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Correlation between Dorsiflexion Ankle Range of Motion and Patellofemoral Pain Syndrome

Correlação Entre a Amplitude da Dorsiflexão do Tornozelo e Síndrome da Dor Patelofemoral

Isabella Pereira da Silva[a]; Baldomero Antonio Kato da Silva[b]; Daniel Martins Pereira[b]; Ana Carolina dos Santos Demarchi[b]; Silvio Assis de Oliveira-Junior[c]; Filipe Abdalla dos Reis[a]*

[a]University Anhanguera - Uniderp, Physiotherapy Course. MT, Brazil
[b]Federal University of Piauí, Physiotherapy Course. PI, Brazil
[c]Federal University of Mato Grosso do Sul, Physiotherapy Course. MT, Brazil
*E-mail: filipeabdalla@anhanguera.com
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Abstract

The change in lower extremity movement pattern has been previously associated with severe knee disorders, including anterior cruciate ligament rupture, patellar tendinopathy, iliotibial band syndrome, and patellofemoral pain (PFP). The aim of this study was to verify the clinical reliability of ankle dorsiflexion range of motion (ADROM) measurement with weight bearing (WB) using an app on the smartphone (iHand) and to verify if there is correlation between the limitation of the ADROM and the PFP. A total of 67 women, mean age 34.3 ± 2.4, height 182 ± 3.6, weight 73.7 ± 4.2, were allocated to the control group (n = 23) and the PFP group (n = 23). Two examiners evaluated the active ADROM (lunge test) in both ankles at two times to test inter-examiner and intra-examiner reliability. It was observed in the PFP group that the mean ADROM was 17.7 ± 2.5 and the control group was 35.3 ± 6.2 (right) and 17.1 ± 2.9 and 32.9 ± 5, 4 (left). It is concluded that the use of the smartphone app proved to be reliable for clinical application in the evaluation of ADROM with WB and that there is a relation between the low DFT of DFT with the presence of patellofemoral pain.
Keywords: Data Accuracy. Ankle. Patellofemoral Pain Syndrome.

Resumo

A alteração no padrão de movimento da extremidade inferior tem sido previamente associada com severas desordens do joelho, incluindo a ruptura do ligamento cruzado anterior, tendinopatia patelar, síndrome da banda iliotibial e dor patelofemoral - DPF. O objetivo do estudo foi verificar a confiabilidade clínica da mensuração da dorsiflexão de tornozelo - DFT com descarga de peso - WB utilizando um app no smartphone (iHand) e verificar se há correlação entre a limitação da DFT com a DPF. Participaram 67 mulheres, idade média 34,3±2,4, altura 182±3,6, peso 73,7±4,2, alocadas em grupo controle (n=23) e grupo DFP (n=23). Dois examinadores avaliaram a DFT ativa (lunge test) em ambos os tornozelos em dois momentos para se testar a confiabilidade inter-examinador e intra-examinador. O coeficiente de correlação intraclasse - CCI foi utilizado para a análise da confiabilidade das medidas. Observou-se alta confiabilidade (0,9965 [p<0,0001]) e (0,9949 [p<0,0001]) para tornozelo direito e esquerdo respectivamente. Observou-se no grupo DFP que a ADM média de DFT foi de 17,7±2,5 e grupo controle de 35,3±6,2 (direito) e 17,1±2,9 e 32,9±5,4 (esquerdo). Conclui-se que a utilização do app de smartphone se mostrou confiável para aplicação clínica na avaliação da DFT com WB e que há relação entre a baixa ADM de DFT com a presença de dor patelofemoral.
Palavras-chave: *Acurácia dos Dados. Tornozelo. Síndrome da Dor Patelofemoral.*

1 Introduction

Changes in the movement pattern of the lower extremity have been previously associated with severe knee conditions, including rupture of the anterior cruciate ligament, patellar tendinopathy, syndrome of the iliotibial band and patellofemoral pain - PFP[1-9]. These movement patterns are typically characterized by a reduction of the hip and knee movement in the sagittal plane and excessive movement in the frontal plane, resulting in medial collapse of the entire lower extremity during activities such as squatting, jumping and landing. It is believed that the collapse of the lower end, called dynamic valgus[5], increases the tension in several ligaments, tendons and joint structures, generating tissue failure and pain.

