured, lower limb-specific exercise protocol consisting of CKC exercises 2 days a week for 12 weeks, in addition to prophylactic treatment. The CTG received exercise training as described in the published literature. The CG continued to receive prophylactic treatment during the study period. Proprioception was measured using a digital goniometer before and after treatment in open and closed kinetic chain positions (CKCPs). The Five Times Sit to Stand (STS), Timed Up and Go (TUG) and Functional Independence Score in Hemophilia were used for the assessment of physical activity level.

Results: A significant pre/post-treatment difference was found among the groups in proprioception ($p = .001$) and physical activity level (TUG $p = .008$, STS $p = .001$, FISH $p = .006$). Improvements in proprioception and physical activity level were greater in the SG compared to the other two groups ($p < .05$).

Conclusion: Compared to conventional exercise, the structured exercise protocol consisting of CKC exercise training produced improvements in proprioception and physical activity in patients with hemophilia A.

KEYWORDS
close kinetic chain, core stabilization, hemophilia, physical activity, proprioception

1 | INTRODUCTION

Hemophilia is a blood disease characterized by bleeding disorder, which is associated with hemarthrosis, resulting in joint degeneration, pain and muscle atrophy.[1] The knee joint is at risk of hemarthrosis due to a number of factors such as three-dimensional movements and weight-bearing function.[2] When combined with pharmacological therapy, exercise training increases proprioception and physical activity level, as well as reduces pain especially in the knee joint. A review of studies on exercise interventions for PWH showed that mostly, range of motion (ROM), strengthening, aerobic training and aquatic exercises have been used for hemophilia.[3–5] Individualized exercise approaches often result in improvements in joint health and mobility, muscle strength and proprioception and also increase functionality.[6] The majority of rehabilitation approaches reported in the literature have addressed polyarticular involvement and studies

demonstrating effectiveness of exercise training on a single joint are rare.[7]

Recent studies on proprioception have mostly focused on the knee joint because the tendons and ligaments around the knee are rich in mechanoreceptors.[8] It has been reported that proprioception may be affected to a greater extent in hemophilia patients with a history of hemarthrosis or haematoma in the knee joint. Hilberg, investigating isometric muscle strength and proprioceptive performance in adult hemophilia patients versus healthy individuals, improved proprioceptive performance was demonstrated in hemophilia patients after exercise training.[9]

Close kinetic chain (CKC) exercises as defined by Steindler in 1955 are exercises in which the terminal or distal segment is fixed. During these exercises, the lower extremities function in a closed chain manner and movements enable simultaneous activation of several successively arranged joints. This type of multi-joint exercise is frequently used to increase performance and plays an important role in working the strongest and largest muscles of the body. In recent years, CKC exercises have been widely used for knee rehabilitation in the clinical setting.[10] CKC exercises promote the stimulation of proprioception and functionality, which is primarily involved in dynamic joint stabilization.

The effectiveness of CKC exercises on proprioception and functionality has been demonstrated in conditions that commonly affect the knee joint such as osteoarthritis, rheumatoid arthritis vb.[11] Since the majority of activities of daily living (ADL) are executed in the closed kinetic chain position (CKCP), these exercises will also enhance ADL performance and functioning of the individual.[12]

In addition, increased proprioception and neuromuscular control have been demonstrated in PWH following postural stabilization training.[13]

No study has been identified in the literature that investigated the effectiveness of an approach consisting of a core stabilization programme combined with CKC exercises on proprioception and physical activity in children with hemophilia.

This study aimed to investigate the effects of a structured exercise protocol consisting of age-appropriate CKC exercises in patients diagnosed with moderate-to-severe hemophilia A and a history of target knee joint. We tested the hypothesis that the structured exercise programme is more effective on proprioception and physical activity level than the conventional treatment and Control Group (CG).

