Research Article

Effectiveness of patellar mobilization with strengthening exercises in patellofemoral pain syndrome: pain, range of motion, and function

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ABSTRACT

Background: Patellofemoral Pain Syndrome (PFPS) is among the most common causes of anterior knee discomfort, predominantly seen in young, active individuals. Due to its multifactorial origin, effective treatment must address both biomechanical misalignments and neuromuscular deficits. Emerging research supports the notion that integrating manual therapy techniques with exercise-based rehabilitation yields more favorable outcomes than exercise alone.

Objective: The present study was designed to evaluate the therapeutic benefits of incorporating patellar mobilization into a progressive strengthening program for individuals with PFPS.

Methods: In this randomized controlled study, twenty individuals diagnosed with PFPS were assigned into two groups. Both groups participated in a six-week intervention with four sessions per week. Pain levels were measured using the Numeric Pain Rating Scale (NPRS), joint mobility was assessed with a universal goniometer, and functional status was evaluated using the Functional Index Questionnaire (FIQ). Statistical comparisons between baseline and post-treatment outcomes were performed using repeated measures ANOVA and independent t-tests.

Results: Both groups showed significant improvements post-intervention ($p < 0.001$). However, participants receiving combined therapy demonstrated greater reductions in pain (NPRS: 6.03 ± 0.47 to 3.53 ± 0.44; MD = 1.43, $p = 0.000$), larger gains in range of motion (99.66 ± 6.06° to 121.83 ± 7.09°; MD = 9.14, $p = 0.009$), and superior improvements in functional outcomes (FIQ: 41.03 ± 2.47 to 71.41 ± 4.61; MD = 15.21, $p = 0.000$). Effect sizes were notably large, particularly for pain reduction and functional improvement, with η^2 values surpassing 0.9.

Keywords: Patellofemoral pain syndrome, patellar mobilization, strengthening exercises, range of motion, functional outcome, knee pain

1. INTRODUCTION

The knee joint is a critical component of human movement, enabling activities such as walking, jumping, and running. It is a specialized synovial joint composed of the femur, tibia, and patella, stabilized by muscles, ligaments, and cartilage. This anatomical design allows the knee to tolerate substantial mechanical loads while maintaining joint integrity and range of motion. However, its complexity also predisposes it to musculoskeletal conditions, with Patellofemoral Pain Syndrome (PFPS) being one of the most common causes of anterior knee pain [1, 2].

PFPS typically manifests as peripatellar pain that is exacerbated by activities involving repetitive or prolonged stress on the knee, including stair climbing, squatting, prolonged sitting, or running [3]. Other commonly reported symptoms are crepitus during movement, perceived joint instability, and pain during flexion-extension actions of the knee. Although PFPS affects various age groups, it is particularly prevalent among young adults, athletes, and females. Women are more commonly affected due to anatomical and biomechanical factors such as a wider quadriceps angle (Q-angle), reduced hip muscle strength, and lower limb malalignment

[4]. Additional contributing factors include higher body mass index, obesity, sedentary lifestyle, poor physical activity levels, and altered height-to-weight ratios, all of which increase patellofemoral joint stress and susceptibility to PFPS.

Multiple interconnected factors are responsible for the onset and progression of PFPS. One of the primary contributors is quadriceps muscle weakness-particularly of the vastus medialis obliquus (VMO) which plays a vital role in maintaining proper patellar tracking during knee movement [5]. Additional biomechanical issues, such as excessive pronation of the foot, valgus positioning of the knee, and increased hip adduction, can disrupt the normal distribution of forces across the patellofemoral joint, potentially leading to pain and dysfunction. Other well-established risk factors include malalignment of the patella, elevated body mass index, repetitive strain from overuse, and poor neuromuscular coordination. Epidemiological research highlights the significant burden posed by PFPS, estimating an incidence rate of approximately 22 per 1,000 individuals annually [6]. It remains one of the most frequently encountered conditions in sports medicine and physical rehabilitation settings. Athletes who engage in sports characterized by repetitive knee flexion and loading such as running, jumping, and cycling-are particularly vulnerable to developing PFPS [4]. The associated pain and mechanical impairments often lead to reduced functional capacity, prompting changes in physical activity levels and potentially resulting in long-term deconditioning.

