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A comparison of isokinetic muscle strength in patients with chondromalacia patella: a cross-sectional study

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Abstract. – OBJECTIVE: Chondromalacia patella (CMP), which is one of the most common causes of anterior knee pain in young adults, is often accompanied by reflex inhibition of the quadriceps muscle. In this respect, a significant correlation between isokinetic parameters and knee muscle strengths would be expected. We hypothesized that an isokinetic dynamometer, which objectively evaluates muscle strength, may be an important guide in detecting muscle weakness in new-onset CMP and determining early treatment strategies.

PATIENTS AND METHODS: A total of 113 participants (mean age 30.33 ± 6.96 years, min: 18, max: 44) were recruited and divided into two groups, thus a CMP group (n=48) and a control group (n=65). The symptom duration of the CMP group and the demographic characteristics of all participants were recorded. Knee flexion and extension muscle strengths were measured at angular velocities of 60°/s and 180°/s [Knee extension Peak Torque at 60°/s (PTE60), Knee flexion Peak Torque at 60°/s (PTF60), Knee extension Peak Torque at 180°/s (PTE180), Knee flexion Peak at 180°/s (PTF180) respectively] (five sets) using an isokinetic dynamometer. We also recorded the total work done in flexion and extension (TWDF and TWDE). A modified MRI staging system based on the Outerbridge arthroscopy system was used to stage CMP. Isokinetic dynamometric parameters were compared between CMP patients and healthy volunteers.

RESULTS: 59 healthy volunteers (90.8%) were right-side dominant and 6 (9.2%) left-side dominant. 33 CMP patients (68.8%) were right-side dominant, and 15 (31.3%) left-side dominant. 20 (41.7%) CMP patients were classified as Stage 1, 20 (41.7%) as Stage 2, and 8 (16.7%) as Stage 3. All the PTF60, PTE60, PTF180, and PTE180 values were significantly lower in the CMP group than in healthy controls (all $p < 0.05$). CMP symptom duration ≥ 6 months was associated with significantly lower knee muscle strength than with symptom duration < 6 months ($p < 0.05$). Also, a statistically negative correlation was found between MRI stages and PTE60 values ($p < 0.05$).

CONCLUSIONS: In conclusion, our findings show that the isokinetic dynamometer reveals muscle weakness in CMP patients, and weakness in isokinetic parameters was negatively correlated with symptom duration and MRI stages. Isokinetic knee muscle strength testing, together with other functional tools, enables the assessment of muscle weakness and early rehabilitation planning for patients with CMP.

Key Words:
Chondromalacia patella, Muscle strength dynamometer, Torque.

Introduction

Chondromalacia patella (CMP) is the most common cause of anterior knee pain in young adults[1-3], impairing normal knee function[1], quality of life[4], and gait[5]. Biomechanically, the patella serves as both a lever and the moment arm of the knee patellofemoral joint[1,2]. The patella cannot perform these functions adequately in CMP patients due to the patella's hyaline cartilage density being less than that of healthy knees[3]. Patients in the early stages of CMP have no difficulty performing daily activities except for compelling movements, such as jumping, squatting, and long-distance running.

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Isokinetic knee muscle strength measured using a dynamometer yields data on muscle torque and power over a specific range of motion at a constant angular velocity. It is possible to rapidly quantify muscle peak torque, angle-specific torque, and work, and to derive (concentric or eccentric) isokinetic indices[6-15]. Very few reports[16,17] have used isokinetic knee muscle strength measurements to assess and follow-up CMP.

Using an isokinetic dynamometer, we compared the isokinetic knee muscle strengths of CMP patients and healthy volunteers. We hypothesized that an isokinetic dynamometer, which measures muscle strength objectively, would be a critical tool for detecting muscle weakness in its earliest stages. The purpose of this study was to demonstrate that it can be a valuable tool for detecting early muscle weakness in CMP disease and developing early treatment strategies.