2 | MATERIALS AND METHODS

2.1 | Participants

This single-blind, randomized, controlled study was designed to investigate the effects of a 12-week, CKC exercises on proprioception and physical activity in pediatric patients diagnosed with Hemophilia A. The exercise protocol was applied under the supervision of a physiotherapist with over 5 years of experience in this field. The study was conducted between December 2020 and October 2021 at the Department of Physiotherapy and Rehabilitation in Hasan Kalyoncu University Faculty of Health Sciences with patients followed at the Pediatric Hematology outpatient clinic of a tertiary care hospital. Approval for the study was obtained from the Ethics Committee for Non-Interventional Studies of Hasan Kalyoncu University Faculty of Health Sciences (No. 2020/116). Informed consent was obtained from the parents prior to the initiation of the study. The study is registered on ClinicalTrials.gov (ID: NCT04754997).

Twenty-four boys from 6 to 18 years of age diagnosed with hemophilia A (moderate-to-severe) were enroled in the study. Patients with a target knee joint who were receiving prophylactic treatment 3 days a week were included. Patients without a history of acute bleeding in the last month were enroled in the study. Patients with inhibitors and those with a history of surgery to the knee joint were excluded from the study. In addition, patients with a neurological disease that may affect lower extremity functionality and patients with lower extremity sensory loss were also excluded. After initial evaluation, three patients were excluded. The remaining 21 patients were randomly divided into three groups using the sealed envelope method: study, conventional treatment and CG. The study flow diagram is presented in Figure 1. Patients in the study and Conventional Treatment Group (CTG) received treatment for 2 days a week for 12 weeks. Treatment days were scheduled as Wednesday–Friday or Tuesday–Thursday to align with routine prophylactic treatment of the patients. Prophylactic treatment was given at 8 AM and the exercises were applied 6 h later.[14] Regular use of prophylaxis was confirmed after baseline evaluation for control patients who were followed by phone calls to identify any bleeding events, and they were asked to return to the clinic at the end of 12 weeks.

2.2 | Assessments

Assessments were performed before/after treatment by a physiotherapist experienced in hemophilia management. Demographic information, factor levels, date of last bleeding episode, frequency of bleeding in target knee joint, involvement of target knee joint and medication use (days/week and dosage) were recorded.

Proprioception assessment was conducted using the Baseline Digital Goniometer (Lafayette IN, USA) with the reposition method.[15] This device is often used in the clinical setting for the evaluation of joint position sense and normal ROM and has a margin of error of 1°.[16] ROM of the knee joint is 0° extension and 140° flexion in healthy children.[17] Proprioceptive measurements were obtained from the knee joint at two different degrees and bilaterally in the open kinetic chain (seated) (OKCP) and CKCP (standing). The patient was seated with eyes closed and hip and knee in 90° flexion. Then, the therapist subjected patient's knee to 30° extension and asked the patient to sense this position. Then, the patient was asked to return to the starting position, reproduce the knee extension at the same angle and measurement was taken. The same measurement was repeated for 60° extension as described above. In the standing position, the measurements followed

