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Long-term functional and sonographic outcomes in Osgood–Schlatter disease

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Abstract
Purpose To evaluate the sonographic characteristics, functional aspects and life quality of a group of adolescent patients 2 years after having been diagnosed with Osgood–Schlatter disease and compare them with an age-matched healthy control group.
Methods The study was conducted on eighteen Osgood–Schlatter patients with unilateral involvement and 14 age-matched healthy controls. The Flaviis classification and patellar tendon characteristics were observed using a GE Logiq 9 scanner. Broad and vertical jump tests were used for jumping performance. The coordination, proprioception, strength and endurance functions were assessed with the Functional Squat System. For the quality of life, the SF-36 questionnaire was used. The Wilcoxon test for the patients' initial and second-year assessment and Mann–Whitney U test for the comparison between the patient and control groups were used.
Results By the end of second year, 38.9 % of the patients had totally recovered. The patellar tendon lengthened, distal diameter and distal area of the tendon had lessened, and no significant difference was observed between patient and control groups (n.s). Improvements were detected for the bilateral broad jump test scores, the quality of life and coordination of the patients after 2 years ($p < 0.05$). The average power of endurance and the total work of strength were significantly higher in control group ($p < 0.05$).
Conclusions According to the sonography results 2 years after diagnosis, nearly half of the patients had totally recovered. Coordination was the only parameter that improved over the 2-year period. The patient group strength and endurance function remained lower than the control group.
Level of evidence III.

Keywords Ultrasonography · Osteochondrosis · Motor skill · Quality of life

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Introduction

Osgood–Schlatter disease (OSD) is a traction apophysitis of the tibial tuberosity, due to repetitive strain from the quadriceps muscle, and chronic avulsion of the tibia [19, 26, 33]. It appears between the ages of 8 and 14 in girls and 10–15 in boys, especially in children and adolescents who participate in sport activities [9, 11, 15].

The symptoms range from aching and soreness to swelling, severe pain and limping. The onset is gradual, with mild, intermittent pain, but in acute phases, the pain may become severe and continuous. The pain is exacerbated with physical activity that involves running, jumping and kneeling [8, 9, 11]. Physical examination usually finds tenderness and local swelling directly over the area of the tibial tuberosity. The treatment is usually conservative, with medication and ice to relieve the pain, stretching and strengthening exercises followed by local warm packs [1–3]. Surgery is rarely recommended in the growing patient, if conservative treatment fails [5, 12, 28, 30]. It is reported that the symptoms tend to subside within 2 years, and the prognosis is excellent in the majority of cases [17, 19]. However, structural and functional recovery is not very well known. Even after treatment, some disability and insufficiency can persist into late adolescence and even adulthood [18, 29, 36]. Therefore, the primary aim of this study was to evaluate the sonographic characteristics, functional aspects and quality of life of recovered OSD patients followed up over 2 years. The secondary aim was to compare the differences with age-matched healthy controls. The following hypotheses were investigated: (1) OSD patients recover in 2 years and have similar outcomes to a non-involved extremity, (2) within 2 years, OSD patients have similar outcomes to healthy adolescents in terms of sonographic characteristics, functional aspects and quality of life.

Materials and methods

The study was conducted on 18 subjects, aged 13–16 (age = 14.6 ± 1.7 years; Body Mass Index (BMI) 21.4 ± 3.6 kg/m^2), who had been diagnosed with OSD. All the patients had received physiotherapy intervention and were considered symptom-free. The 18 adolescents previously diagnosed with OSD, were followed up 2 years after diagnosis (patients group), were compared with 14 healthy age-matched young people (control group) that were selected for this study according to certain criteria.