Patients and Methods

Study Design and Study Population

48 CMP patients and 65 healthy volunteers were enrolled in this controlled cross-sectional study. 70 consecutive patients with CMP clinical signs and symptoms, such as anterior knee pain, grinding feeling, crepitus, no complaint but knee pain during leg extension and effusion were referred to the radiology department for diagnosis and Outerbridge's Modified Magnetic Resonance Imaging (MRI) staging system[18]: Stage 0 is normal cartilage; Stage 1 is softening or edema of the cartilage without abnormal contours; Stage 2 is fragmentation, fissuring, or focal defects affecting less than 50% of the cartilage; Stage 3 is fragmentation, fissuring, or focal defects affecting more than 50% of the cartilage; and Stage 4 is full-thickness cartilage lesions. There were 63 patients included in the study who met the following criteria: (I) age between 18 and 45 years; (II) CMP on the dominant side, as determined by Outerbridge's modified MRI staging system. The following criteria were used to exclude participants: (I) a prior diagnosis of neuromuscular or rheumatologic disease; (II) a history of prior knee surgery; (III) a history of severe lower extremity trauma; (IV) severe hearing or vision impairment; (V) uncontrolled hypertension; (VI) pregnancy. Additionally, subjects who did not complete follow-up or were unable to complete isokinetic testing were excluded. Clinical examinations were performed on 65 controls who self-reported good health without complaint. Only the subject's dominant side was evaluated; if the subject was left-handed, the left lower extremity was considered dominant; and vice versa if the subject was right-handed.

Data Collection

Data including sociodemographic characteristics (age, height, weight, and gender), duration of symptoms, and MRI stages of patients were recorded. A detailed physical examination including locomotor system and neurological examination was performed. The knee extension/flexion isokinetic tests were performed using an isokinetic dynamometer (HUMAC NORM, Version: 10.000.0039, CSMi, USA) operating at angular velocities of 60°/s and 180°/s[19]. Due to the lack of a standardization study using isokinetic dynamometer muscle strength values, we compared the isokinetic knee muscle strength of chondromalacia patella patients to that of healthy volunteers and examined the relationships between isokinetic parameters and symptom duration. Finally, 15 subjects were excluded because they did not show up for their test appointments or were unable to complete the test due to pain and/or weakness. Participant flow and study profile are presented in Figure 1.

Isokinetic Testing

An isokinetic dynamometer was performed to evaluate knee extension and knee flexion peak torque and total work done. In an isokinetic dynamometer, the speed of movement is constant, and the resistance applied to the muscle is equal at every angle of movement. Peak torque is the highest torque output by muscular contraction through the range of motion and maximal concentric force was measured by determining peak torque during knee movement. In isokinetic systems, work is defined as the area of angular displacement against the force. Work is the torque times angular distance. Total work is the amount of muscular work during repetitive movement and is defined in isokinetic as the area under the torque curve (Figure 2). It is a speed-dependent parameter, and the highest value is obtained at low speeds. Total work is used to measure endurance in isokinetic tests. As a result of total work done measurements, it is difficult to distinguish between true muscle weakness and a decrease in endurance. However, the total work done increased with increased muscle strength and/or endurance increases[20,21]. Normally, 2 or 3 speeds should be done in an isokinetic test. These speeds are low (30-60°/s), medium