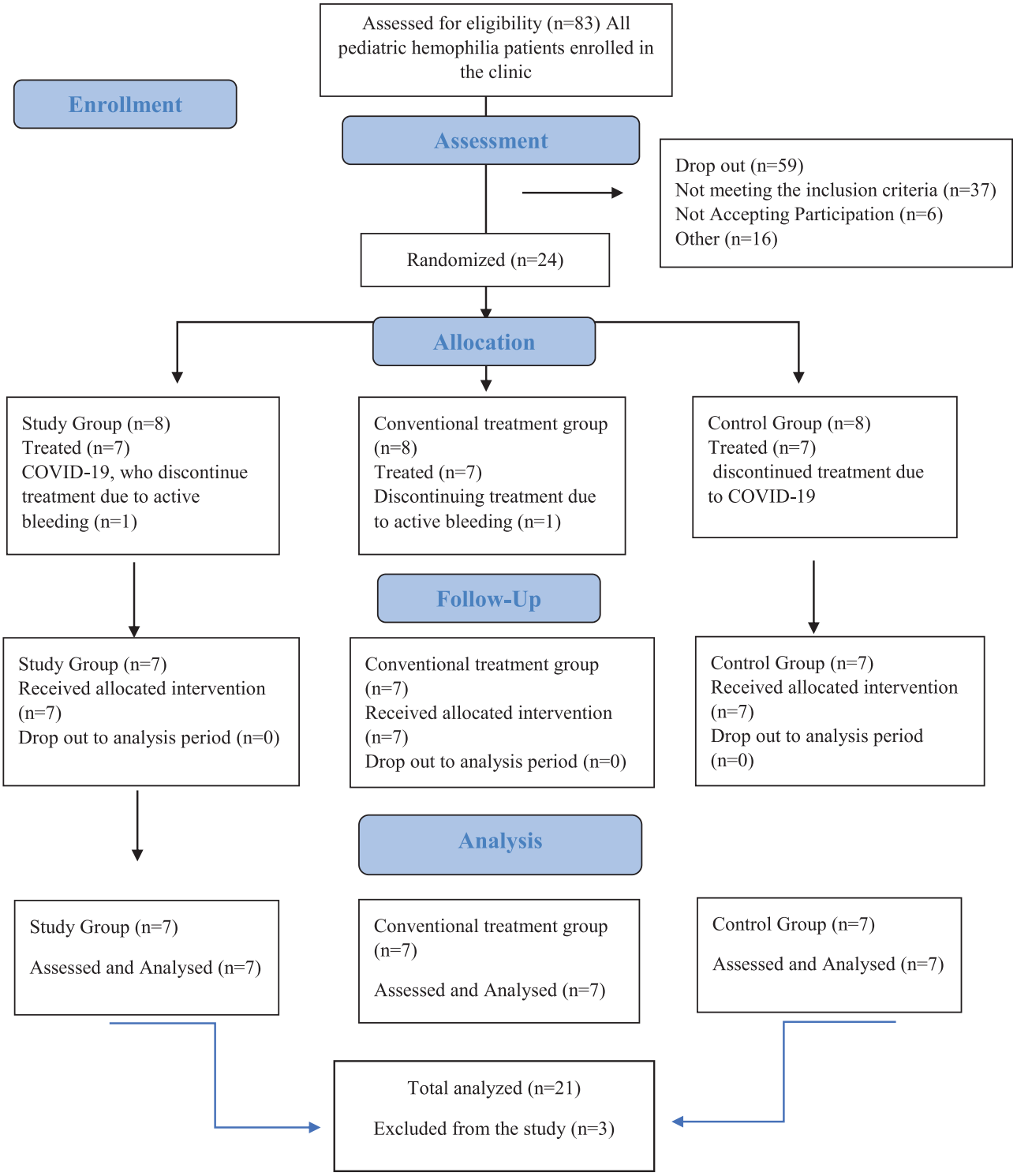

FIGURE 1 Flow diagram of the study

the same order for 30° and 60° extension as described above. The measurements were repeated three times and average angular error recorded.

The Five Times Sit to Stand (STS) Test, Timed Up and Go (TUG) Test and Functional Independence Score in Hemophilia (FISH) were used for the assessment of physical activity level. For children, being able to sit and stand is crucial to gain independence in ADL. The STS test is an outcome measure for functional lower extremity muscle strength.[18] For the test, the patient was seated in a chair with hips and knees in 90° flexion, feet touching the floor, half of the thighs on the chair, arms folded across the chest and the back against the chair. With the start command, the patient was asked to stand up and sit down as quickly as

they can five times in a row, each time being told how many repetitions they had completed so far.[19]

The TUG test is used to determine the functional level and mobility. For the test, the patient sits on a standard chair, stands up and walks a pre-specified distance of 3 m as quickly and safely as possible, turns back at the marked point, walks back, sits back on the chair and the test is terminated. The time elapsed was calculated using a stopwatch and recorded in seconds.[20] All tests were repeated three times and the average value was included in the analysis.

The FISH has been developed according to the principles of the International Classification of Functioning, Disability and Health, taking into account ADL that could be affected by hemophilia. As a performance-based tool, it can be administered in different languages. The scale includes a total of eight items under three categories of self-care, transfers and locomotion. Total scores range from 8 to 32. Higher scores indicate functional independence of the individual.[8]

2.3 | Interventions

The Study Group (SG) received a structured exercise protocol comprising of CKC exercises. CTG received an exercise programme typically applied to PWH as reported in the literature, which consisted of active ROM, isometric, isotonic, balance and proprioception exercises.[4,5] Exercise training was applied 2 days a week for 12 weeks for both groups. Exercises were revised every 3 weeks to maintain interest and enhance the motivation of children with constant diversification of exercises[21] (Appendices 1 and 2).

