CLINICAL JOURNAL OF SPORT MEDICINE

TITLE PAGE

Hip and knee weakness and ankle dorsiflexion restriction in individuals following lateral patellar dislocation: A case-control study

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Acknowledgments: We thank the chief of Physical Therapy Department of IAMSPE, Aparecida Cristina Chrispim Pires, for developing the scientific knowledge in this institution. Dr Smith is supported by funding from the National Institute for Health Research (NIHR) Oxford Health Biomedical Research Centre. The views expressed are those of the author(s) and not necessarily those of the NIHR.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest: The authors declare no potential conflicts of interest with respect to the research, authorship, and publication of this manuscript.

Abstract word count: 219

Manuscript word count: 2581

ABSTRACT

Objective: To explore the relationship between ankle dorsiflexion range of motion (ROM) and hip and knee muscle strength between patients with a history of patellar dislocation (PD) to healthy controls.

Design: Case-control study.

Setting: Orthopaedical specialty outpatient clinic at a tertiary hospital.

Participants: 88 individuals were recruited; 44 individuals aged 16 years or older, of both sexes, with a history of at least one episode of atraumatic unilateral or bilateral PD requiring emergency care (14 males; 30 females; mean age 20 years) and 44 healthy (control) individuals (11 males; 33 females; mean age 21 years) matched for age, weight and height to PD cases.

Intervention: Assessment of hip and knee strength and ankle dorsiflexion ROM.

Outcome measures: Ankle dorsiflexion ROM was assessed through the lunge test with a goniometer. Hip and knee muscle strength was evaluated through isometric hand-held dynamometry. Differences between healthy and control individuals were assessed using Student T-Tests and Mann-Whitney U Test.

Results: PD individuals presented with a reduced ankle dorsiflexion ROM (mean difference (MD): 9°; effect size (ES): 1.39; $p<0.001$) and generalised hip and knee weakness (MD range: 4.74 kgf to 31.4 kgf; ES range: 0.52 to 2.35; $p<0.05$) compared to healthy subjects.

Conclusion: Individuals with a history of PD have reduced ankle dorsiflexion ROM and hip and knee muscle strength compared to healthy controls.

Keywords: Patellar dislocation**;** patellofemoral joint; ankle joint; range of motion; muscle weakness; lower extremity.

INTRODUCTION

Patellar dislocation (PD) is a condition which mostly affects young individuals, aged 15 to 20 years.[1] It corresponds to 2% to 3% of all knee injuries. It is catagorised as a lateral displacement of the patella from the trochlear groove, and associated with a rupture of the medial patellofemoral ligament (MPFL) in 90% of cases.[2] Mechanically it often occurs through a contraction of the quadriceps with the knee in 20° to 30° flexion and medial femoral rotation, prior to the patella engaging in the trochlear groove.[3] After a first episode, there is a 36% incidence of ipsilateral recurrence and a 5% incidence of contralateral dislocation.[4] These can lead to pain, instability and decreased physical activity.[4]

Several anatomical factors may contribute to PD and its recurrence.[5] These may include trochlear dysplasia, lateral patellar tilt, a high patella, increased TT-TG distance and a history of skeletal immaturity at the first episode.[5] Conservative treatment is currently recommended for the management of first-time PD in the absence of an osteochondral fracture.[6] Such programmes often include: quadriceps strengthening regimes, lower limb proprioceptive training and proximal (glutei) muscle strengthening/training.[7,8] However, the evidence-base is largely centred on poorly reported paper with methodological limitations such as: limited information on prescribed interventions, insufficient follow-up periods and not blinding assessors to group allocation.[9] Moreover, little is known about muscle strength and range of motion (ROM) deficits as pathological features in this population.[10]

Recent research found that women with patellofemoral pain (PFP) present with reduced hip abduction, external rotation, flexion and extension strength.[11–13] This can influence lower limb dynamic alignment, such as a dynamic valgus, whose magnitude may be influenced by limited ankle dorsiflexion ROM.[14] Based on this notion, it has been previously reported that reduced closed-kinetic chain ankle dorsiflexion can increase the magnitude of dynamic valgus, thereby contributing to PFP and PD.[14,15]

Several rehabilitation protocols following PD are based on PFP literature.[7,8,16] Patellofemoral pain and PD are different pathologies in both their mechanism of injury and natural history.[10] There is an absence of evidence on the association of muscle strength and ROM impairment following PD and particularly on the influence of glutei control and lower limb dynamic alignment. Accordingly, this study aimed to determine the presence (or not) of a difference in hip and knee strength and ankle dorsiflexion ROM between patients with a history of PD and healthy, control subjects.