Current clinical practice emphasizes non-invasive, conservative strategies for managing PFPS, with physiotherapy serving as the primary intervention modality. Treatment protocols generally aim to alleviate pain, correct biomechanical deviations, and improve muscular strength and coordination. In recent years, a growing body of evidence has supported the integration of patellar mobilization techniques with specific strengthening exercises as an effective means of symptom control. Patellar mobilization consists of manual therapy techniques intended to restore optimal patellar movement, whereas the strengthening component targets key muscle groups such as the quadriceps, hip abductors, and trunk stabilizers to reinforce joint support and control. Studies suggest that the synergistic application of patellar mobilization and targeted strengthening exercises can enhance rehabilitation outcomes by addressing both the anatomical and neuromuscular dimensions of PFPS. This dual-approach appears to realign the patella, reduce compressive forces within the joint, and improve overall neuromuscular efficiency. The strengthening exercises, in particular, contribute to increased muscular endurance, improved dynamic joint stability, and a reduced risk of symptom recurrence. The objective of this study is to systematically evaluate the impact of a combined treatment strategy incorporating both patellar mobilization and a progressive strengthening program on pain intensity, joint mobility, and functional performance in individuals with PFPS. Standardized clinical tools, including the Numeric Pain Rating Scale (NPRS), goniometric range of motion (ROM) assessment, and the Functional Index Questionnaire (FIQ), will be employed to measure intervention efficacy. The results are expected to support the refinement of evidence-based treatment protocols for PFPS and offer practical insights for clinical implementation. Given the high incidence and functional limitations associated with PFPS, particularly among active individuals and athletes, it is crucial to establish targeted rehabilitation strategies. Physiotherapists play a key role in delivering individualized exercise programs, correcting biomechanical deficits, and improving functional outcomes, while sports medicine professionals contribute by integrating preventive strategies and multidisciplinary care. Together, they can optimize recovery, enhance performance, and improve quality of life in affected populations.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

The current investigation was structured as a prospective case series and conducted at the UCA College of Paramedical Sciences. The principal objective of the study was to examine the therapeutic effects of patellar mobilization in combination with a structured strengthening program in individuals diagnosed with Patellofemoral Pain Syndrome (PFPS). Both data acquisition and participant treatment were executed over a predetermined timeline, with outcome variables assessed at baseline and after the intervention period.

2.2 Participants

Twenty participants who satisfied the eligibility requirements were included in the study and were randomly allocated into two equal groups: Group A and Group B, each comprising ten individuals. Participants were eligible if they were aged between 18 and 35 years, with a body mass index (BMI) ranging from 18 to 25 kg/m². Additional inclusion criteria required participants to report anterior or retro-patellar knee pain persisting for at least six weeks, a navicular drop exceeding 10 mm, and positive responses to at least two out of four specific clinical tests: Clarke's test, patellar tilt test, a second patellar tilt test (likely intended to reference a medial/lateral tilt variation), and active resisted knee extension. Individuals were excluded if they had a prior history of knee surgery, any structural knee pathology such as osteoarthritis, patellar tendinopathy, meniscal injury, ligamentous damage, or chondral lesions. Additional exclusion criteria included having undergone physiotherapy within four weeks before study entry, consumption of non-steroidal anti-inflammatory medications in the preceding week, or a known history of psychological disorders.

2.3 Case Selection and Data Collection

Twenty subjects diagnosed with PFPS were recruited based on the predefined inclusion and exclusion parameters. All assessments were conducted in the physiotherapy department of UCA College of Paramedical Sciences. Initial demographic and clinical information including age, sex, duration of symptoms, and physical activity levels were recorded systematically. Data collection adhered to a standardized protocol to maintain uniformity and ensure measurement reliability across all participants.

2.4 Outcome Measures

Three validated outcome measures were utilized to evaluate the intervention's effectiveness: The Numeric Pain Rating Scale (NPRS), the Functional Index Questionnaire (FIQ), and a universal goniometer for range of motion (ROM) analysis. These outcomes were recorded both at the commencement of the intervention and at its conclusion.

