

The effectiveness of Pilates for partial anterior cruciate ligament injury

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Abstract

Purpose This study explored the effects of Pilates on the muscle strength, function, and instability of patients with partial anterior cruciate ligament (ACL) injuries in situations in which a non-surgical treatment option is preferred.

Methods Fifty participants 20–45 years of age who were diagnosed with isolated ACL injuries were included in the study. The participants were randomly assigned to either the Pilates exercise group ($n = 24$) or the control group ($n = 26$). The subjects in the Pilates exercise group performed basic mat exercises that focused on the muscle strength and flexibility of the lower limbs and core muscles during each class session, which met three times per week for 12 weeks. The control group did not receive any treatment or home exercise programme. All patients were evaluated using the Lysholm Knee Scale, the Cincinnati Knee Rating System, and isokinetic quadriceps and hamstring strength. Patient satisfaction regarding improvement in knee stability was assessed using the Global Rating of Change scale.

Results The Pilates group experienced significant improvement over the control group as measured by the difference in quadriceps strength at 12 weeks ($p = 0.03$). Both groups showed some clinical change over time, but

the Pilates group improved for all outcome measurements at the 12-week follow-up, and the control group only improved for functional outcomes. Patient satisfaction with the level of knee stability based on the Global Rating of Change scale was higher in the Pilates group than in the control group.

Conclusion Although both groups exhibited improvements in knee strength and functional outcomes, the results suggest that Pilates is a superior management approach over a control treatment for increasing quadriceps strength in participants with partial ACL injury. Pilates may provide clinicians a novel option when choosing a treatment for a partial ACL injury. Further study is needed to determine whether certain subgroups of individuals might achieve an added benefit with this approach.

Level of evidence II.

Keywords Copers · ACL rupture · Conservative treatment · Isolated ACL rupture

Introduction

Partial tears of the anterior cruciate ligament (ACL) are common; in fact, they account for 10–28 % of all ACL tears [28]. Natural history studies following patients with these types of injuries have demonstrated that fewer than 50 % of patients return to their pre-injury activity level; moreover, many studies have also documented that progression to a complete rupture is a common outcome for patients who attempt to return to an active lifestyle [30]. Thus, the chosen treatment plan needs to be individualized and appropriate for each patient's needs. Identifying patients with partial ACL tears who are at low and high risk of progression to complete ligament deficiency is fundamental

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for providing appropriate therapeutic guidance [29]. Dawson et al. [8] reported that patients who were treated non-surgically could achieve similar functional and satisfaction levels as compared to those who had undergone reconstructive surgery. Recent studies showed that conservative treatment options produce good results when prescribed to the appropriate type of patient and are associated with a minimal reduction in activity level and no reduction in stability [16, 27, 30].

The main aim of conservative treatments for ACL injuries is to prevent the re-injury of the ACL and surrounding tissue and to maintain the strength, function, and stability of the knee. Therefore, the inclusion of core stability exercises in the treatment regimen has recently become very important [4]. Core stability can be defined as the body's ability to maintain or resume an equilibrium position of the trunk after perturbation. Deficits in neuromuscular control of the body's core may lead to uncontrolled trunk displacement during athletic movement, which in turn may place the lower extremity in a valgus position, thereby increasing knee abduction motion and torque and resulting in increased knee ligament strain and ACL injury [13]. Zuzalak et al. [32] reported that athletes with decreased core stability were more prone to ACL injuries.

Pilates has been used since the early twentieth century as a method to increase core stability and to increase strength, flexibility, and range of motion through controlled movements of the body [31]. Exercises within Pilates emphasize correct postural alignment; breathing; coordination and balance; and the use of core postural muscles, including abdominal, pelvic, spinal, and gluteal muscles [21]. Systemic reviews in the literature showed that Pilates is effective for many musculoskeletal problems, such as lower back pain, pelvic muscle weakness, and postural balance disorders in elderly people [1, 3, 22]. Only a few studies in the literature specifically investigated the effectiveness of Pilates on lower extremity pathology [15, 18]. To date, no study that has investigated the effects of Pilates on total or partial ACL injury has been published in the literature. The hypothesis of the current study is that Pilates will help improve pain, strength, function, and stability for patients with partial ACL injuries. The purpose of this study was to explore the effect of Pilates on the muscle strength, function, and instability of participants with partial ACL injuries in situations in which a non-surgical treatment option is preferred.