The patients were recruited for the first assessment when the pain had subsided to at least 3 out of 10 cm according to the Visual Analog Scale during a function [10]. The following criteria were considered to exclude both patients and controls from the study; (i) being over 16 years of age; (ii) having had knee pain for more than 3 months after completion of the intervention; (iii) having had pain severity in movement rated at least 3/10 on an 11-point numeric rating scale; (iv) having had radiological evidence of knee joint calcification or prior fracture; (v) having a systemic pathology including inflammatory joint disease; (vi) having symptoms of complex regional pain syndrome; (vii) having had active intervention in the last 3 months including corticosteroid/hydrodilatation injection or physiotherapy; (viii) having taken anti-inflammatory medication in the 2 weeks prior to examination for the study. Inclusion in both the patient and control groups required no prior history of knee anterior dysfunction, and symptomatic range of motion.

After the first assessment of function and ultrasound imaging, the 25 cases were put on the list for long-term follow-up. The flow chart of the selection of the OSD group with all exclusions and reasons was given in Fig. 1. The results of the follow-up of the 18 patients were analysed compared with the involved and non-involved extremities, and with the control group.

The 32 members of the two groups and their parents read and signed an institutionally approved informed consent form before the evaluations. The Research Ethics Committee of Hacettepe University approved the study (FON 09/95).

The orthopaedic examination was carried out by an orthopaedic surgeon (HO), and sonographic data was collected by a radiologist (UT) who is an expert on musculoskeletal examination. All functional assessments were conducted by the same physiotherapists (D.O & B.Y). They used a standardized protocol to ensure the consistency of subject positioning, instructions, and overall testing procedures. Before testing, the following information was obtained: age, height and weight. Body composition was analysed by a Tanita Body Analyzer TBF-300 M. The characteristics of the patients at the baseline and in the second year, and controls are shown in Table 1. The following assessments were performed.

Sonographic assessment

A GE Logiq 9 scanner (General Electric Medical Systems; Milwaukee, WI, USA) and linear 12-MHz (10-14 MHz) high-resolution linear probe were used with musculoskeletal calibration. Patients were positioned supine, and the back of knee was supported. Sonographic changes on the patellar tendon proximal and distal attachment thicknesses and diameter, distal, medial and proximal areas were measured by the radiologist. The apophysis of tibial tubercle was assessed, and the Flaviis classification was determined. The pathological changes corresponded to the following types: Type 1 being the presence of a hypoechoic zone superficial to the apophysis of the anterior tibial tubercle representing pretibial cartilaginous swelling with a forward displacement of the subcutaneous tissues and elevation of the patellar tendon from the tibial outline from the longitudinal view; Type 2 being a fragmented and hypoechoic ossification centre in addition to the above-mentioned Type 1 findings; Type 3, which is a diffuse thickening of the insertion portion of the patellar tendon with or without vacuolation; Type 4 being a fluid collection in the retrotendineal soft tissues representing infrapatellar bursitis [4, 6, 13, 20, 22, 35].

Functional assessment

Before the tests, all subjects were informed about the particular requirements of the tests. They performed an appropriate warm-up exercise programme including basic stretching exercises for the lower extremities. Then, the testing procedure was launched. The measurements of the