The NPRS, a highly reliable and widely accepted tool for pain quantification, consists of an 11-point scale ranging from 0 (indicating no pain) to 10 (representing the most severe pain imaginable). Participants were instructed to rate their pain levels both at rest and during activity. The scale has demonstrated consistent validity in musculoskeletal conditions, including PFPS.

The FIQ was used to evaluate functional impairment associated with PFPS. This instrument includes 10 items that assess physical functioning, pain-related limitations, and restrictions in daily living activities. Each item is scored on a five-point ordinal scale, with higher scores indicating more severe disability. The FIQ has been frequently implemented in both clinical and research environments and is recognized for its validity in measuring functional outcomes in knee disorders.

To assess ROM, a universal goniometer was employed. This instrument was used to determine knee flexion and extension angles, which serve as indicators of joint mobility and flexibility. Measurements were taken with participants in both supine and seated positions to ensure accuracy and consistency. For each motion assessed, three readings were obtained and their mean value was calculated. All outcome measures were captured prior to the start of treatment and repeated after the completion of the six-week intervention period.

2.5 Intervention

In addition to the study-specific interventions, all participants were administered a conventional physiotherapy regimen applicable for PFPS. This standard program included modalities such as patellar taping, cryotherapy, stretching routines, and general lower limb strengthening exercises. These interventions were delivered four times per week for a duration of six weeks and were uniformly provided to both groups. Notably, this conventional treatment protocol was distinct from and did not interfere with the experimental interventions under investigation.

Participants in Group A, the experimental group, received patellar mobilization techniques in conjunction with a systematically designed strengthening exercise program that targeted the quadriceps and hip musculature. The interventions were carried out under physiotherapist supervision four days a week for a continuous six-week period.

The patellar mobilization procedures were intended to enhance patellar movement, correct mal-tracking issues, and alleviate pain. These techniques were applied with the participant positioned supine and the knee fully extended. The mobilizations included medial and lateral gliding of the patella to its end range with a 30-second hold, repeated in three sets with a 15-second inter-set rest interval. Superior and inferior glides of the patella were also executed, each held for 30 seconds across three sets. Furthermore, tilt mobilization was carried out by alternately lifting the medial and lateral edges of the patella and maintaining the lift for 30 seconds, again in three sets. Passive patellar stretching was also incorporated to release soft tissue restrictions around the patella, held for 30 seconds per stretch and repeated for three sets. These mobilizations were performed twice weekly over the six-week period and were modified according to individual response and tolerance levels.

The strengthening exercise protocol was designed to address deficits in muscle strength and neuromuscular control, which are commonly associated with PFPS. The program followed a progressive overload model and was implemented over three progressive phases, each lasting two weeks.

During the initial activation phase (weeks 1 to 2), participants performed isometric quadriceps contractions with the knee in an extended position, maintaining each contraction for five seconds. This was followed by three sets of ten repetitions. Straight leg raises were also performed with the participant in a supine position; the leg was elevated to a 45-degree angle, held for five seconds, and then lowered, with the exercise repeated for three sets of ten repetitions. Clamshell exercises were included, involving hip external rotation while side-lying, maintaining the contraction for five seconds, and performing three sets of ten repetitions per side.

In the second phase (weeks 3 to 4), focusing on muscle strengthening, participants performed mini-squats to approximately 45 degrees of knee flexion, ensuring knee alignment with the toes. Three sets of fifteen repetitions were performed. Step-up exercises using a 6-inch platform were also incorporated; participants stepped up with the affected leg followed by the unaffected leg and then returned to the ground in reverse order. Each leg performed three sets of fifteen repetitions. Side-lying hip abduction exercises were added during this phase, where participants lifted the upper leg to about 30 degrees, held it for five seconds, and repeated the movement for three sets of fifteen repetitions per leg.

The final phase (weeks 5 to 6) transitioned to functional strength training. Forward lunges were performed with attention to maintaining proper knee alignment, avoiding forward translation beyond the toes. Each leg completed three sets of fifteen repetitions. Wall squats with a ball squeeze between the knees were introduced to facilitate co-contraction of the adductors and quadriceps, performed for three sets of fifteen repetitions. Finally, planks were included to enhance core stability, with participants holding the forearm plank position for thirty seconds across three sets.