2.4 | Statistical analysis

SPSS version 22.0 (IBM Corp., Armonk, NY) software package was used to analyse the study data. The descriptive statistics were summarized as an arithmetic mean and standard deviation (X ± SD) for numerical variables, and frequency and percentage for categorical variables. The data normality were checked using the Kolmogorov–Smirnov Test. As the data did not follow a normal distribution, Kruskal–Wallis Test was used to compare three groups. Mann–Whitney *U* Test was employed for pairwise comparisons between the groups. Small (.2), medium (.5), and large (.8) effect sizes (*d*) were defined. Effect size can be used to determine the true effectiveness of treatments and to obtain the power of results.[22] A $p < .05$ was considered statistically significant in all analyses.

2.4.1 | Sample size

The minimum number of participants required for each group was determined to be 7($\alpha = .01$) in order to detect a significant difference among three different subgroups at the large effect level ($f = 1.4$) with a power of .86. G*power version 3.9.1.7 was used for power analysis.

3 | RESULTS

Twenty-one patients with hemophilia A (moderate, $n = 6$; severe, $n = 15$) included in the study were divided into three groups: study, conventional and CG s. The pre-test data for physical characteristics, proprioception and TUG, STS and FISH parameters were similar among the groups ($p > .05$, each) (Table 1).

A significant difference was observed among the groups in post-treatment proprioception measurements ($p < .001$) (Table 2). An advanced statistical analysis, which was done to determine the source of difference in post-treatment proprioception measurements among the groups, showed worse OKCP and CKCP results in the CG versus other two groups. The effect size in proprioception subdomains was medium for the SG versus CTG and for the CTG versus CG. In addition, a large effect size was observed when the difference between the SG and CG was examined (Table 3).

The groups showed a significant difference in post-treatment results for physical activity parameters ($p < .05$) (Table 2). Further analysis, which was conducted to determine the group accounting for the improvement in post-treatment results, revealed that the TUG times were better in the SG than in other groups ($p < .008$). For the TUG results, while a small effect size was found for the difference between the CTG and CG, the effect size was large for the difference between the study and CG s. STS results were similar between the SG and CTG and between CTG and CG ($p > .05$), with a small effect size. However, there was a significant difference between the study and CG s ($p < .013$), which accounted for a medium effect size. As for FISH results, the SG showed the best post-treatment results ($p < .006$). When the differences among the groups were analysed, the results were similar between CTG and CG ($p > .05$) but the effect size was small. The SG showed a significant difference compared to the other two groups ($p < .05$), resulting in a medium effect size (Table 3).

4 | DISCUSSION

The CKC exercise protocol was found to be more effective than conventional treatment protocol in improving proprioception and increasing physical activity level in our study.

Previous studies on the musculoskeletal system have used proprioceptive training along with flexibility and strengthening exercises.[23–25] In diseases affecting the knee joint, CKC exercises improve the quadriceps muscle strength, resulting in better activity performance. Moreover, patellar maltracking improves and the stress on the joint is reduced. CKC exercises facilitate the neuromuscular system, which in turn leads to better functioning of the joint. At the same time, they improve proprioception and increase joint stabilization.[26,27] Leite et al. investigated the acute effects of proprioceptive CKC exercises on proprioception. They applied aerobic training to one group and proprioceptive exercises to the other group and observed that the greatest reduction in angular error occurred in the group receiving proprioceptive CKC exercises.[28] The decrease in the angular error reported in that

TABLE 1 Comparison of physical characteristics, proprioception and physical activity parameters among the groups