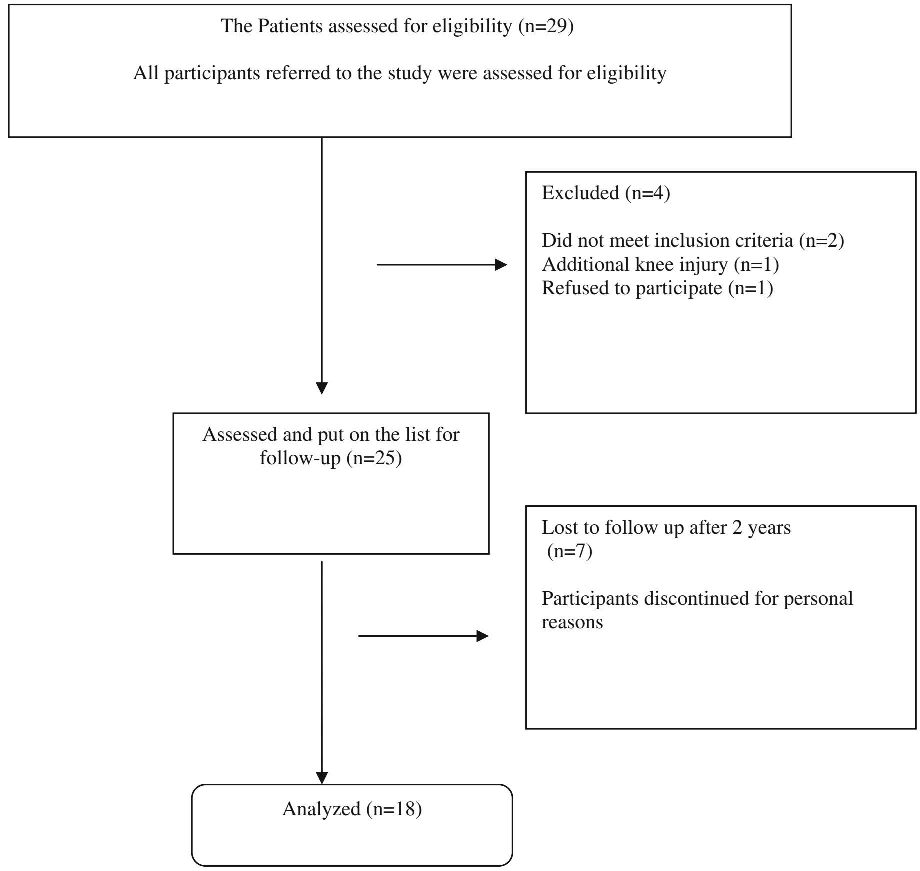

Fig. 1 Flow chart for the patients from assessment to analysis

Table 1 Patient and control group demographic data at the first assessment and patient data at the 2-year follow-up

	OSD ($n = 18$) first assessment	OSD ($n = 18$) 2-year follow-up assessment	p values (first–second)	Healthy controls ($n = 14$)	p values (second controls)
Physical characteristics	Mean ± SD	Mean ± SD		Mean ± SD	
Age (years)	14.6 ± 1.7	16.6 ± 1.7	<0.001*	15.8 ± 0.8	n.s.
Height (cm)	169.9 ± 13.5	176.5 ± 11.9	<0.001*	177.5 ± 7.1	n.s.
Weight (kg)	61.8 ± 17.5	70.4 ± 18.8	<0.001*	68.1 ± 9.1	n.s.
BMI (kg/m^2)	21.4 ± 3.6	22.8 ± 3.8	0.03*	21.6 ± 1.9	n.s.
Fat %	20.3 ± 9.5	17.0 ± 8.1	n.s.	11.1 ± 5.5	0.02*

OSD Osgood–Schlatter disease, *BMI* body mass index, *ns* non-significant

* $p < 0.05$

broad jump and vertical jump tests were applied to the groups bilaterally and subsequently to the dominant side and non-dominant side. The dominant leg was determined by asking the participants which leg they would prefer to use to kick a ball.

The broad jump test was repeated three times, and the best value of the longest distance jumped was recorded in cm [24, 25, 32]. For the vertical jump test, the best value of the three attempts was recorded in cm [23].

The Medical Outcomes Study Short Form 36 (SF-36) questionnaire (Turkish version) was used to measure quality of life. The SF-36 consists of one multi-item scale that assesses eight health concepts: physical functioning, role limitations—physical, body pain, general health, vitality; social functioning, role limitations—emotional and mental health. The eight scales are hypothesized to form two distinct higher-ordered clusters related to the physical and mental health variance that they have in common.

SF-36 scales are standardized in a range from 0 to 100 with a higher score indicating better health status. The validity and reliability study of the Turkish version of SF-36 has been well documented [14].

Functional squat system tests

The assessment of coordination, proprioception, strength and endurance was achieved using a Functional Squat System Machine (Monitored Rehabilitation Systems, Harlem, The Netherlands). This machine mimics the movement pattern of a squat jump, under the control of external load in closed kinetic chain [16, 21].