In runners, PFP is one of the most common disorders of the lower end[10-12]. The condition is not self-limiting; 90% of patients with PFP still have symptoms 4 years after diagnosis[13,14] and only 6% are asymptomatic after 16 years of follow-up[4]. The publications of the experts' consensuses generated after three encounters of International Research on PFP propose biomechanical risk factors for the symptoms development, described by anatomical location in relation to the knee. These factors are described in the following regions: The Upper Proximal (femur, hip and trunk); Local (inside and around the patella and the patellofemoral joint); Distal (lower leg and ankle)[15-17].

Among the distal factors that can contribute to reducing the motricity in the sagittal plane and increase it in the coronal plane, is included the limitation of amplitude of ankle dorsiflexion - ADROM. Under conditions of weight bearing - WB, limited ADROM can stop prematurely the tibia protrusion at the talus, thus limiting also the knee flexion. Indeed, limited ADROM has been associated to the knee flexion decrease[18-20], increase of the knee valgus[18-20], greater medial collapse of the lower extremity[21] and increase in the reaction forces on the ground during various functional tasks[18-20,22]. Therefore, the precise measurement of articular amplitude is often necessary in biomechanics research and in clinical practice. One of the most reliable tools to measure the joint mobility is the digital inclinometer[23,24], however, the accessibility and the high costs often prevent their use. There is a great variety of methods and tools available to measure ADROM, both with - WB and without weight bearing - NWB. The WB measurements have greater precision and correlation with functional activities such as walking, running, or walking the stairs, and have demonstrated higher reliability (ICC = 0.93-0.96) than the measurements obtained on the condition NWB (ICC 0.32-0.72)[25].

Among the tools in common use for measuring ADROM there is the universal goniometer[26], and inclinometer[1,2,27-29]. Nowadays with the advent of smartphone, there are now many free of charge and available applications (app), allowing the smartphone to be used as an inclinometer.

The use of app for articulate measurement is a growing area, as shown in the first systematic review, which collected 17 articles from 2011 onwards[17]. Many of the apps available use incorporated accelerometers from smartphone, but magnetometers and photographic systems are also used. It was demonstrated that[30] app *iHand Level* (iPhone; Apple, Cupertino, CA) is reliable (ICC 0,93) and valid to measure ADROM. iHandy Level was assigned to use the accelerometers incorporated from smartphone and had been previously validated only to measure the mobility of the spinal column, though its development was initially used in carpentry.

In view of the assumptions above, this study is justified to elucidate whether there is a correlation between amplitude of ADROM and occurrence of PFP using the measurement with WB, for being more functional with more symptomatic activities of patellofemoral pain.

The study herein presents as a hypothesis the high correlation between the limitation of the DFT to the ADROM symptoms. The objective was initially, to check the clinical reliability of ADROM measure with WB using a smartphone app and later, check If there is a correlation between the limitation of ADROM with the PFP.

2 Material and Methods

2.1 Participants and study site

Forty-nine volunteers, female, aged between 18 to 55 years (34.3 ± 2.4), height between 170 and 185 cm (182±3.6), body weight between 60 to 85 Kg (73.7±4.2) were invited. The participants were distributed in two groups, according to PFP occurrence: Control group, consisting of 23 healthy volunteers, and PFP, populated by 23 volunteers with a history of PFP, proven by clinical examination, radiological (Nuclear Magnetic Resonance) and functional (Single-Leg Squat Test and Step Down Test). Three volunteers were excluded from the sample selection who had history of knee and ankle acute lesion, previous surgical procedures six months ago and articulate sprains which prevented the performing of the measurement. The inclusion and exclusion criteria were analyzed after filling in the standardized assessment and anamnesis file.

All the volunteers were informed about the study procedures, with the signature of free and informed consent term according to the guidelines and regulatory standards for research involving human beings contained in the resolution of the National Health Council number 466/12 and was approved by the Ethics Committee of University Anhanguera - Uniderp under protocol number 2.128.451. All the volunteers were assessed at Byofisio Clinic - Specialized Physiotherapy[1]

2.2 Experimental approach

Before the beginning of the experiment (pre-test) two beginner examiners (students of the 8th semester of Physiotherapy) went through about three hours of training with an experienced examiner for procedures of standardized tests and practiced these procedures in five volunteers before starting the experiment.