	Study	Conventional	Control	Kruskal–Wallis		
	Pre-test	Pre-test	Pre-test	χ^2	*P*	Pairwise comparison
AGE (y)	11.43 ± 1.81	13 ± 3.06	11.14 ± 2.41	1.898	.387	–
HEIGHT (cm)	1.49 ± .10	1.58 ± .16	1.47 ± .18	1.229	.541	–
BODY WEIGHT (kg)	42.43 ± 11.82	50.71 ± 14.17	43.57 ± 17	1.174	.556	–
BMI (kg/m2)	18.69 ± 3.18	19.95 ± 2.75	19.54 ± 3.46	.603	.740	–
FACTOR LEVEL (%)	1.30 ± .78	1.31 ± .31	1.23 ± .60	1.810	.405	–
OKCP 30° (L)	8.61 ± 2.69	7.17 ± 1.76	8.66 ± 3.19	2.550	.279	–
OKCP 60° (L)	8.91 ± 2.51	7.61 ± 1.60	7.44 ± 1.58	2.080	.353	–
OKCP 30° (R)	9.03 ± 1.33	8.19 ± 2.28	6.47 ± 1.65	5.645	.059	–
OKCP 60° (R)	8.17 ± 1.82	7.26 ± 2.16	7.54 ± 2.67	.519	.771	–
CKCP 30° (L)	9.21 ± 2.48	7.60 ± 2.22	7.71 ± 2.45	1.934	.380	–
CKCP 60° (L)	8.77 ± 3.77	6.57 ± 2.25	7.94 ± 2.49	1.244	.537	–
CKCP 30° (R)	8.61 ± 2.69	7.17 ± 1.76	8.66 ± 3.19	1.934	.380	–
CKCP 60° (L)	8.91 ± 2.51	7.61 ± 1.60	7.44 ± 1.58	1.244	.537	–
TUG (m)	10.73 ± 2.00	9.84 ± 1.69	9.81 ± 1.41	.435	.804	–
STS (sec)	16.01 ± 1.81	14.87 ± 1.87	14.83 ± 1.49	1.624	.444	–
FISH (score)	23.14 ± 1.57	25.71 ± 1.80	23.43 ± 3.95	4.209	.122	–

Data are presented as mean ± SD.

Abbreviations: %, percentage; BMI, body mass index; CKCP, closed kinetic chain position; cm, centimetre; FISH, Functional Independence Score in Hemophilia; kg, kilogram; kg/m2, kilograms per square metre; L, left; m, metre; OKCP, open kinetic chain position; p > .05: non-significant; R, right; sec, second; STS, Sit to Stand Test; TUG, Timed Up and Go Test; y, years. χ^2, Kruskal–Wallis test.

study is consistent with our findings. We consider that these factors account for the greater effect found for the closed kinetic chain protocol in our study. The relationship between lower extremity injuries and core stabilization was investigated in athletes. The core region has gained importance especially in the proximal knee control. Reduced core control would result in increased displacement of the center of mass. Since the knee is the articulation at the distal end of the femur, the uncontrolled center of mass displacements would result in excessive torques experienced at the knee. When the core stabilization was compared between athletes with or without knee injury, non-injured athletes were found to have greater core strength and endurance. This clearly highlights the significance of the core region in the treatment of the knee joint.[29] When added to closed kinetic chain exercises, core stabilization training provides proximal stability for mobility in the distal segment. Thus, with the establishment of neuromuscular control, an increase in proprioception is observed.

The time to complete TUG test was found to vary by a mean of 3.21 to 6.7 s among healthy children.[30,31] There are no studies reporting TUG reference values in children with hemophilia. For the adult population, one study reported a value of 11.61 s in 20 patients with hemophilia. In another study, the mean value of 88 adult patients with hemophilia was 9.8 s.[32,33] In our study, the pre-treatment TUG values of the patients were worse than those of healthy children and closer to those of adult hemophilia patients. In a study on 42 patients, Lobet et al. applied a 20-week exercise training programme consisting of ROM, strengthening and proprioceptive exercises. They reported a reduction in TUG values from a pre-treatment mean of 9.2 s to a post-treatment mean of 7.4 s as well as improved mobility.[34] In line with Lobet's study, post-treatment improvement was observed in the groups receiving exercise training in the current study. Greater improvement in our SG may be related to reduced axial loading and faster Vastus Medialis Obliquus firing by CKC exercises resulting in increased mobility, as well as improved postural control by core stabilization. Among the ADL, standing up from sitting and going from upright position to a sitting position are the most common movements.