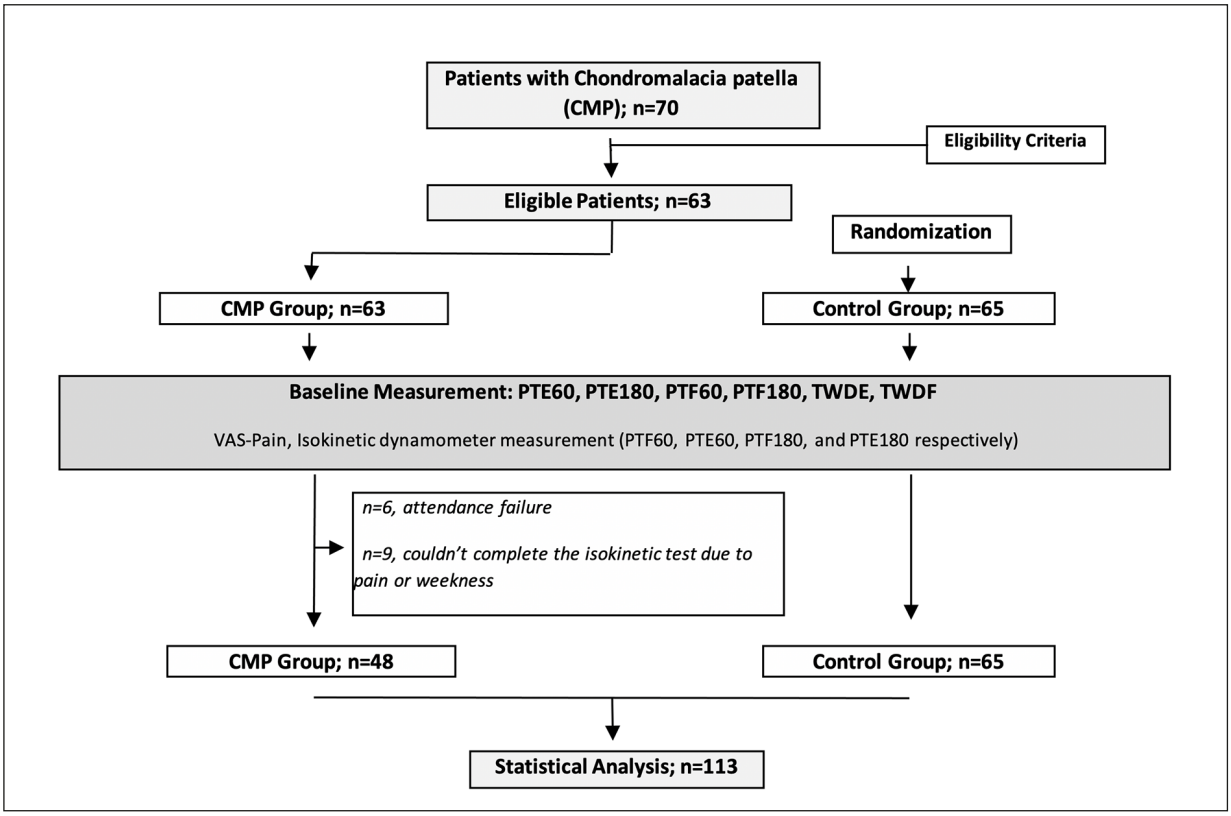

Figure 1. Participant flow and study profile.

(90-120°/s), and high (180-300°/s). Strength tests are done at low speeds, while strength and endurance tests are done at high speeds[20,21].

In the study, the dynamometer had been calibrated before testing. Each knee was placed on the knee flexion/extension plate and secured with Velcro straps. For familiarization, each subject was instructed to move the knee from maximal flexion to maximal extension three times. Before testing, each subject underwent a light (less than 50 W) warm-up on a cycle ergometer, followed by 30-s stretches of the quadriceps and hamstring muscles[16,19]. The same investigator performed all the tests. The isokinetic evaluation was carried out using the concentric mode. The protocol comprised a set of 5 repetitions at 60°/sec angular velocity for detecting muscle strength, a set of 15 repetitions at 180°/sec, then the last set of 30 repetitions at 180°/sec for detecting strength and endurance. Between the sets, the subjects rested for one minute. All subjects were encouraged both verbally by the examiner, and visually by following the visual feedback displayed in real-time on the computer screen (Figure 3).

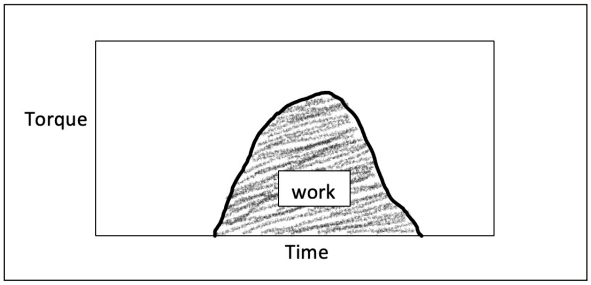

Figure 2. Isokinetic peak torque and work.

Statistical Analysis

The data were analyzed using the SPSS statistical package version 21.0 (IBM Corp., Armonk, NY, USA). The Humac Norm software yielded the peak torque (PT) values and the total work done (TWD) during knee extension and flexion. The means, standard deviations, and ranges were determined. The Kolmogorov-Smirnov test was used to confirm that the parameters were normally distributed. We used a parametric test (Independent group *t*-test) and a nonparametric test (Mann-Whitney U test), as appropriate. The significance level was set to $p < 0.05$.

Figure 3. Encouragement of all participants verbally and via computer screen by examiners.