Materials and methods

Previously diagnosed patients with an isolated ACL injury ($n = 72$) were invited to participate in the study. The participants were patients of the Department of Orthopaedics

of the Faculty of Medicine at Istanbul University. The diagnoses were established by a physician based on the patient histories, physical examinations, and diagnostic imaging. Participants with meniscus injuries, meniscus tears, chondral lesions, other ligament laxities, a grade IV injury based on the Lachman test, a generalized laxity, and/or a body mass index (BMI) higher than 30 kg/cm² were excluded from the study. Participants included in the study were between the ages of 20 and 45, had a sedentary occupation or low activity level, required conservative care rather than surgery, and had visual analogue scale scores lower than 3. Before they were included in the study group, all participants were asked to read and sign an informed consent form, which had been approved by the ethical committee at Istanbul University (IRB study protocol: 2010/875-265).

Outcome measurements

Knee function was measured using the Lysholm Knee Scale and the Cincinnati Knee Rating System. The Lysholm Knee Scale is scored from 0 to 100, i.e. from worst to best, respectively; note that 25 points are attributed to pain, 25 points to instability, 15 to locking, 10 each to swelling and stair climbing, and 5 each to limping, use of a support, and squatting [7, 28]. The test–retest reliability of the original version was 0.90 [28]. Briggs et al. [5] reported high test–retest reliability (0.94) for ACL injuries 25 years after the injury. In addition, the Turkish version of the Lysholm Knee Scale showed very good test–retest reliability (0.82) [7]. The Cincinnati Knee Rating System includes a functional assessment based on the following six abilities: walking, using stairs, squatting and kneeling, straight running, jumping and landing hard, and twists cuts and pivots—all of which are important for participation in sports. This scale can be used to evaluate change following surgery or other treatments. The minimum score is 120, and the maximum score is 420 points. The goal is to have the highest possible function in each of the six categories; thus, a higher score indicates better functionality. The test–retest reliability of the Cincinnati Knee Rating System was found to be between 0.71 and 0.98 for subjects with uninjured, injured, or ACL-reconstructed knees [2].

The isokinetic strength of the participants' quadriceps and hamstrings was assessed at the velocity of 180 degrees/s with a Biodex System 3 (Biodex Inc., Shirley, NY, USA). A standardized approach with equipment, data collection, and procedures for warm-up was used before testing. The subjects performed active exercises with a stationary bike for a 5-min warm-up. During testing, each subject sat in a dynamometer with his/her pelvis stabilized with straps; the thigh bolster was set over his/her thighs,

and the ankle cuff was placed around his/her ankle. The lever arm was adjusted individually, and the rotation of the axis was positioned to align with the axis of the knee. The range of motion at testing was set between 0 for extension to 90 for flexion. During testing, the subjects were allowed to grasp the handles of the bench. Before the data collection began, each subject performed three practice repetitions. After 1 min of rest, five maximal extension–flexion concentric efforts were performed at 180 degrees/s with 1-min rest intervals between subsequent five rounds of tests [24, 26]. Subjects were encouraged to give their maximal effort each time. The uninjured leg was always tested first. The isokinetic peak torques for the quadriceps and hamstrings were recorded. The isokinetic concentric mode of the Biodex dynamometer was found reliable for test–retest measures of peak torque [10].

The Global Rating of Change (GRC) scales were used to quantify the patients' improvement in stability. The participants rated their condition compared to the beginning of the exercise programme by stating if they had improved significantly, improved slightly, stayed the same, deteriorated slightly, or deteriorated significantly [19]. The GRC scales offer a flexible, quick, and simple method for charting self-assessed clinical progress within either research or clinical settings. The instrument provides the advantages of clinical relevance, adequate reproducibility, and sensitivity to change and is intuitively easy to understand by the patient and the person administering the test [14].