METHODS

Study design

Cross-sectional, case-control, observational study.

Sample size calculation

The sample size was based on detecting a difference in ankle dorsiflexion ROM (primary study objective). The sample size calculation parameters were based on a mean difference of 5.7° in lunge test result between the groups, with a standard deviation (SD) of 10.2°.[17] To test at a power of 80%, and a statistical significance level of $p<0.05$ (one-sided), a minimum of 44 individuals per group was required.

Participants

Eighty-eight individuals were recruited. Forty-four individuals with a history of (at least one episode) atraumatic PD requiring emergency care (14 males; 30 females; mean age 20 years) were recruited from the Institute of Medical Assistance to the State Public Servant

(IAMSPE). Forty-four healthy individuals (11 males; 33 females; mean age 21 years) were recruited from a cohort of physical therapy students and friends/relatives of IAMSPE users, matched for age, weight and height. All participants signed an informed consent form or an assent form dependent on age. The study was approved by the IAMSPE Ethics and Research Committee on August 16, 2018 (reference: 2.824.477).

Inclusion criteria

Cases

We included individuals aged 16 years or older, of both sexes, with a history of at least one episode of atraumatic unilateral or bilateral PD requiring emergency care. Participants were required to be 'irregularly active' according to the International Physical Activity Questionnaire (IPAQ).[18] As recommended by Smith et al,[19] participants were required to exhibit: a positive apprehension sign to the lateralisation of the patella; pain on palpation along the medial retinaculum; and an increased patellar inclination in knee flexion-extension (J-sign).

Controls

We included individuals of both sexes, matched for age, weight and height to the PD cases. Control participants were required to be 'irregularly active' on the IPAQ.[18] Control participants were required to have experienced no lower limb (hip, knee, ankle) or spinal injuries during the previous 12 months.

Exclusion criteria

We excluded, from both case and control groups, individuals who had previously experienced meniscal, cruciate or collateral ligament injury of the knee, those with hip, knee or ankle osteoarthritis, and participants who reported a previous ankle injury, lower limb fracture or had undergone spinal or lower limb surgery.

Outcome measure

Demographic data collected including: age, gender, weight, height, number of episodes of patellar dislocations, age of onset, and pain at rest and during effort.

As described by Konor MM et al[20], the lunge test was performed to measure ankle dorsiflexion ROM. Participants were instructed to perform a closed kinetic chain dorsiflexion movement through a lunge, without removing the knee from the wall and the heel from the floor, with the knee in line with the second toe to prevent foot pronation. A universal goniometer[20] was positioned on the lateral aspect of the participant's leg, positioned at plantargrade, with the moveable axis in line with the fifth metatarsal and the fixed-axis parallel to the fibula[20] (**Figure 1**). When maximum dorsiflexion was reached, the examiner recorded the angle obtained. For comparative purposes, three measurements were performed, from which the mean value was calculated.[21]

Hip and knee muscle strength was evaluated through isometric hand-held dynamometry, using the Lafayette Manual Muscle Testing System Model-01165 (Lafayette Instrument Company, Lafayette IN, USA), factory calibrated.[22] The hand-held dynamometer was stabilised with counter-resistance (from an assessor) or externally using an inelastic belt as previously recommended.[22,23] Through this approach, the following muscle groups were assessed: hip flexors, hip extensors, hip abductors, hip adductors, lateral hip rotators, medial hip rotators and femoral quadriceps. To account for a potential difference in muscle recruitment at different degrees of hip flexion, isometric muscle strength was assessed in 0º and 90º hip flexion.[24,25]

All patients were evaluated in a pre-determined sequence, alternating measurements between the lower limbs to minimise fatigue. The sequence and positioning of participants illustrated in **Figure 2** and **Figure 3**. Before the evaluation, two submaximal contractions were performed to familiarise individuals to the tests. Subjects were then verbally encouraged to perform the contraction at a maximum capacity. For each muscle group, three measurements were performed, with an interval of 30 seconds between tests. If the difference between measurements was greater than 10%, the result was discarded, and a new measurement made. The muscle strength values obtained were normalised by body mass, employing the following formula: strength (kgf) / mass (kg) x 100. The mean of the three contractions was determined.