Results

Demografic Characteristics

48 CMP patients and 65 healthy controls were included in our study with a mean age of 30.33 ± 6.96 years (min: 18, max: 44 years). Demographic characteristics are presented in Table I. 59 healthy volunteers (90.8%) were right-side dominant and 6 (9.2%) left-side dominant. 33 CMP patients (68.8%) were right-side dominant, and 15 (31.3%) left-side dominant. 20 (41.7%) CMP patients were classified as Stage 1, 20 (41.7%) as Stage 2, and 8 (16.7%) as Stage 3.

Isokinetic Parameters

The knee flexion and extension PTs at 60°/s and 180°/s (PTF60, PTE60, PTF180, and PTE180) and the TWD during knee flexion and extension (TWDF and TWDE) were assessed (Table II). The PTF60, PTE60, PTF180, and PTE180 values differed significantly between the groups (all $p < 0.05$), but the TWDE and TWDF values did not (both $p > 0.05$).

Duration of Symptoms

The mean duration of symptoms in the CMP group was 7.13 ± 4.9 months; 26 (54.20%) patients had symptom durations > 6 months. Table III lists

Table I. Demographic characteristics of CMP group and control group.

	Total		CMP group (n=48)		Control group (n=65)		*p*
	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	
Age (years)	30.33±6.96	18-44	31.71±7.49	18-43	29.31±6.4	18-44	0.07
Height (cm)	175.62±10.12	150-210	178.81±10.04	158-210	173.26±9.58	150-190	0.001
Weight (kg)	77.56±15.86	45-120	81.08±16.35	53-120	74.95±15.09	45-115	0.04
BMI	24.93±3.44	17,.58-38.42	25.15±3.41	18.78-31.88	24.76±3.48	17.58-38.42	0.56
Gender	Number	Percentage (%)	Number	Percentage (%)	Number	Percentage (%)	
Male	77	68.1%	33	68.8%	44	67.7%	0.905
Female	36	31.9%	15	31.3%	21	32.3%	

CMP: Chondromalacia patella; BMI: Body Mass Index; SD: Standard Deviation.

Table II. The results of isokinetic dynamometer analysis in CMP group and control group.

	Total		CMP group (n=48)		Control group (n=65)		p
	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	
Knee extension							
PTE60	139.19±62.19	14-298	108.92±51.01	14-262	161.55±60.52	50-298	***<0.001***
PTE180	85.34±34.16	18-170	73.5±32.21	18-140	94.08±33.12	28-170	***0.001***
TWDE	1,207.38±478.59	183-2,110	1,136.9±535.76	183-2,003	1,259.43±428.45	324-2,110	0.179
Knee flexion							
PTF60	67.69±33.23	7-175	56.71±34.16	7-175	75.8±30.29	19-167	***0.002***
PTF180	43.81±18.72	9-96	39.98±19.37	9-96	46.63±17.85	14-88	***0.045***
TWDF	533.42±292.56	4-1,229	492.13±334.94	4-1196	563.91±255.31	14-1,229	0.217

CMP: Chondromalacia patella; PTE60: Knee extension Peak Torque at 60°/s; PTE180: Knee extension Peak Torque at 180°/s; TWDE: Total work done for knee extension; PTF60: Knee flexion Peak Torque at 60°/s; PTF180: Knee flexion Peak Torque at 180°/s; TWDF: Total work done for knee flexion; SD: Standard Deviation.

Table III. Duration of symptoms and isokinetic parameters correlation in CMP group.

	Duration of symptoms*
PTE60	-.726**
PTF60	-.573**
PTE180	-.734**
PTF180	-.562**
TWDE	-.704**
TWDF	-.461**

*Pearson Correlation **$p<0.05$. CMP: Chondromalacia patella; PTE60: Knee extension Peak Torque at 60°/s; PTE180: Knee extension Peak Torque at 180°/s; TWDE: Total work done for knee extension; PTF60: Knee flexion Peak Torque at 60°/s; PTF180: Knee flexion Peak Torque at 180°/s; TWDF: Total work done for knee flexion.

the significant negative correlations between symptom duration and the isokinetic parameters of the CMP group (all $p < 0.05$). As symptom duration increases, the PT, the TWD, and knee muscle strength decreased in the CMP group (all $p < 0.05$). Table IV lists the isokinetic parameters of CMP patients with symptom durations < 6 and ≥ 6 months. All isokinetic parameters were significantly lower in the latter than in the former group (all $p < 0.0001$).