When we compared the STS results among thethree groups, the structured exercise protocol showed better improvement in the SG than CG. In a study, patients with hemophilia received a home-based programme consisting of balance, strengthening and gait exercises for 4 months. Although an improvement was observed in post-treatment STS test results, the difference was non-significant compared to healthy controls.[32] That study supports the similar results between the CTG and CG at the end of 12 weeks in the present study. In the SG, mean STS time decreased from a pre-treatment time of 16 s to a post-treatment time of 12 s, which was superior to the other two groups. We think that improved STS results observed in the SG are related to the use of a variety of exercises as part of the treatment protocol. In the SG, squat exercises were performed at different angles and on different surfaces. This group also received a range of exercises at different intensity levels (from simple to complex) to improve core

TABLE 2 Comparison of pre-treatment and post-treatment proprioception and physical activity parameters

	Proprioception and physical activity	Study group (X ± SD)	Conventional treatment group (X ± SD)	Control group (X ± SD)	χ^2	*P*
Pre-treatment	OKCP 30° (L)	8.61 ± 2.69	7.17 ± 1.76	8.66 ± 3.19	2.550	.279
	OKCP 60° (L)	8.91 ± 2.51	7.61 ± 1.60	7.44 ± 1.58	2.080	.353
	OKCP 30° (R)	9.03 ± 1.33	8.19 ± 2.28	6.47 ± 1.65	5.645	.059
	OKCP 60° (R)	8.17 ± 1.82	7.26 ± 2.16	7.54 ± 2.67	.519	.771
	CKCP 30° (L)	9.21 ± 2.48	7.60 ± 2.22	7.71 ± 2.45	1.934	.380
	CKCP 60° (L)	8.77 ± 3.77	6.57 ± 2.25	7.94 ± 2.49	1.244	.537
	CKCP 30° (R)	8.61 ± 2.69	7.17 ± 1.76	8.66 ± 3.19	1.635	.442
	CKCP 60° (R)	8.91 ± 2.51	7.61 ± 1.60	7.44 ± 1.58	.972	.615
	TUG (m)	10.73 ± 2.00	9.84 ± 1.69	9.81 ± 1.41	.435	.804
	STS (sec)	16.01 ± 1.81	14.87 ± 1.87	14.83 ± 1.49	1.624	.444
	FISH (score)	23.14 ± 1.57	25.71 ± 1.80	23.43 ± 3.95	4.209	.122
Post-treatment	OKCP 30° (L)	2.37 ± 1.08	4.74 ± 1.37	9.71 ± 2.78	16.117	.001**
	OKCP 60° (L)	1.51 ± .55	4.37 ± 1.72	7.30 ± 2.32	16.018	.001**
	OKCP 30° (R)	2.47 ± 1.30	4.87 ± .96	8.21 ± 1.94	16.067	.001**
	OKCP 60° (R)	2.14 ± 1.06	4.97 ± 2.03	7.79 ± 2.01	13.829	.001**
	CKCP 30° (L)	2.91 ± .94	4.07 ± 2	7.74 ± 2.33	11.181	.004**
	CKCP 60° (L)	1.60 ± .61	4.11 ± .92	8.19 ± 1.67	17.830	.001**
	CKCP 30° (R)	2.33 ± 1.10	4.34 ± .87	7.59 ± 2.85	14.525	.001**
	CKCP 60° (R)	2.37 ± 1.08	4.74 ± 1.37	9.71 ± 2.78	14.408	.001**
	TUG (m)	7.40 ± .91	8.90 ± 1.22	10 ± 1.70	9.784	.008**
	STS (sec)	12.04 ± 1.68	13.46 ± .93	14.99 ± 1.89	8.629	.013*
	FISH (score)	28.71 ± .76	27.29 ± 1.11	24.43 ± 3.95	10.120	.006**

Data are presented as mean ± SD.

Abbreviations: CKCP, closed kinetic chain position; FISH, Functional Independence Score in Hemophilia; L, left; m, meter; OKCP, open kinetic chain position; R, right; sec, second; STS, Sit to Stand Test; TUG, Timed Up and Go Test.

*$p < .05$: significant, **$p < .01$: highly significant.

strength. These exercises increased lower limb muscle balance and improved core stability. We believe that all of these exercises resulted in improved functioning.