Participations and randomization

In this study, 72 participants with isolated ACL injuries were recruited for the study. Of the recruited patients, 11 participants did not fit the inclusion criteria and were excluded from the study. The remaining 61 participants were randomly assigned to either the Pilates group (i.e. these participants would perform Pilates three times per week over a period of 12 weeks as part of their treatment plan) or the control group. The randomized assignment of participants to study groups was performed by using a computer-generated randomized table of numbers that was created before the beginning of the study. Thirty-one of the 61 participants were assigned to the Pilates group, and 30 participants were assigned to the control group. The Pilates group was further divided into five groups, and each group consisted of 6–7 participants. Twenty-seven participants completed the Pilates course of exercises, but three of them did not continue through the follow-up at 12 weeks. The data from the remaining 24 participants (i.e. mean age 25.2 ± 5.3 years, range 20–43, female: 9) were analysed for the Pilates group. Four of the participants in the control group did not continue through the follow-up at 12 weeks.

The data from the remaining 26 participants (i.e. mean age 25.8 ± 4.2 years, range 22–45, female: 14) were analysed for the control group (Fig. 1).

Interventions

Pilates group

Prior to the onset of the exercise programme, the participants received 5 days of instruction on the principles of Pilates, including centring, concentration, control, precision, flow, and breathing. The selected Pilates principles especially emphasized strengthening both the quadriceps and hamstring muscles along with the core muscles (Appendix 1).

The participants who were assigned to the Pilates group engaged in a 60-min Pilates class three times per week for 6 weeks. The classes were conducted in a group setting (i.e. 6–7 participants per group) and were led by a trained physical therapist. Each exercise session commenced with a 10-min warm-up and finished with a 5- to 10-min cooldown. The rest interval between sets and exercises was 45 s. The average duration of each repetition was 3–4 s. The volume of training was progressively increased every 2 weeks. The exercise intensity was adjusted by increasing the number of repetitions. A home programme was given to the participants at the end of the 6-week group programme. The participants were instructed to engage in the home programme for the 6 weeks following the group programme. A gym ball and exercise band were provided for the patients to use in their home programme. The home programme was similar to the group programme, but the intensity and repetition of the exercises was dependent on the participants' compliance. During the 6-week home programme period, the participants visited the Pilates instructor every 2 weeks to discuss their home programme. Blinded assessments (i.e. functional scores and isokinetic strength) were done at baseline and at 12 weeks by a physical therapist (NT, HC).

Control group

The control group did not receive any treatment or home exercise programme. The functional scores and isokinetic strength tests were done at baseline and at 12 weeks. Following the 12-week assessment, the control participants were offered the opportunity to attend a 6-week course of free Pilates classes.

Statistical analysis

The data were analysed using the Statistical Package for the Social Sciences version 17 for Windows (SPSS Inc.,