Ankle dorsiflexion ROM and lower limb muscle strength of both groups were evaluated by the same physiotherapist (PRdO) who was experienced in the test procedures.

Statistical analysis

Descriptive data were represented by the mean, SD and standard error of the mean (SEM). Prior to analysis, data distribution was assessed for normality and homogeneity by visual inspection of histograms and using the Shapiro-Wilk and Levene tests. For data with an asymmetric distribution, we calculated their logarithmic or square root transformation. When an asymmetric distribution persisted after transformation, non-parametric tests were adopted.

An independent t-test was conducted to evaluate the differences between cases and controls. A paired t-test was used to compare the outcomes of individuals with unilateral PD, comparing affected with unaffected lower limbs data. A Mann-Whitney U Test was adopted for asymmetric distribution. Data were presented with 95% confidence intervals (CIs). For statistical purposes, we considered the most affected side of individuals with a history of bilateral PD and the dominant side of healthy individuals.

A significance level of p=0.05 was used for all statistical tests. Effect size (Cohen *d*) was calculated and interpreted where: 0.00-0.49 was a small effect; 0.50-0.79 a medium effect, and ≥0.80 a large effect.[26]

All analyses were performed using IBM SPSS software version 20.0 for Windows (IBM, New York, USA).

RESULTS

The cohort's demographic characteristics' are presented in **Table 1**. There was no substantial difference between the groups regarding: age, weight, height and body mass index (BMI). The minimum duration from last PD to assessment was 4 weeks (mean: 9.27 weeks (SD: 4.16).

Ankle Dorsiflexion ROM

There was a difference between the two groups based on ankle dorsiflexion ROM ($p<0.001$) where cases (PD) presented with a reduced ROM (**Table 2**). This was a large effect size (Cohen *d*: 1.39).

There was no difference in ankle dorsiflexion ROM between affected and unaffected lower limbs in individuals with unilateral PD ($p>0.05$; N=27: **Table 3**).

Hip and knee muscle strength

As illustrated in **Table 2**, there was a significant difference between the case (PD) and control groups in hip and knee muscle strength ($p<0.05$). The medium effect size for hip flexors (Cohen *d:* 0.52*)* and hip extensors (Cohen *d:* 0.77). There was a larger effect size for hip abductors (Cohen *d:* 0.80), hip adductors (Cohen *d:* 1.26), lateral hip rotators at 90º (Cohen *d:* 1.62), lateral hip rotators at 0º (Cohen *d:* 1.83), medial hip rotators at 90º (Cohen *d:* 1.06), medial hip rotators at 0º (Cohen *d:* 0.95) and for knee extensors (Cohen *d:* 2.35).

As **Table 3** demonstrates, this was also evident between the affected and unaffected lower limbs for quadriceps strength ($p<0.01$) and for lateral hip rotators strength at 90°

($p<0.05$). There was a medium effect size for quadriceps strength (Cohen *d*: 0.53) and smaller effect size for lateral hip rotators strength at 90º (Cohen *d*: 0.29).

DISCUSSION

This is the first study to evaluate hip and knee muscle strength and ROM deficits in individuals with a history of PD. The main findings were: (1) individuals with a history of PD have reduced closed kinetic chain ankle dorsiflexion ROM compared to matched healthy controls; (2) individuals with a history of PD have hip and knee strength deficits compared to matched healthy control; (3): individuals with a history of unilateral PD have a deficit in quadriceps and lateral hip rotators strength at 90º hip flexion, when affected and non-affected sides were compared.