The Functional Squat System was introduced to the participants, and they became familiar with the equipment. In order to prevent the occurrence of fatigue first, the coordination and proprioception tests were applied, followed by the strength and endurance tests. The participants were instructed to lie on the bed of the Functional Squat System, supine with legs lifted up, hips and knees flexed to 90°, and feet in full contact on the platform of the machine in a squat position. To determine the minimum and maximum range of motion (ROM) of the lower extremity, the participants were asked to extend their knees to 0° maintaining full contact of their feet with the platform. Specific instructions to perform the tests were given.

Coordination and proprioception

The coordination test was performed unilaterally with a load minimizing force control (5 kg) and consisted of 60 s of target tracking during the eccentric and concentric contractions of the lower limb. Participants were provided with ongoing visual feedback of their position by means of a cursor (a sort of target) displayed on the monitor in front of them. They were instructed to match the given trajectory as accurately as possible. The software automatically calculated the absolute average error (metric value, centimetres) and the standard deviation (S.D.) of the average error. Then, the software calculated the deficit between the involved and non-involved sides. For the comparison within groups after 2 years, the deficit results were used. For the comparison between the patient and control groups, and for the involved and non-involved leg of the patients group in the second-year follow-up, the deviation results were used.

In the proprioceptive test, participants were instructed to keep a cross-hair on the line, even after the visual aid was removed, for an objective quantification of proprioceptive ability for 60 s. For the comparison within the groups after 2 years, the deficit results were used. The deviation results were taken into account for the comparison between both groups and for involved and non-involved leg [27].

Strength and endurance

After setting the minimum and maximum ROM, the participant being tested was asked to reach a (concentric) high speed and then to slow down in an (eccentric) controlled manner. The weight was 30 kg for all participants, and 10 trial repetitions were undertaken. Testing began with the dominant side and after resting for 15 s, the non-dominant side was tested. After 3 min, the functional endurance test was performed to obtain information about the endurance of muscle groups. The positions were the same as the strength test. The participant being tested was asked to perform 20 repetitions at the highest speed possible under a 10-kg weight. The main results from the strength and endurance tests were the deficits for total work that shows total capacity within ROM in Nm and the average power, which was total work divided by time. For the comparison within groups over 2 years the deficit results were applied, for the comparison between groups, and within involved and non-involved leg for the patients group after 2 years, the deviation results were used.

Statistical analysis

In this study, the 18 patients with OSD had 90 % power with a 5 % overall type I error level using the data of the tendon structure (especially distal diameter and distal area), which was normalized according to the control group to detect the differences.

The data analyses of the differences between and within groups were performed using SPSS–PC software (SPSS, Inc., Chicago, IL, USA). The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov–Simirnov/Saphiro–Wilk) to determine whether they were normally distributed. The results for the measurements of the three settings were provided with means and standard deviations. The Wilcoxon test was used for statistical analyses between the first and assessment after 2 years of the patient group. The Mann–Whitney U test was used for the comparison between the patient and control groups. The level of significance for all statistical analyses was set at an α value of <0.05.

Results

The demographic data of the patients at the first and after 2 years, and control group data is given in Table 1. Over 2 years, the height, weight and body mass index of the patients changed but body fat percentage did not changed. The only difference between patient and control groups was the fat percentage of the body. The patient group had

Table 2 Phases of the Osgood–schlatter disease patients according to Flaviis classification

Phases according to Flaviis classification	First assessment frequency/percent	2-year follow-up assessment frequency/percent
Stage 0 (Recovered)	0	7/38.9
Stage 1	9/50	7/38.9
Stage 2	4/22.2	2/11.1
Stage 3	2/11.1	1/5.6
Stage 4	3/16.7	1/5.6
Total	18/100	18/100

higher fat percentages than the healthy adolescents in the control group.

All the patients had unilateral involvement OSD. The stages according to the Flaviis classification were shown in Table 2.