The FISH has also been used to evaluate the effects of pharmacological therapies including prophylaxis on functional independence.[35] In a study assessing functional independence in children with hemophilia A, FISH was used to evaluate musculoskeletal function in 98 patients. The study reported a mean FISH score of 28.[36] A study by Poonnoose et al. using FISH to assess functionality in 35 patients over 10 years of age who had a target joint reported a mean FISH score of 23.[37] In a more recent study, reported mean FISH score was 18 in 30 children with hemophilia.[38] The mean pre-treatment FISH scores observed in our study are consistent with previous reports. In Tat et al.'s study, FISH was used to assess the impact of treatment approaches on functional level in adult patients. In that study, one group received a home-based programme consisting of strengthening and stretching exercises, while the other group received manual therapy additionally. Comparable improvements were demonstrated with FISH scores in both groups.[39] In our study, post-treatment FISH scores showed improvement versus baseline in both SG and CTG. But when the difference among the groups was analysed, superior outcomes were observed in the SG compared to the other groups. Better outcomes (as assessed by FISH) achieved in patients receiving our structured exercise programme indicate improved proprioception, hence better joint health.

In conclusion, the 12-week CKC exercise protocol was superior to the conventional exercise programmes reported in literature in improving proprioception and increasing physical activity level. In light of these data, CKC and core stabilization exercises can be included in rehabilitation programmes to improve especially proprioception and lower extremity functionality.

Some limitations should be noted for this study. First, the sample size seems to be low and long-term follow-up results of the patients are not available and the rater was not blinded. During the 12-week treatment period, the pubertal development of the men was not measured. One of the most important changes in the pubertal period is rapid physical growth. Men reach anthropometric measurement values in adult life in a very short time. There is a marked increase in bone, fat and muscle mass.[40] Considering the average age of the groups, parameters

TABLE 3 Pairwise comparisons of the post-treatment proprioceptive measurement and physical activity results of the groups

Proprioception and physical activity	Study group versus conventional treatment group			Study group versus control group			Conventional treatment group versus control group		
	Z	*P*	*d*	*z*	*p*	*d*	*Z*	*p*	*d*
OKCP 30° (L)	−2.625	.009**	.70	−3.137	.002**	.83	−3.003	.003**	.80
OKCP 60° (L)	−.897	.370	.23	−1.343	.179	.35	−2.494	.013*	.66
OKCP 30° (R)	−2.814	.005**	.75	−3.130	.002**	.83	−2.814	.005**	.75
OKCP 60° (R)	−2.625	.009**	.70	−3.130	.002**	.83	−2.108	.035*	.56
CKCP 30° (L)	−.831	.406	.22	−3.130	.002**	.83	−2.433	.015*	.65
CKCP 60° (L)	−3.134	.002**	.83	−3.134	.002**	.83	−3.130	.002**	.83
CKCP 30° (R)	−1.351	.177	.36	−3.130	.002**	.83	−2.175	.030*	.58
CKCP 60° (R)	−.192	.848	.05	−3.137	.002**	.83	−2.619	.009*	.69
TUG (m)	−2.122	.034*	.56	−3.137	.002**	.83	−1.241	.214	.33
5XSTS (sec)	−1.863	.062	.49	−2.561	.010*	.68	−1.731	.084	.46
FISH (score)	−2.253	.024*	.60	−2.823	.005**	.75	−1.494	.135	.39

Abbreviations: CKCP, closed kinetic chain position; FISH, Functional Independence Score in Hemophilia; L, left; m, metre; OKCP, open kinetic chain position; r, effect size; R, right; sec, second; STS, Sit To Stand Test; TUG, Timed Up And Go Test.
*$p < .05$; significant, **$p < .01$: highly significant Mann–Whitney *U* Test.

such as body mass index and muscle strength could not be compared between the groups. Therefore, it is not known whether it has an effect on group differences over the course of treatment. Although we considered the age of the study population in terms of intensity when choosing the exercises, children may have experienced difficulties in some exercises. Although we questioned the exercise doses verbally, the use of questionnaires measuring physical effort while creating individual exercise programmes will improve methodological quality.