Reduced ankle dorsiflexion ROM is directly associated with kinematic changes during closed kinetic chain activities (i.e. squatting and step down). This can include increased hip adduction in the frontal plane, increased peak knee external rotation in the transverse plane and decreased knee flexion in the sagittal plane.[14] This reduction can be associated with the presence and magnitude of a dynamic knee valgus, whose biomechanical pattern is similar to that of individuals with PFP.[14,15] Reduced ankle dorsiflexion ROM may also be associated with several lower limb injuries including anterior cruciate ligament injuries,[27] iliotibial tract syndrome[27] and PD.[28] In the present study, patients with a history of PD demonstrated a mean ankle dorsiflexion deficit of 9° (approximately 31%) compared to healthy controls. This is biomechanically plausible given that the principal mechanism for PD is a quadriceps contraction during early knee flexion with dynamic valgus.[3,29] In this situation, the quadriceps demonstrate less activation in closed kinetic chain activities, contributing to reduced patellofemoral joint stability.[30]

The conservative treatment of PD is often based on treatments advocated for PFP including strengthening programmes for the gluteus, quadriceps and specifically the vastus medialis obliquus muscles.[7,19] Quadriceps weakness is a risk factor for the development of PFP.[31] People with PFP often demonstrate reduced quadriceps, hip abductors and lateral rotation strength compared to healthy individuals.[11,32] However, this has not been investigated in the PD population until now.[33] The findings of our study showed that individuals with a history of PD have reduced hip and knee muscle strength compared to healthy individuals of the same age and sex. Statistically and clinically significant between-group differences were evident for all the muscles evaluated. This therefore provides a scientific rationale for strengthening exercises to target these muscle groups to prevent or treat PD.

Patients with a history of PD have previously demonstrated cortical alterations such as an increased activation of the anterior cingulate cortex.[34] This is associated with the sensation of knee instability and perceived joint insecurity, leading to a sedentary behaviour and muscle atrophy.[35] Although both groups had similar numbers of irregularly active individuals, individuals in the PD group tended to show increased sedentary behaviour compared to control participants. We hypothesise this sedentary behaviour may lead to muscle weakness. Subjects with hypermobility tend to have lower generalised lower limb muscle strength compared to the control group.[36,37] Although joint hypermobility was not assessed, patients with a history of PD often present with generalised joint laxity and hypermobility.[38] It remains unclear whether this is associated with reduced physical capability in PD. This warrants further investigation.

Individuals with a history of unilateral PD demonstrated statistically significant differences in lateral rotator hip muscle strength at 90º, with small and medium effect sizes, respectively (0.29 and 0.53). Mean difference between the affected and unaffected sides for both muscle groups was 7% and 17% respectively. This may be attributed to quadriceps atherogenic inhibition, resulting from pain and capsular distension caused by joint effusion .[39,40]

Interestingly, the other muscle groups evaluated did not show statistically significant differences. Accordingly, it is possible to assume that generalised muscle weakness also occurs on the unaffected side, further corroborating the hypothesis of sedentary lifestyle and hypermobility mentioned above.

The present study presented with some limitations. Firstly, the cross-sectional design of the study does not allow the assessment of a cause-effect relationship between dorsiflexion ROM and generalised muscle strength following atraumatic PD. Secondly, whilst ankle ROM was assessed, ankle muscle strength and instability were not. The relationship between ankle muscle strength and functional stability and PD have yet to be assessed. Thirdly, assessors were not blinded to case or control group allocation. Finally, only individuals with a history of atraumatic PD were evaluated, making it impossible to extend the findings to individuals with a history of traumatic PD. However, given that these are the minority of cases, examining the atraumatic population was viewed as a priority.

This study provides a new theoretical justification for exercise prescription for people following PD. Ankle ROM should be evaluated given that this may be a pathological feature of PD. The results provide a rationale for the assessment and subsequent prescription of glutei recruitment exercises; this has not been previously reported in the literature. Further study is now warranted to better phenotype this population. Through this, the conservative management of this population can be better targeted to pathological features, to improve the recovery and reduce recurrence of PD.

CONCLUSION

Individuals with a history of PD have decreased ankle dorsiflexion ROM during a closed kinetic chain exercise and generalised lower limb muscle strength deficits compared to healthy individuals. People following PD should therefore be routinely assessed for ankle ROM and hip and knee muscle strength, with treatments directed accordingly.