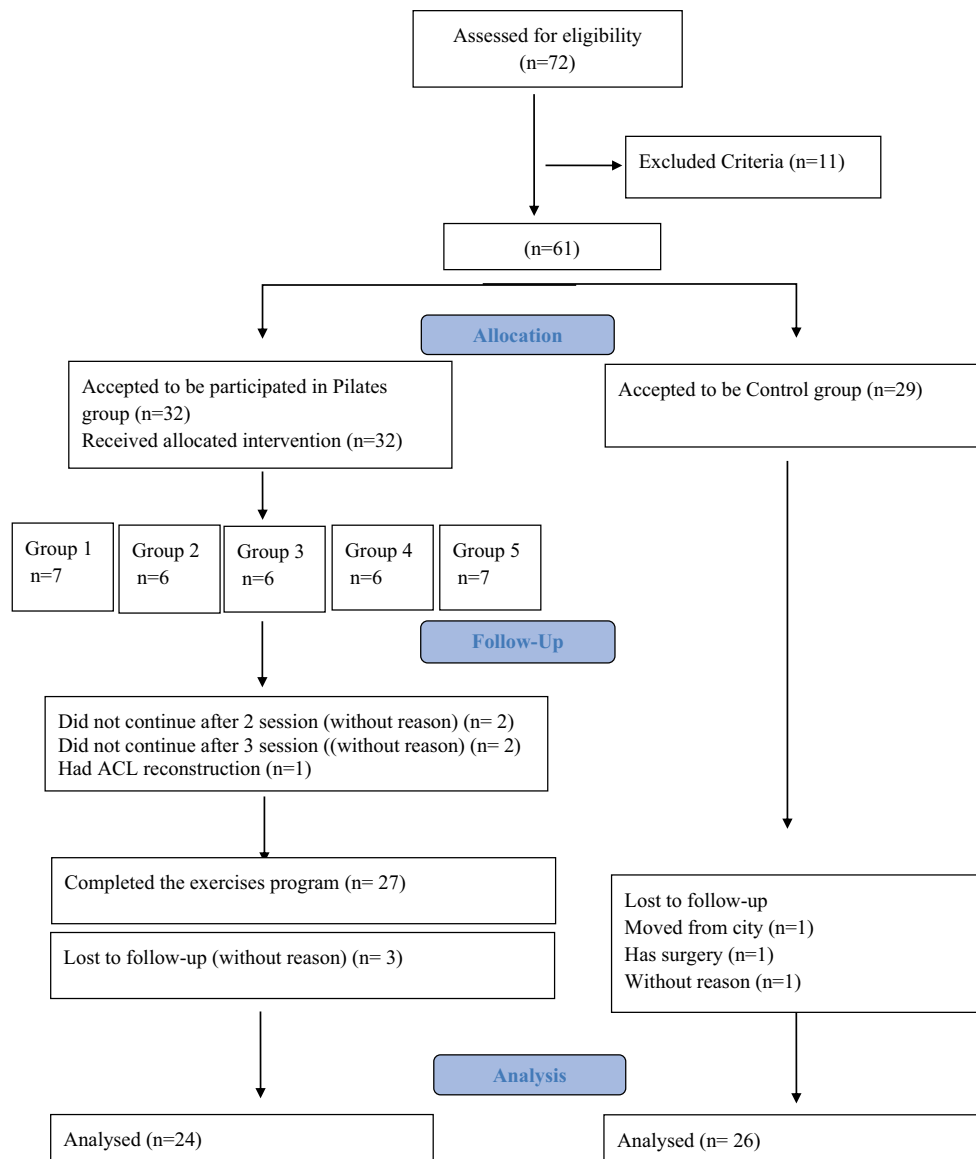


Fig. 1 Flow chart of the study design

Chicago, Illinois). Descriptive statistics were used to analyse the participants' characteristics. Prior to statistical analysis, the Shapiro–Wilk test was used to assess the distribution of the data. The data were found to be normally distributed; thus, parametric tests were used for statistical analysis. Demographic comparisons of the two groups were conducted using Chi-square analysis for categorical variables, and *t* tests were used for continuous variables. The changes in dependent variables before treatment and after treatment were analysed using a two-way repeated measure of analysis of variance (ANOVA) to assess the overall group as well as time (i.e. before and after treatment) and group (i.e. Pilates and control) interaction effects. Pairwise comparisons were performed to

examine the difference between the baseline and follow-up periods. All outcome analyses were conducted according to the intention-to-treat (ITT) principle. Effect sizes (ES) were determined by calculating the differences in the means of the baseline and the follow-up data divided by the standard deviation at the baseline; ES of 0.2, 0.5, and 0.8 was considered small, moderate, and large, respectively [9, 19]. The level of significance was set at $p \leq 0.05$.

Sample size

The sample size was determined, and power calculations were performed with the instant sample size calculator.