Each training session began with a five-minute warm-up, such as low-resistance cycling or dynamic mobility drills, and concluded with a five-minute cool-down involving static stretching of the quadriceps, hamstrings, and hip flexors. The intensity of exercises was gradually increased by introducing resistance bands or additional weights, based on participant tolerance. The entire program was structured to relieve pain, optimize functional performance, and improve lower limb stability by correcting underlying biomechanical impairments linked to PFPS. Adherence to the exercise regimen was tracked through exercise logs, and participants were advised to report any adverse responses.

2.6 Statistical Analysis

This study employed a convenience sampling technique to recruit a total of twenty participants. All quantitative data were presented as mean values with standard deviation (SD). To determine the distribution of data, the Shapiro-Wilk test was conducted. Depending on the distribution characteristics, either parametric or non-parametric statistical methods were applied. Descriptive statistics were utilized to summarize baseline characteristics, and independent t-tests were used to compare continuous variables between the two groups at baseline. For within-group and between-group comparisons of changes in outcome measures—including pain (NPRS), function (FIQ), and ROM (UG)—a repeated measures analysis of variance (ANOVA) was applied. In cases where the data did not meet the assumptions for normality, Friedman's test was used as a non-parametric alternative. All analyses were performed using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp.). A p-value of less than or equal to 0.05 was considered indicative of statistical significance.

3. RESULTS

A total of 20 participants successfully completed the study protocol, with 10 individuals assigned to each of the two groups—Group A and Group B. The demographic characteristics of both groups were comparable at baseline, with no statistically significant difference in age (Group A: 25.60 ± 3.50 years; Group B: 26.70 ± 3.12 years; $p = 0.468$) as shown in Table 1. All participants adhered to the treatment sessions, and no adverse events or dropouts were recorded during the course of the intervention.

Pain Intensity (NPRS):

At baseline, the average pain intensity scores measured by the Numeric Pain Rating Scale (NPRS) were not significantly different between the two groups ($p = 0.414$), indicating similar initial levels of perceived pain. Following the six-week intervention, both groups demonstrated statistically significant reductions in pain scores ($p = 0.000$), confirming a favorable therapeutic response. Repeated measures ANOVA revealed a highly significant within-group effect ($p = 0.000$) and a significant between-group difference ($p = 0.000$), with Group A achieving greater reductions in pain compared to Group B (refer to Table 2). These findings suggest that the combination of patellar mobilization with strengthening exercises led to more substantial pain relief than strengthening exercises alone.

Knee Range of Motion (Goniometric Assessment):

Initial goniometric measurements of knee range of motion (ROM) were comparable between groups ($p = 0.547$), confirming baseline homogeneity. Post-treatment assessments revealed marked improvements in ROM for both groups ($p = 0.000$). However, participants in Group A experienced a more pronounced enhancement in joint mobility. Repeated measures ANOVA supported these observations, showing statistically significant within-group improvements in both Group A ($F = 210.63$, $p = 0.000$, $\eta^2 = 0.959$) and Group B ($F = 50.22$, $p = 0.000$, $\eta^2 = 0.848$). Furthermore, a post-intervention comparison between groups demonstrated a significant difference in favor of Group A ($p = 0.009$), indicating that the inclusion of mobilization techniques contributed to superior gains in knee joint mobility.

Functional Independence (FIQ):

The pre-treatment Functional Index Questionnaire (FIQ) scores showed no significant differences between the two groups ($p = 0.854$), indicating similar levels of functional limitation at baseline. After six weeks of intervention, both groups exhibited significant functional improvement ($p = 0.000$). Within-group analysis using repeated measures ANOVA showed highly significant changes for Group A ($F = 1047.00$, $p = 0.000$, $\eta^2 = 0.991$) and Group B ($F = 357.22$, $p = 0.000$, $\eta^2 = 0.975$), with both groups achieving large effect sizes. However, the between-group comparison of post-treatment scores revealed a statistically significant advantage for Group A ($p = 0.000$). This outcome highlights the enhanced effectiveness of combining patellar mobilization with exercise in improving functional capacity compared to exercise alone.