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TABLE 1. Characteristics of the participants

Variable	Patellar Dislocation Group (n = 44)		Control Group (n = 44)		P value
	Mean (SD)	SEM	Mean (SD)	SEM	
Female	30		33		
Male	14		11		
Age (y)	22 (8)	1	21 (5)	1	ns
Weight (kg)	65.45 (2.33)	2.33	62.47 (13.45)	2.03	ns
Height (m)	1.67 (0.09)	0.01	1.66 (0.10)	0.02	ns
BMI (kg/m^2)	23.25 (4.39)	0.66	22.43 (3.51)	0.53	ns
Number of episodes	3.36 (2.67)	0.40			
Age at first episode (y)	14.57 (4.53)	0.68			
NPRS at rest	2.2 (2.78)	0.42			
NPRS during effort	5.21 (2.77)	0.41			
Duration from last PD to assessment (wks)	9.27 (4.16)	0.62			
Bilateral dislocation	17				
Unilateral dislocation	27				

y: years; kg: kilogram; m: metre; BMI: Body Mass Index; kg/m^2: kilogram/square metre; NPRS: Numerical Pain Rating Scale; PD: Patellar Dislocation; wks: weeks; SD: Standard Deviation; SEM: Standard Error of Mean; ns: non-significant.

TABLE 2. Comparison between groups of lower limb strength and ankle dorsiflexion range of motion.

Variable	Patellar Dislocation Group (n = 44)		Control Group (n = 44)		CI 95%	Effect Size (Cohen *d*)
	Mean (SD)	SEM	Mean (SD)	SEM		
Lunge test (degrees)*	29.23 (7.23)	1.10	38.36 (5.79)	0.87		1.39
Hip flexors (kgf/kg x 100)†	30.82 (7.67)	1.16	35.56 (10.21)	1.54	-8.57, -0.91	0.52
Hip extensors (kgf/kg x 100)*	27.14 (7.85)	1.18	38.23 (18.53)	2.79		0.77
Hip abductors (kgf/kg x 100)*	17.53 (4.04)	0.61	20.81 (4.13)	0.62	-5.01, -1.55	0.80
Hip adductors (kgf/kg x 100)*	15.46 (4.77)	0.72	22.30 (5.94)	0.90	-9.11, -4.54	1.26
Hip LR 90° (kgf/kg x 100)*	14.09 (3.76)	0.57	21.15 (4.88)	0.74	-8.91, -5.21	1.62
Hip LR 0° (kgf/kg x 100)*	12.51 (3.55)	0.54	19.33 (3.87)	0.58		1.83
Hip MR 90° (kgf/kg x 100)*	17.11 (5.68)	0.86	23.77 (6.73)	1.01	-9.29, -4.01	1.06
Hip MR 0° (kgf/kg x 100)*	11.48 (3.50)	0.53	14.78 (3.42)	0.52	-4.76, -1.83	0.95
Quadriceps (kgf/kg x 100)*	40.44 (12.33)	1.86	71.84 (14.22)	2.14	-37.03, -25.4	2.35

kgf: kilogram-force; kg: kilogram; LR: Lateral Rotators; MR: Medial Rotators; SD: Standard Deviation; SEM: Standard Error of Mean; CI: Confidence Interval. Statistically significant at: *****$p<0.001$; †$p<0.05$

TABLE 3. Comparison between the affected side and non-affected side of lower limb strength and ankle dorsiflexion range of motion in individuals with unilateral patellar dislocation.

Variable	Affected side (n = 27)		Non-affected side (n = 27)		CI 95%	Effect Size (Cohen *d*)
	Mean (SD)	SEM	Mean (SD)	SEM		
Lunge test (degrees)	30.35 (6.22)	1.22	31.81 (6.86)	1.35	-3.42, 0.50	0.22
Hip flexors (kgf/kg x 100)	31.30 (8.26)	1.59	32.17 (9.12)	1.75	-1.95, 0.21	0.09
Hip extensors (kgf/kg x 100)	28.18 (7.41)	1.43	28.04 (8.13)	1.56	-0.17, 0.23	0.01
Hip abductors (kgf/kg x 100)	17.71 (3.81)	0.73	17.74 (4.35)	0.84	-0.93, 0.86	0.007
Hip adductors (kgf/kg x 100)	16.48 (4.60)	0.88	17.06 (4.64)	0.89	-2.00, 0.83	0.12
Hip LR 90° (kgf/kg x 100)*	14.15 (3.38)	0.65	15.16 (3.51)	0.68	-0.25, -0.01	0.29
Hip LR 0° (kgf/kg x 100)	12.26 (3.45)	0.66	12.61 (4.22)	0.81		0.09
Hip MR 90° (kgf/kg x 100)	16.41 (4.96)	0.95	16.69 (5.29)	1.02	-1.85, 0.74	0.05
Hip MR 0° (kgf/kg x 100)	10.73 (2.64)	0.51	10.94 (3.04)	0.59	-0.76, 0.33	0.07
Quadriceps (kgf/kg x 100)†	40.14 (12.99)	2.50	47.12 (12.88)	2.48	-11.78, -2.18	0.53