Table 1 Demographic features

Characteristics	Pilates group (<i>n</i> = 24)	Control group (<i>n</i> = 26)	<i>p</i> value
Age (mean ± SD)	25.0 ± 9.1	25.9 ± 7.5	n.s
Female/male	22/2	24/2	n.s
Dominant side R/L	20/4	20/6	n.s
Body mass index (kg/cm ²)	25.5 ± 5.1	24.7 ± 6.0	n.s
Involved dominant/Non-dominant	16/8	14/10	n.s
Duration of the symptoms	5.4 ± 2.4 months	6.2 ± 1.2 months	n.s

Values expressed as mean ± SD

SD Standard deviation, R right, L left

The calculations were based on a standard deviation of 12 points, a between-group difference of 8.9 points [i.e. represents the minimal clinically important difference (MCID) for the Lysholm Knee Scale], an alpha level of 0.05, a β level of 20 %, and a desired power of 80 % [3]. These parameters generated a necessary sample size of at least 28 participants for each group. Allowing for a conservative dropout rate, we recruited 61 subjects into the study. This sample size predicted power greater than 80 % to detect both statistical significance and clinically meaningful changes in the Lysholm Knee Scale.

Results

The demographic data and the outcomes for the two groups are shown in Table 1. No significant differences were observed between the groups for any of the demographic variables. The participants sustained injuries while playing the following sports: football (*n* = 26; 52 %), volleyball (*n* = 2; 4 %), basketball (*n* = 5; 10 %), skiing (*n* = 5; 10 %), snowboarding (*n* = 3; 6 %), ice-skating (*n* = 1; 2 %), and tennis (*n* = 6; 12.0 %). Also, two participants (4 %) sustained their injuries in traumatic accidents. None of the participants played sports professionally.

The overall group-by-interaction for the two-way repeated measure ANOVA was significant for quadriceps strength ($p = 0.001$) (Table 2). The between-group differences revealed that the Pilates group experienced significant improvement over that of the control group as measured by the difference in quadriceps strength at 12 weeks ($p = 0.03$). Both groups showed some clinically meaningful change over time; however, in the Pilates group, change was observed for all outcome measurements at the 12-week follow-up, yet the control group improved only for the functional outcomes. The longitudinal ITT analysis indicated that no differences were observed between treatment groups for any of the outcome measures at the 12-week follow-up. In

Table 2 Isokinetic (180° s⁻¹) strength tests and functional outcomes results at baseline and after 12-week intervention

	Baseline mean (CI)	12-week mean (CI)	<i>p</i> [†]
Flexion peak torque			
Pilates group	113.3 (104–123)	132.0 (121–142)	n.s
Control group	114.1 (104–123)	122.9 (112–133)	
<i>p</i> *	n.s	n.s	
Extension peak torque			
Pilates group	146.5 (132–160)	182.6 (167–197)	0.001
Control group	153.1 (138–167)	158.7 (143–174)	
<i>p</i> *	n.s	0.03	
Lysholm Knee Scale			
Pilates group	70.3 (64–76)	86.1 (82–91)	n.s
Control group	75.5 (70–82)	89.2 (85–94)	
<i>p</i> *	n.s	n.s	
Cincinnati Knee Rating System			
Pilates group	66.1 (59–73)	87.1 (82–92)	n.s
Control group	67.8 (60–75)	83.0 (78–87)	
<i>p</i> *	n.s	n.s	

CI Confidence interval

* Independent simple *t* test † Repeated measure ANOVA

addition, the magnitude of treatment (ES) was higher for all outcome measurements in the Pilates group (Table 3). According to the responses of the participants in the Pilates group on the GRC, 22 participants (88.0 %) stated that they felt much better in terms of stability, and two (12.0 %) of the participants reported that they were slightly better. In comparison, six (23.0 %) of the participants in the control group declared that they were slightly better, and ten (38.4 %) of the participants declared that they felt the same; moreover, ten (38.4 %) participants in the control group reported that they felt that they had deteriorated slightly. In summary, patient satisfaction with knee stability was higher in the Pilates group than in the control group.