MRI Stages

MRI stages and isokinetic parameters were assessed (Table V). A statistically negative correlation was found between MRI stages and PTE60 values ($p < 0.05$). As the stage progresses, knee muscle strength decreased in the CMP group.

Discussion

We compared the isokinetic knee muscle strength of CMP patients and healthy volunteers using an isokinetic dynamometer and examined the relationships between isokinetic parameters and symptom duration. At 60°/sec and 180°/sec

Table IV. Isokinetic parameters analysis between < 6 months of symptom duration and ≥ 6 months of symptom duration in CMP group.

	< 6 months of symptom duration in CMP group		≥ 6 months of symptom duration in CMP group		p
	Mean±SD	Min-Max	Mean±SD	Min-Max	
PTE60	147.77±43.71	104-262	76.04±28.89	14-115	***< 0.0001***
PTF60	79±36.01	39-175	37.85±17.25	7-81	***< 0.0001***
PTE180	99.05±24.06	56-140	51.88±20.1	18-110	***< 0.0001***
PTF180	52.68±18.61	31-96	29.23±12.35	9-56	***< 0.0001***
TWDE	1,563.73±372.58	702-2,003	775.73±356.44	183-1,400	***< 0.0001***
TWDF	694.18±290.75	20-1196	321.15±271.22	4-955	***< 0.0001***

CMP: Chondromalacia patella; PTE60: Knee extension Peak Torque at 60°/s; PTE180: Knee extension Peak Torque at 180°/s; TWDE: Total work done for knee extension; PTF60: Knee flexion Peak Torque at 60°/s; PTF180: Knee flexion Peak Torque at 180°/s; TWDF: Total work done for knee flexion.

Table V. MRI stages and isokinetic parameters correlation in CMP group.

	MRI Stage*
PTE60	-.284**
PTF60	-.276
PTE180	-.231
PTF180	-.267

*Pearson's Correlation **$p<0.05$. MRI: Magnetic resonance imaging; CMP: Chondromalacia patella; PTE60: Knee extension Peak Torque at 60°/s; PTE180: Knee extension Peak Torque at 180°/s; PTF60: Knee flexion Peak Torque at 60°/s; PTF180: Knee flexion Peak Torque at 180°/s.

angular velocities, the knee flexion and extension muscle strengths of CMP patients were significantly lower than those of healthy volunteers ($p < 0.05$), but the TWDE and TWDF values did not differ significantly. In other words, while CMP patients demonstrated a significant decrease in muscle strength at low and high angular velocities, no difference in muscle endurance was observed. There is a negative correlation between the duration of symptoms and the CMP group's isokinetic parameters (all $p < 0.05$). As symptom duration increased, knee muscle strength decreased in the CMP group. A symptom duration ≥ 6 months was associated with significantly lower knee muscle strength than a symptom duration < 6 months ($p < 0.05$) in the CMP group. There were also negative correlations between MRI stages and PTE60 parameters ($p < 0.05$).

Larsson et al[22] examined quadriceps muscle strength and speed of movement in 114 subjects aged 11-70 years. They emphasized that isometric and dynamic strengths increased up to the mid-thirties and then remained near-constant to the mid-fifties. Our study participants' mean age was 30.33 years (CMP and control groups 31.71 and 29.31 years, respectively). Although both groups were young, the mean PT in extension and flexion at 60°/s and 180°/s was significantly lower in the CMP group than in the control group ($p < 0.001$ for PTE60; $p = 0.001$ for PTE180; $p = 0.002$ for PTF60; and $p = 0.045$ for PTF180). CMP may have a significant impact on the well-being of young people, impairing their ability to walk and run.

Bakrac[17] investigated the improvement of muscle strength in athletes aged 16-35 years (n = 44) undergoing isokinetic rehabilitation with CMP. All subjects received 15 sessions of isokinetic rehabilitation, with an average increase in muscle strength of 144% (SD = 130). Yildiz et al[16] examined the relationship between isokinetic muscle strength and functional capacity in 30 recreational athletes with CMP. During rehabilitation, exercise sessions were performed three times weekly at angular velocities of 60°/s and 180°/s. The PTs, TWDs, and endurance parameters of the quadriceps and hamstrings improved significantly, as did the functional and pain scores. Thus, isokinetic strength training can help CMP patients improve their muscle strength and power[16,17]. Isokinetic devices have been extensively used to study the dynamics of muscles[2]. In practice, our study would be beneficial for establishing a baseline assessment of CMP before rehabilitation. Early muscle strengthening could be used in combination with medical and interventional procedures.