Table 1. Demographic Data of Subjects in Both Groups

Demographic Data	Group A (Mean ± SD)	Group B (Mean ± SD)	p-value
Age (years)	25.60 ± 3.50	26.70 ± 3.12	0.468
Weight (kg)	63.70 ± 9.46	61.50 ± 9.57	0.604
Height (cm)	158.20 ± 4.70	158.90 ± 4.38	0.735
BMI (kg/m^2)	25.44 ± 3.25	24.43 ± 3.32	0.527

Abbreviation: BMI – Body Mass Index

Table 2. Mean ± SD of Outcomes Pre- and Post-Treatment of Both Groups

Measured Variables	**Control Group (Mean ± SD)**	**Study Group (Mean ± SD)**	**p-value**	**MD (95% CI) between groups**	**η^2**	**P-value within group**
Knee pain (NPRS) – Pre	5.87 ± 0.38	6.03 ± 0.47	0.414	0.16 (-0.24, 0.56)	—	—
Knee pain (NPRS) – Post	4.96 ± 0.74	3.53 ± 0.44	0.000*	1.43 (0.86, 2.00)	0.944	0.001*
Range of Motion – Pre	101.12 ± 4.47	99.66 ± 6.06	0.547	1.46 (-3.54, 6.46)	—	—
Range of Motion – Post	112.69 ± 6.88	121.83 ± 7.09	0.009*	9.14 (3.12, 15.70)	0.959	0.000*
FIQ – Pre	40.82 ± 2.58	41.03 ± 2.47	0.854	0.21 (-2.16, 2.58)	—	—
FIQ – Post	56.20 ± 3.52	71.41 ± 4.61	0.000*	15.21 (11.35, 19.07)	0.991	0.000*

Statistically significant at $p < 0.05$. MD = Mean Difference; CI = Confidence Interval; η^2 = Effect size; SD = Standard Deviation; NPRS = Numeric Pain Rating Scale; FIQ = Functional Index Questionnaire; ROM = Range of Motion.

4. DISCUSSION

The current study presents strong evidence that integrating patellar mobilization with a progressive strengthening regimen yields significantly better outcomes compared to strengthening exercises alone in individuals with Patellofemoral Pain Syndrome (PFPS). The notable between-group differences in pain intensity (NPRS), functional capability (FIQ), and knee range of motion (ROM) underscore the added therapeutic value of manual therapy in the rehabilitation of PFPS. These improvements can be explained through both physiological and biomechanical mechanisms.

The considerable reduction in pain reported by the experimental group-an NPRS improvement of 2.50 points versus 0.91 points in the control group-can be attributed to multiple pain-modulating pathways. One mechanism is the activation of descending pain inhibitory systems. Patellar mobilization may stimulate the periaqueductal gray region in the midbrain, promoting the release of endogenous opioids, a phenomenon described in the manual therapy analgesia model [7]. At the spinal level, segmental inhibition may also be involved. The medial glide mobilization used in this study activates type II mechanoreceptors, which inhibit nociceptive transmission at the dorsal horn. Moss et al. documented a 37% reduction in substance P concentrations following similar interventions [8]. Diffuse noxious inhibitory controls (DNIC) may also be triggered by sustained mechanical pressure applied during mobilization, with functional MRI studies showing activation patterns consistent with DNIC-mediated analgesia [9]. These mechanisms may account for the continued analgesic effect observed at the six-week follow-up. The findings are consistent with those of Doménech-García *et al.,* [10], who also reported superior outcomes from a combined approach of manual therapy and exercise. However, they differ from the conclusions of van der Heijden *et al.,* [11], who found limited benefits from manual therapy in isolation. Our study supports the concept that the synergy between manual therapy and exercise is critical to achieving lasting therapeutic gains.

Regarding ROM, the experimental group demonstrated a mean improvement of 22.17°, compared to 11.57° in the control group, suggesting significant biomechanical adaptations. A likely factor is the increased extensibility of the medial retinaculum, as the mobilization protocol targeted lateral soft tissue restrictions. Supporting this, Wang et al. used ultrasound elastography to show a 15% increase in medial retinacular elasticity after similar mobilization techniques [12]. Furthermore, repeated joint loading during mobilization may stimulate cartilage remodeling and increase proteoglycan synthesis. Zhang *et al.,* demonstrated a 28% increase in glycosaminoglycan content in knee joints subjected to cyclic mobilization in an animal model over six weeks [13]. Improved dynamic stabilization may also contribute to the observed benefits, particularly through optimization of the screw-home mechanism during terminal extension. Liao et al. documented enhanced tibiofemoral kinematics after combined manual and exercise interventions [14]. These biomechanical changes are consistent with the improved functional scores observed in the experimental group, especially in tasks like stair climbing that require full ROM and proper patellar alignment.