From the sonographic assessment, it was shown that the patellar tendon had lengthened, the distal diameter and distal area of the tendon had lessened while proximal diameter, and proximal and medial area remained same in the patients (Table 3). However, there was no difference between controls and second-year results of the patients (n.s.) (Table 3).

Although there was a significantly difference in the broad jump scores, there was no difference in vertical jump scores of the patients. While bilateral broad jump scores were higher than the controls in patients at the second year, the unilateral vertical jump scores were lower ($p < 0.05$) (Table 4).

The quality of life improved physically within 2 years ($p < 0.05$). The mental health component scores of the patients were higher than controls ($p < 0.05$) (Table 4).

There was no difference for the proprioceptive deficit result after 2 years. However, a significant difference was detected for both the concentric and eccentric coordination test results in that the patient group that they had improved ($p < 0.05$) (Table 5). In the follow-up, no difference was found between the involved and non-involved sides of the OSD group, and in the control group for proprioception (n.s.). There were differences for concentric and eccentric coordination between involved and non-involved sides ($p < 0.05$) of the patients. A difference was also observed between dominant and non-dominant sides of controls ($p < 0.05$) (Table 6).

There were no statistical differences for the endurance and strength deficit parameters after 2 years (n.s.) (Table 5). The average power scores of the concentric endurance on both legs, the eccentric endurance on involved side and the concentric and eccentric total work on involved side were significantly higher in the controls than patients ($p < 0.05$) (Table 6).

Discussion

The most important finding of this study was that the changes in the patellar tendon mostly occurred in the distal diameter and area of the patellar tendon. The patient group showed patellar tendon characteristics that were similar to the healthy controls over 2 years. The most significant improvements were shown in broad jumping, the physical component of life quality and multi-joint coordination of the lower extremity. However, after 2 years the patients were still not able to reach the endurance average power and strength total work scores of healthy adolescents in both eccentric and concentric phases.

OSD is an extensor mechanism injury that tends to involve active extension of the knee with vigorous contraction of the quadriceps muscles [15]. The extensor mechanism of the knee is essential for ambulation and the

Table 3 Sonographic findings of the patients and healthy control groups

Ultrasound parameters	OSD ($n = 18$) First assessment non-involved side	OSD ($n = 18$) First assessment involved side	p values	OSD ($n = 18$) 2-year follow-up assessment	p values	Healthy controls ($n = 14$)	p values
Patellar tendon	Mean ± SD	Mean ± SD	Involved non-involved	Mean ± SD	Involved first–second	Mean ± SD	Involved second controls
Length	4.5 ± 0.6	4.5 ± 0.8	n.s.	4.8 ± 0.7	0.008*	4.8 ± 0.7	n.s.
Proximal diameter	0.4 ± 0.9	0.4 ± 0.8	n.s.	0.4 ± 0.8	n.s.	0.4 ± 0.1	n.s.
Distal diameter	0.4 ± 0.9	0.4 ± 0.1	n.s.	0.4 ± 0.8	0.03*	0.7 ± 1.0	n.s.
Proximal area	1.2 ± 0.1	1.2 ± 0.2	n.s.	1.1 ± 0.2	n.s.	1.1 ± 0.2	n.s.
Medial area	1.0 ± 0.1	1.1 ± 0.2	n.s.	1.0 ± 0.2	n.s.	1.0 ± 0.2	n.s.
Distal area	1.0 ± 0.2	1.1 ± 0.2	n.s.	1.0 ± 0.2	0.02*	1.2 ± 0.1	n.s.

ns non-significant

*$p < 0.05$

Table 4 Results of the functional assessments of the patients and healthy control groups