Table 3 Pairwise comparisons at each period

	Baseline mean $\pm$ SD	12-week mean $\pm$ SD	<i>p</i>	ES (CI)
Flexion peak torque				
Pilates group	113.3 $\pm$ 16.8	132.0 $\pm$ 17.2	0.001	1.2 (0.5–1.2)
Control group	114.1 $\pm$ 28.2	122.9 $\pm$ 31.9	n.s	0.3 (0.0–0.6)
Extension peak torque				
Pilates group	146.5 $\pm$ 22.5	182.6 $\pm$ 33.0	0.001	1.6 (1.0–2.2)
Control group	153.1 $\pm$ 43.3	158.7 $\pm$ 40.7	n.s	0.1 (0.1–0.3)
Lysholm Knee Scale				
Pilates group	70.3 $\pm$ 18.2	86.1 $\pm$ 12.3	0.001	1.5 (1.0–2.0)
Control group	75.5 $\pm$ 9.2	89.2 $\pm$ 8.9	0.001	0.9 (0.5–1.2)
Cincinnati Knee Rating System				
Pilates group	66.1 $\pm$ 17.8	87.1 $\pm$ 9.0	0.001	1.2 (0.7–1.6)
Control group	67.8 $\pm$ 17.2	83.0 $\pm$ 12.5	0.001	0.9 (0.6–1.2)

ES Effect size, CI confidence interval, SD standard deviation

Discussion

The most important finding in the present study was that participation in Pilates resulted in superior recovery when compared to no exercise participation; i.e. Pilates improves quadriceps strength, which aids the treatment of patients with partial ACL injuries. Even though functional outcomes for the control group improved, the increased magnitude of the benefit resulted in larger ES in the Pilates group.

The non-operative treatment options for partial ACL tears are largely supportive and often at least partially involve recommending that the patient take time to recover from the initial injury and make a gradual return to activities after rehabilitation. Even though there is no definitive non-operative treatment for partial ACL tears recommended in the literature, many previous studies showed the effectiveness of certain non-operative treatments of partial ACL tears [6, 20, 26]. Odensten et al. [20] prospectively followed up 21 patients with partial ACL tears for 6 years and concluded that partial tears are benign and that the long-term results are good. Sommerlath et al. [26] evaluated 22 patients with acute partial ACL tears and followed up them for 9–15 years. No patient in this study required ACL reconstruction surgery, and the authors concluded that conservative treatment can be effective for this condition. Buckley et al. [6] evaluated 25 patients with partial ACL tears at an intermediate follow-up period and found that 60 % had good or excellent results. However, only 44 % of patients had resumed sports at their pre-injury levels, and 72 % reported activity-related symptoms. A more recent systematic review was performed by Mauidi et al. [17] who followed up patients for 12–66 months and suggested that mixed or

isolated ACL-deficient knees reported good knee function and functional performance, but the activity level of the patients decreased by 21 % following the injury.

Even though these studies suggest that a non-operative treatment course after partial ACL rupture is appropriate, no study has described a specific exercise protocol that should be used or even if patients should be followed by a physical therapist. Therefore, this study fills the gap by describing a potential exercise management for patients with partial ACL ruptures. Indeed, current evidence has indicated that decreased core stability may predispose individuals to injury and that appropriate training may reduce the rates of back and lower extremity injury [11, 12, 25]; therefore, we generated a Pilates programme mainly focused on core stability and lower extremity strength and flexibility. For example, Pilates heel slides are particularly useful for anyone suffering from an ACL tear or any type of injury that limits flexion and extension. The side-kick series increases range of motion, flexibility, and strength of the hip and knee muscles. An exercise known as “swimming on the gym ball” strengthens the back, abdominal, hip, and knee muscles. In the present study, scores on the Lysholm Knee Scale, the Cincinnati Knee Rating Score, the strength measurements, and stability according to the GRC were improved in the Pilates group. As compared to the control group, significant improvement was observed in quadriceps strength, which is very important for patients with ACL injuries. The results of the study also showed that even though the ES was higher in the Pilates group, the function of the control group was, indeed, improved. This may be due to the natural course of recovery from the ACL injury. Indeed, natural history studies have demonstrated satisfactory knee function at follow-up, and significant declines in activity level and return to pre-injury activity level have been noted by most investigators [23]. Interestingly, significant improvement was expected in hamstring strength, but the observed improvement was not statistically significant as compared to that of the control group. This may be explained by the type of exercises that were chosen for the regimen for the Pilates group; i.e. the regimen mainly concentrated on core stability and quadriceps strength rather than hamstring strength.