AUTHOR CONTRIBUTIONS

Tuğba Gönen performed the study exercises, involved in data collection and wrote the manuscript. Yavuz Yakut designed the research study, statistical analysis and critical review. Sinan Akbayram revised the manuscript and provided a critical review.

CONFLICT OF INTEREST

The authors stated that they have no conflicts of interest to declare that are relevant to the content of this article.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

DISCLOSURES

None.

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APPENDIX 1: CONTENTS OF THE INTERVENTIONS APPLIED TO THE STUDY GROUP

Week	Intervention		Characteristics of intervention
1–3	Supine position spine neutralization Posterior pelvic tilt Bridge-building exercise Leg single tablet tab position Double single tablet tab position	Double leg squat on the wall (45°) Mini squat on different ground. Supported single leg squat (toe level). Standing single leg 4-way stretch	10 reps 5-s of contraction with 5-s interval between each reps
4–6	Abdominal hollowing posterior pelvic tilt exercise Bridge-building exercise on soft ground Hands-side sit-ups in the hook position. Dead bug exercise Superman exercise (unilateral)	Double leg squat on the wall (45°) Mini squat on soft ground. Single leg squat (toe level) Resist Standing single leg 4-way stretch Step up and down exercise	10 reps 5-s of contraction with 5-s interval between each reps
7–9	Right-left oblique shuttle movement in the hook position. Single leg standing on foam Bird Dog exercise Superman exercise (kontralateral) 4-way weight transfer on the balance board	Mini squat on balance board With theraband in one limb squat position, the other foot reaching in 4 directions Resist single-leg squat (toe level) Step up and down exercise Lunge exercise	10 reps 5-s of contraction with 5-s interval between each reps
10–12	Straight-oblique sit-up motion with hands-on shoulders in a hook position. Single leg standing on foam soft ground Bird Dog exercise Superman exercise (bilateral) Mini squat on balance board	Standing on one leg on a balance board With theraband in one limb squat position, the other foot reaching in 4 directions Therebandla desteksiz tek ayak squat. Lunge exercise Side step up and down exercise	10 reps 5-s of contraction with 5-s interval between each reps

°: degree.
Abbreviation: reps, repetitions.

APPENDIX 2: CONTENTS OF THE INTERVENTIONS APPLIED TO THE CONVENTIONAL TREATMENT GROUP

Week	Intervention		Characteristics of intervention
1–3	Active ROM exercises Hip ROM: Flexion/Extension/Abduction/Adduction Knee ROM: Sitting knee flexion/extension Ankle ROM: Dorsiflexion/Plantarflexion		10 reps × 2 times 5-s interval between each reps
4–6	Strengthening exercises From isometrics to resistive sandbags Hip İsometrics: Flexion/Extension/Abduction/Adduction Knee İsometrics: Sitting knee flexion/extension Ankle İsometrics Dorsiflexion/Plantarflexion	Resistive sandbags – 1 exercise per muscle group (%40 MIF) Hip resistive sandbags: Flexion/Extension/Abduction/Adduction Knee resistive sandbags: Sitting knee flexion/extension Ankle resistive therebands in submaximal ranges: Dorsiflexion/Plantarflexion	10 reps 5-s of contraction with 5-s interval between each reps
7–9	Resistive sandbags – 1 exercise per muscle group (%50 MIF) Hip resistive sandbags: Flexion/Extension/Abduction/Adduction Knee resistive sandbags: Sitting knee flexion/extension Ankle Resistive therebands in submaximal ranges: Dorsiflexion/Plantarflexion	Proprioceptive and balance exercises Eyes open/closed balance training Proprioception training on different ground	10 reps 5-s of contraction with 5-s interval between each reps
10–12	Resistive Sandbags – 1 exercise per muscle group (%60 MIF) Hip resistive sandbags: Flexion/Extension/Abduction/Adduction Knee resistive sandbags: Sitting knee flexion/extension Ankle resistive therebands in submaximal ranges: Dorsiflexion/Plantarflexion	Proprioceptive and balance exercises Eyes open/closed balance training Proprioception training on different ground	10 reps 5-s of contraction with 5-s interval between each reps

°: degree, %: percentage.
Abbreviations: MIF, maximal isometric force; reps, repetitions; ROM, range of motion.