	OSD ($n = 18$) First assessment	OSD ($n = 18$) 2-year follow-up assessment	p values	Healthy controls ($n = 14$)	p values
Functional parameters	Mean ± SD	Mean ± SD	(first–second)	Mean ± SD	(second controls)
Broad jump (cm)					
Involved	136.3 ± 36.3	161.0 ± 33.9	0.02*	149.8 ± 13.1	n.s.
Non-involved	141.8 ± 30.6	159.5 ± 33.8	0.02*	153.7 ± 18.7	n.s.
Bilateral	152.8 ± 34.0	183.6 ± 35.1	<0.001*	156.6 ± 13.3	0.01*
Vertical jump (cm)					
Involved	22.0 ± 9.8	24.3 ± 5.6	n.s.	32.0 ± 3.9	<0.001*
Non-involved	22.8 ± 9.7	23.7 ± 6.2	n.s.	32.6 ± 4.8	<0.001*
Bilateral	32.0 ± 10.7	33.3 ± 7.4	n.s.	32.9 ± 5.4	n.s.
Quality of life					
SF 36 scores					
PCS	46.0 ± 9.5	50.5 ± 7.4	0.05*	54.1 ± 5.8	n.s.
MCS	54.4 ± 6.1	54.7 ± 4.8	n.s.	49.9 ± 4.6	0.007*

PCS physical component summary; *MCS* mental component summary, *ns* non-significant

* $p < 0.05$

Table 5 Squat system analysis of the deficit results between involved and non-involved legs of patients within 2 years

Squat system analysis	OSD ($n = 18$) First assessment	OSD ($n = 18$) 2-year follow-up assessment	p values*
Proprioception	18.8 ± 68.3	51.7 ± 107.2	n.s.
Coordination			
Concentric	39.5 ± 50.1	−13.9 ± 34.6	0.01*
Eccentric	32.4 ± 56.7	−18.8 ± 25.4	0.01*
Endurance concentric			
Total work	3.8 ± 10.4	1.1 ± 7.3	n.s.
Average power	−1.5 ± 33.7	4.5 ± 16.0	n.s.
Endurance eccentric			
Total work	4.5 ± 19.4	1.6 ± 8.2	n.s.
Average power	2.3 ± 9.8	3.3 ± 11.2	n.s.
Strength concentric			
Total work	4.0 ± 8.3	−2.6 ± 29.4	n.s.
Average power	26.3 ± 40.0	49.8 ± 90.2	n.s.
Strength eccentric			
Total work	1.4 ± 6.7	2.0 ± 7.5	n.s.
Average power	15.8 ± 30.0	10.2 ± 36.2	n.s.

OSD Osgood–Schlatter disease, *ns* non-significant

* $p < 0.05$

functions of the adolescent. The symptoms were particularly exacerbated by sporting activities that involve jumping (basketball, volleyball, running) and/or on direct contact (e.g. kneeling) [17]. OSD runs a self-limiting course, and usually complete recovery is expected with the closure of the tibial growth plate within 2 years [36]. Although the overall prognosis for OSD was declared as good, some discomfort in kneeling and activity restriction remains in a few cases [17]. Krause et al. [19] reported the natural history of OSD in 69 knees with radiological fragmentation that had separated ossicles or abnormally ossified tuberosity. According to the Flaviis classification, nearly half of the cases (45 %) totally improved and nearly 40 % only had a class 1, which can be considered a good result for conservative long-term results. In the previous study that nearly 40 % totally healed and 40 % had Type 1, which is similar to that found by Krause et al. [19]. Blankstein et al. [6] also assessed their patients according to Flaviis classification. This study supported the validity and reproducibility of the classification method for the ultrasonographic evaluation of children with OSD. According to their results, 26 % of patients fell into the Type 1 category, 43 % were Type 2, 20 % Type 3 and 11 % Type 4 [6]. Although the Type 3 and 4 percentages were similar to our patient group; however, 40 % of our patients had Type 1.