We attempted to understand if the feeling of “giving way”, i.e. the typical symptom associated with ACL injuries, could be improved with Pilates. Zazulak et al. [32] found that increased displacement was consistently observed in the knees and ligaments of ACL-injured athletes due to impairment in the control of the body’s core. In this study, we believe that the participants’ engagement in Pilates improved their core strength, which resulted in decreased feelings of “giving way”

according to the GRC. Eighty-eight percentage of the participants declared that they felt much better in terms of knee stability in the Pilates group, so we can conclude that Pilates exercise helped to decrease the feelings of instability.

We acknowledge that our study has some limitations. First, the short duration of the Pilates programme (i.e. 6 weeks of group classes and 6 weeks of home exercises) may not be sufficient for the improvement of all outcome measurements for comparison with the control group. Second, although we carefully followed up with each patient during the home programme session throughout the study protocol (i.e. we met with each patient every 2 weeks to discuss their progress and provide support), we could not ensure home exercise compliance. Third, we intended to determine if Pilates would serve as a rehabilitation programme for patients with partial ACL tears. Therefore, we did not compare Pilates with any other exercise intervention. The control group was advised not to attend any other exercise programme during the 12-week study period; however, we offered attendance to free Pilates classes after the assessment was complete for all of the control participants. Consequently, we are trusting in their declaration that they did not participate in any exercise programme. Fourth, we did not use any objective or subjective assessment, such as the KT-1000, to measure the feeling of “giving way”. Our results depended only on the patients declarations on the GRC.

Finally, our power was diminished to 80 % due to the participant dropout rate.

In conclusion, this study presents an alternative rehabilitation programme for non-surgically treated patients with partial ACL injuries. While no prospective randomized studies using Pilates for conservative partial ACL rehabilitation appear in the literature to date, this study shows that Pilates is a potential treatment option for patients with partial ACL injuries to improve function and quadriceps strength as well as stability. Studies with longer follow-up periods and larger samples are needed to determine whether increases in knee muscle strength, function, and stability will improve with certain subgroups of patients who might achieve an added benefit with this approach such as other ligament injuries, meniscus pathologies, and quadriceps and hamstring injuries.

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Compliances with ethical standards

Conflict of interest The authors declare no conflicts of interest in preparing this article.

Appendix 1

See Table 4.

Table 4 Pilates exercise programme given to the participants

0–2 weeks	2–4 weeks	4–6 weeks
Heel slides	Hundreds	Short supine prep (T)
Hundreds in supine crook lying (GB)	Scissors with neck support	Side-kick press (T)
Single-leg heel (GB)	One-leg stretch (T)	Side circles (T)
Side circles	Double-leg stretch (GB)	Swimming while kneeling (T)
Side-kick in lying (GB)	Swimming (GB)	One-leg kick while kneeling (T)
Shoulder bridge (GB)	Hundreds while sitting (GB)	Shoulder bridge 1, 2, 3 (GB)
Heels together toes apart (GB)	Hundreds while standing (GB)	Swimming (GB)
Parallel (GB)	Parallel (T)	Walking (GB)
One-leg circle	External rotation (T)	Leg push with stretch (GB)
	Heels together, toes apart (T)	

T Theraband®, GB gym ball

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