kgf: kilogram-force; kg: kilogram; LR: Lateral Rotators; MR: Medial Rotators; SD: Standard Deviation; SEM: Standard Error of Mean; CI: Confidence Interval. Statistically significant at: *$p < 0.05$; †$p < 0.01$

FIGURE 1. Measurement of the ankle dorsiflexion range of motion in a closed kinetic chain exercise using the lunge test.

(A): Positioning of the participant; (B): Positioning of the goniometer to measure ankle dorsiflexion.

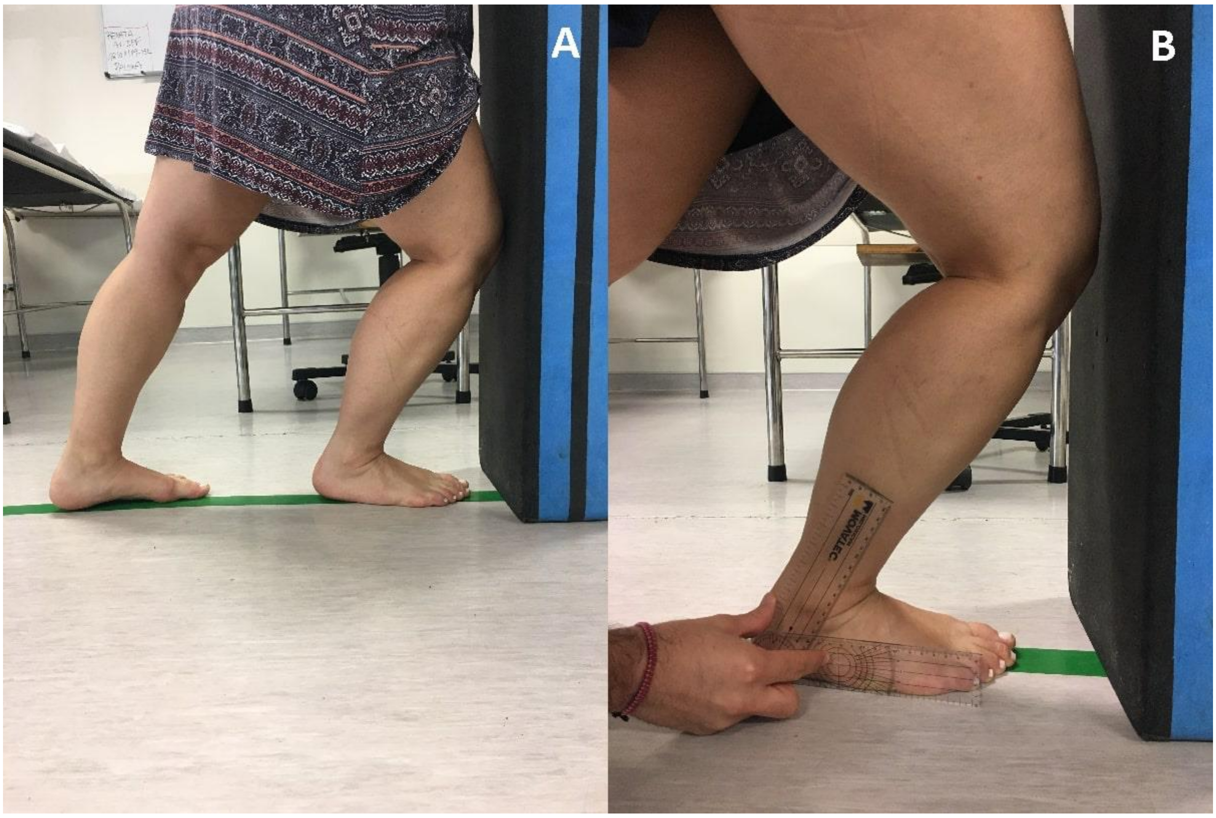

FIGURE 2. Sequence and positioning during the evaluation of the isometric strength of the hip muscles.