In this study, the patellar tendon characteristics were also observed in order to investigate the non-osseous tissues. Most significant changes were observed in the distal area and distal diameter of the tendon. Histological studies performed on the tibial tuberosity growth plate have revealed three zones that gradually coalesce. *The proximal zone*, containing short cell columns, is analogous to the upper tibial growth plate. *The middle zone mostly* consists of fibrocartilage that alternates with layers of hyaline cartilage. *The distal zone* mainly comprises fibrous tissue [35]. The fibrous tissue in the distal zone seems to be highly affected in OSD. Over the tibial tuberosity, the involved

Table 6 Squat system analysis of the deviation results of the patients within 2 years and the control group

Parameters	OSD ($n = 18$) 2-year follow-up			Healthy controls ($n = 14$)			p values*	
	Involved	Non-involved	p values	Involved (Non-dominant side)	Non-involved (Dominant side)	p values	Involved	Non-involved
Proprioception								
Non-visible	17.4 ± 8.5	17.1 ± 7.9	n.s.	19.9 ± 5.9	19.9 ± 9.9	n.s.	n.s.	n.s.
Visible	15.8 ± 6.7	15.9 ± 6.4	n.s.	13.6 ± 4.9	16.6 ± 5.5	n.s.	n.s.	n.s.
Coordination								
Concentric	0.6 ± 0.1	0.9 ± 0.4	<0.00*	0.8 ± 0.5	0.9 ± 0.3	0.04*	n.s.	n.s.
Eccentric	0.6 ± 0.2	0.8 ± 0.5	0.01*	0.8 ± 0.6	0.8 ± 0.3	n.s.	n.s.	n.s.
Endurance concentric								
Total work (Nm)	437.7 ± 97.9	436.4 ± 115.2	n.s.	406.5 ± 101.6	416.5 ± 81.1	n.s.	n.s.	n.s.
Average power (Nm/s)	17.4 ± 4.8	17.3 ± 4.9	n.s.	24.8 ± 4.4	24.5 ± 3.5	n.s.	<0.00*	<0.00*
Endurance eccentric								
Total work (Nm)	222.3 ± 48.4	223.3 ± 57.1	n.s.	203.7 ± 32.5	201.7 ± 35.8	n.s.	n.s.	n.s.
Average power (Nm/s)	10.1 ± 2.3	10.0 ± 2.7	n.s.	11.7 ± 1.3	11.5 ± 1.2	n.s.	0.03*	n.s.
Strength concentric								
Total work (Nm)	304.3 ± 56.8	306.5 ± 53.0	n.s.	341.3 ± 43.3	318.8 ± 25.6	<0.00*	0.05*	n.s.
Average power (Nm/s)	45.2 ± 16.1	44.5 ± 17.0	n.s.	50.6 ± 10.3	46.2 ± 8.7	0.05*	n.s.	n.s.
Strength eccentric								
Total work (Nm)	215.3 ± 45.2	216.8 ± 46.5	n.s.	238.7 ± 21.6	227.8 ± 23.9	<0.00*	0.05*	n.s.
Average power (Nm/s)	30.1 ± 11.1	29.6 ± 10.7	n.s.	33.5 ± 6.2	30.8 ± 5.4	n.s.	n.s.	n.s.

OSD Osgood–Schlatter disease; *ns* non-significant

* $p < 0.05$

patellar tendon decreases its diameter and area within 2 years and reaches the same level as in the healthy controls. Although there was no statistical difference between the involved and non-involved sides, for non-involved side the diameter and area in the distal portion were lower. The increase in size might be related to a focal area of low echogenicity in the tendon and the inflammatory stage.

Jumping, proprioception, coordination, strength and endurance were considered to be the functional performance outcomes. Furthermore, quality of life was assessed and calculated with physical and mental components. In the literature, the functional assessments were mostly undertaken subjectively with function and pain questionnaires [29, 30, 37]. In this study, the functional tests were objectively applied to all patients. The recovery progress of the disease allowed us to administer these tests to the patients after the pain subsided to at least a level of three according to the Visual Analog Scale. Collins et al., found that moderate pain intensity starts from 30 mm on the VAS and severe pain from 54 mm. These reference values were taken into account both for the clinical practice and research [10].