The isokinetic dynamometer is the gold standard for measuring torque, work, and power as a function of angular velocity, as well as the agonist/antagonist muscle strength ratio[8,9,11,23-26]. The PT is a good indicator of maximum muscular tension, and strength tests are performed at low speeds (PT30-60°/s), whereas endurance and strength tests are performed at high speeds (PT180-300°/s). Generally, work is defined as force multiplied by distance. The TWD is the total of all work performed on a set[19]. Total work is used to measure endurance in isokinetic tests.

CMP patients had significantly lower knee extensor and flexor strengths at 60°/s and 180°/s, respectively, than the control group (all $p < 0.05$). Although the CMP had slightly lower TWDE and TWDF values than the control group, statistical significance was not achieved ($p > 0.05$). If we interpret these findings correctly, the maximum force that a muscle can generate decreased when compared to healthy muscles, but no difference in total work performed or endurance was observed. We presume that including more CMP patients would have revealed significant differences in TWDE and TWDF values between groups.

Muscle strength is of great clinical importance in both health and disease[27]. Isokinetic dynamometers easily quantify muscle strength in daily practice and research trials[16,17,28,29]. We consider that isokinetic evaluation may be usefully diagnostic of CMP, as is conventional MRI staging. During a patient's rehabilitation, it is important to accurately, reliably, and appropriately measure how strong their muscles are and how well they can do things[30]. Ouazzani et al[28] explored the isokinetic profiles of the knee extensor and flexor muscles in patients with patellofemoral pain

syndrome (PFPS). 58 PFPS patients underwent isokinetic examinations at 60°/s and 180°/s using the Cybex Humac Norm dynamometer. The muscle PTs were lower for the involved than for healthy knees; 87.9% of patients evidenced low peak extension torques. Van Tiggelen et al[29] analyzed isokinetic parameters associated with the development of anterior knee pain syndrome (AKPS) in a military setting (n = 96). The peak extensor torque at 60°/s was significantly lower in the AKPS than in the control group. CMP is associated with MRI-detectable changes in patellar cartilage but develops in only some PFPS patients who present with anterior knee pain[2,3]. Although the patients of the abovementioned studies differed somewhat from our patients, we also observed significantly lower peak extension and flexion torques in the CMP compared to the control group (both $p < 0.05$).

Damgaci et al[31] analyzed the effect of patellofemoral joint morphology and patellar alignment on the presence of CMP. They evaluated the MRI of 243 patients retrospectively and grouped the participants as a normal group, group with mild chondromalacia (grades 1-2), and group with severe chondromalacia (grades 3-4). They assessed the angle between the patella and patellar tendon (P-PTA), the angle between the quadriceps tendon and patella (Q-PA), and also patellar tilt was assessed by lateral patellar tilt angle (LPTA). Results showed that P-PTA, Q-PA, and LPTA values were significantly lower in patients with severe chondromalacia than in patients with both normal and mild chondromalacia ($p < 0.001$). We did not measure P-PTA, Q-PA, or LPTA values in our study, but we found a statistically negative correlation between MRI stages and extensor muscle strengths (PTE60). This can be explained by the decrease in P-PTA, Q-PA, and LPTA in the advanced stage. We knew that in isokinetic testing, strength tests are done at low speeds (30-60°/s) because the degree of difficulty increases as the angle decreases and it is possible to detect muscle weakness at low angles. Therefore, this may be the reason why we could not find this negative correlation in other parameters.

Limitations

Our study has some limitations. First, there are no MRI images of healthy individuals; instead, they are determined to be healthy based on their statements and clinical examination. Secondly, there is also the concern of a small sample size.

Conclusions

In conclusion, using an isokinetic dynamometer, we revealed muscle weakness in CMP patients. Rehabilitation for patients with CMP should begin as soon as possible and should incorporate the isokinetic knee muscle strength test in addition to other tools for assessing weakness. Thus, early isokinetic dynamometry can aid rehabilitation planning by allowing for an early assessment of CMP while maintaining muscle strength.

Conflict of Interests

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

Ethics Approval

The protocol was approved by the institutional Local Ethics Committee of the Istanbul Medipol University (IRB No.: E-10840098-772.02-6119).

Informed Consent

Written informed consent was obtained from each patient.

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