(A): Hip flexors; (B): Hip extensors; (C): Hip abductors; (D): Hip adductors; (E): Lateral rotators at 90º; (F) Lateral rotators at 0º; (G): Medial rotators at 90º; (H) Medial rotators at 0º.

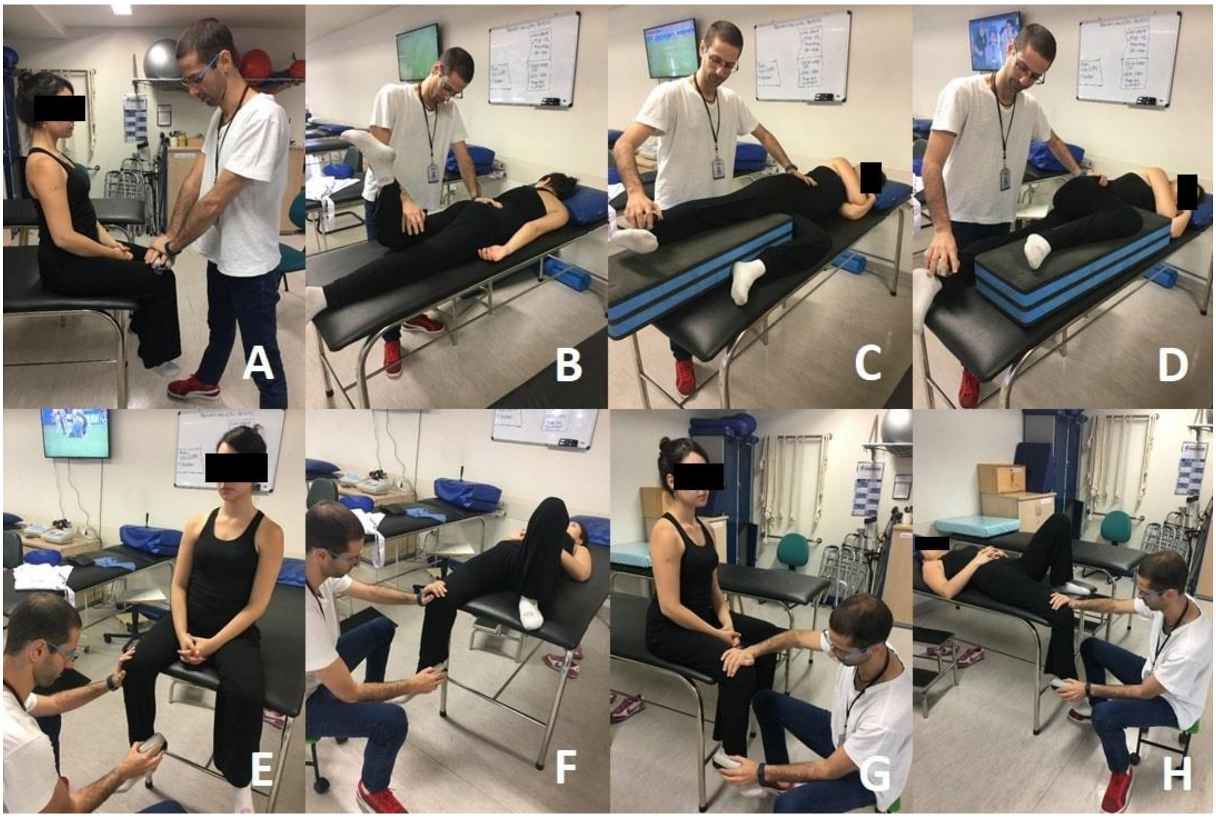

FIGURE 3. Sequence and positioning during the evaluation of isometric strength of the quadriceps femoris muscle.

(A): Positioning of the participant; (B): Positioning of the lower limb with knee flexed at 60º; (C) Positioning of the dynamometer.