The broad jump test is strongly associated with lower body muscular strength; it is valid and reliable test to assess musculoskeletal fitness [32]. The significant differences in this result both for the involved and non-involved sides indicate that there is a large improvement in musculoskeletal fitness for the patient group. It might be related not only to the healing process of the knee joint but also the physiological growth in this adolescent group. Furthermore, the bilateral broad jump performance of the patients was better in 2 years after diagnosis than that of the controls. On the other hand, the patients' vertical jump scores were lower than the controls. On contrary to the results of the broad jump test, the vertical jump score correlated the body weight for both groups. Although there was no difference for body weight between groups, the body fat percentage was higher in the patients than the controls. This might be one potential reason for the difference between patient and control groups.

Quality of life assessments are highly important for musculoskeletal dysfunctions, and especially lower extremity disorders. Although it is well recognized for various knee problems, it is underestimated for OSD. It was observed that in the life quality assessment, the physical component had decreased with the disease but then improved over time. The mental component remained same, but higher in the patients than the controls. A score of about fifty was declared to be normal [31], and it could be considered normal for both groups.

The functional outcomes of squat system are important since this is the first study in which this assessment tool has been used in this type of patient group. There was great improvement in the lower limb inter-joint coordination of the patient group after 2 years. This indicates that coordination with concentric and eccentric loading in a closed kinetic chain seems to be the most important issue in OSD in comparison with the other parameters. Similarly to the results of this study St-Onge et al. [34] emphasized that the analysis of inter-joint coordination may be effective in characterizing motor deficits in people with knee injuries. On the other hand, the involved side deviations were better that the lower deviation results indicated better results for both groups. This might be related to the concentration of the patients and their motor learning function. Using coordination assessment and training during the rehabilitation phase might be important for OSD patients.

Strength and endurance are the main parameters of the musculoskeletal system. They were assessed in closed kinetic chain that was safe for the knee extensor mechanism. The average power scores of the endurance and total work of strength were higher in controls even after 2 years. The strength and endurance of the adolescent patients remained lower than the healthy adolescents. Disfiguration in extensor mechanism may remain for an extended period and may cause problems in terms of the strength and endurance, and this should be considered in physiotherapy and other rehabilitation treatments. In the long-term exercises for strengthening, extensor mechanism both with concentric and eccentric phases could be recommended to the patients [7, 36].

One potential limitation of this study was that the deficit analyses presented the results as positive and negative ranks. This increased the intervals of the standard deviation results. However, using the deviations made the results clearer. Moreover, the current study did not compare the functional performance of the patients before and after physiotherapy intervention. It focused on the functional status 2 years after symptomatic relief had been achieved.

To detect the power analysis of this study, normalized data for tendon structure was used. This study had 90 % power with 18 subjects in the case group. From a total of 29 patients, 25 were included in the first assessment, but over the 2-year period 18 patients remained. This dropout rate of nearly 20 % of dropout number could be considered as a limitation.

Carrying out a long-term follow-up of OSD patients appears to be very important since it allows the observation of the patient's progress towards recovery if the disease is in a healing process or getting worse and creating functional problems. In the present study, nearly 40 % of the patients who had been diagnosed with OSD and had been treated conservatively totally recovered in terms of the tendon structure, within 2 years. Sonography can be used objectively as a non-invasive, cost-effective and practical tool to show the structure of the tendon. However, clinicians should be aware that the structural healing of the tendon may not always correlate with normal functional performance. Multi-joint lower extremity coordination and jumping performance seem to be the most affected components of the performance, but usually they improve over time. Life-long exercise and a physical activity approach could be useful for OSD recovered patients in late adolescent and adulthood. Future work could include extending the current study by following up the patient and control groups into adulthood to determine any knee problems.

Conclusion

The follow-up of patients having been diagnosed with OSD seems very important in terms of determining chondral and functional changes. Over a 2-year period from diagnosis, nearly half of the patients had totally recovered according to the results of the musculoskeletal ultrasonography, and their patellar tendon characteristics were similar to those in the healthy controls. For the patients functional improvements were gained for coordination and broad jumping, however, over a 2-year period following diagnosis the patients were not able to reach the endurance average power and strength total work scores of the healthy adolescent controls.

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