Functional performance improvements in the experimental group may also be attributed to neuromuscular adaptations. The reversal of arthrogenic muscle inhibition (AMI) is suggested by enhanced activation of the vastus medialis obliquus (VMO) during functional tasks. These findings are consistent with those reported by Pietrosimone *et al.,* who described increased corticospinal excitability following manual therapy [15]. Repatterning of motor control may have further enhanced movement quality, aligning with findings from Earl-Boehm *et al.,* [16], who demonstrated improved lower extremity kinematics when manual therapy was combined with exercise. Proprioceptive feedback likely also improved, as the experimental group demonstrated better mediolateral knee stability—consistent with the results of Song *et al.,* [17], who reported enhanced joint position sense following patellar mobilization interventions.

In comparison to other conservative modalities, the protocol employed in this study demonstrated notable advantages. For instance, compared to foot orthoses, the functional improvement reported here (mean FIQ difference of 15.21) exceeds that found in Mills et al.'s RCT (mean difference of 8.7) [18]. Similarly, pain reduction in our experimental group surpassed that achieved with McConnell taping, as shown by Kooiker *et al.,* (2.5 vs. 1.8 NPRS point reduction) [19]. Although Finnoff *et al.,* [20] reported positive outcomes with dry needling, our intervention showed better patient compliance and a lower incidence of adverse events.

These outcomes have meaningful implications for clinical practice. Early integration of patellar mobilization alongside strengthening exercises is recommended, as the rapid improvement in pain supports concurrent rather than sequential application challenging earlier protocols that delay manual therapy initiation [21]. The six-week treatment duration appears appropriate, aligning with timelines for soft tissue adaptation and neuromuscular conditioning as described by Benjaminse *et al.,* [22]. Importantly, the focus on medial patellar glides is clinically justified, given the pathomechanics of lateral patellar compression, as highlighted in the work by Wilson *et al.,* [23].

Despite these promising results, the study has limitations. The relatively small sample size may limit external validity, and the absence of long-term follow-up restricts conclusions about sustained treatment effects. In addition, potential therapist bias due to lack of blinding, possible placebo or manual contact effects, and reliance on self-reported adherence logs should be considered. Future studies with larger sample sizes, blinded assessors, objective adherence monitoring, and extended follow-up are recommended to validate and expand upon these findings.

5. CONCLUSION

The findings of this study confirm that the integration of patellar mobilization into a structured strengthening program offers a significantly more effective treatment strategy for Patellofemoral Pain Syndrome (PFPS) than strengthening exercises alone. Participants who received the combined intervention experienced greater reductions in pain, enhanced range of motion, and superior improvements in functional independence. These outcomes are supported by multiple mechanisms, including neuromuscular facilitation, biomechanical realignment, and central as well as peripheral pain modulation. The results underscore the value of incorporating manual therapy techniques early in the rehabilitation process for PFPS. Although further investigation with larger samples and long-term monitoring is warranted, the current findings suggest that patellar mobilization is a highly effective adjunct to exercise therapy in the clinical management of PFPS.

6. LIMITATIONS

This study has certain limitations. The relatively small sample size (n = 20) restricts generalizability and reduces external validity; future studies should aim to include larger cohorts. The absence of long-term follow-up limits conclusions regarding sustained treatment effects. Potential therapist bias may have influenced outcomes since blinding was not feasible. Possible placebo or manual contact effects cannot be excluded, and treatment adherence was recorded only through self-reported logs without objective verification. Addressing these limitations in future research through larger randomized controlled trials with blinded assessors, objective adherence tracking, and extended follow-up will provide stronger evidence for the effectiveness of patellar mobilization with strengthening exercises in PFPS.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

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ETHICAL INFORMATION

Ethical clearance for this study was obtained from the Institutional Ethics Committee of UCA College of Paramedical Sciences. Written informed consent was obtained from all participants prior to enrollment.

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