2.3 Procedures

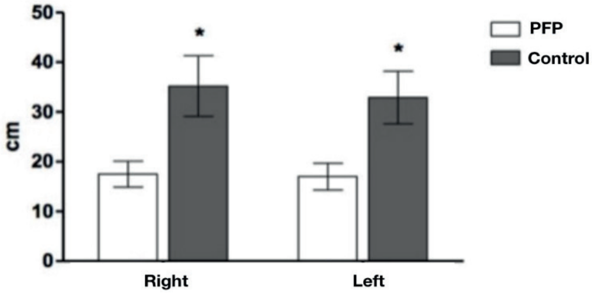
ADROM was measured using an iPhone app iHandy *Level* iPhone (iPhone, Apple, Cupertino, CA). Participants were evaluated independently by two examiners in a single day. One examiner performed the measurements, while the other recorded them to maintain the blinding. No examiner was aware of which group the volunteer belonged to, as well as the volunteers were not aware of the allocation into groups (double-blind test). Both examiners assessed the volunteers initially to test the inter-examiner reliability, with re-assessment after a 5-minute rest period for intra-examiner reliability. Before the test, each volunteer performed actively 1 calf stretching for 60 seconds on both legs as a warm-up. The ADROM measurement procedure was explained to each volunteer.

It was used the test with WB, called Lunge Test, in which each evaluator marked a point 15 cm distal to the anterior tuberosity of the tibia - TAT with a felt tip pen[23]. Between each measurement, the mark was removed with alcohol 70% The demarcated point served as a guide for positioning the smartphone. In order to standardize the smartphone positioning, BHome (home button on the iPhone), was

1 Rua Dr. Michel Scaff, 93, Chácara Cachoeira, Campo Grande, MS, UP ZIP CODE: 79.040-860 - contato@byofisio.com.br.

aligned with the TAT pen mark. To ensure the same distance from the foot to the test, the distance of the hallux to the wall was measured (tape measure), recorded and reused for each test (Figure 1).

Figure 1 - Comparison of ADROM means measured by the examiner 01 (Student's t-test for independent samples; "*" p<0.0001).



Source: The authors.

Each volunteers' foot was positioned perpendicular to a wall, using their forward to assist in balance[23]. A tape measure was placed on the floor to ensure that the second toe and the center of the calcaneum were aligned perpendicularly to the wall. After that, the volunteers were instructed to move forward, putting their knee in contact with a vertical strip on the wall. For the tests, the volunteers were encouraged to keep the foot away from the wall in order to obtain the highest angle possible, keeping the heel on the floor. Upon touching the knee on the wall or reaching the maximum of ADROM, the angulation value shown on the smartphone screen was written down. For each ankle, three measures were obtained to subsequently perform the mean calculation.

2.4 Statistical analysis

The data were tabulated in an electronic spreadsheet Microsoft Excel for Mac 2017 and analyzed statistically in BioEstat 5.0. The continuous variables were expressed as mean and standard deviation. The reliability was tested by the intraclass correlation coefficient (ICC), which measures the association between two variables. The decision level was alpha=0.05

Student's t-test was used for independent samples, in order to assess the relationship between the deficit of PFP with ADROM, with alpha decision level = 0.05.

3 Results and Discussion

The Student's t-test for independent samples showed no difference between the variables age, weight and height (p>0.05). The mean values of ADROM are displayed in Table 1. The results of the analysis of inter-examiner reliability showed very high reliability for ADROM of 0.9965 (p<0.0001), and 0.9949 (p<0.0001) for the right and left ankles, respectively. The observed means of the inter-examiners measurements showed no significant difference for the right (p = 0.9929) and left sides (p = 9663).

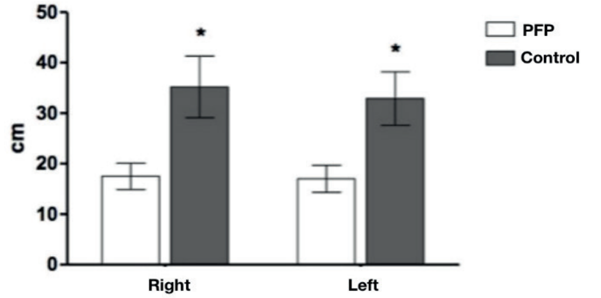
Table 1 - Mean values of ADROM (in cm) according to the groups and report evaluated for each examiner.

	Examiner 1			Examiner 2		
	ADROM	Control	p-value	ADROM	Control	p-value
Right Ankle	17.7±2.5	35.3±6.2	<0.0001	17.5±2.6	35.2±6.1	<0.0001
Left Ankle	17.1±2.9	32.9±5.4	<0.0001	17.0±2.7	32.9±5.3	<0.0001

Source: Research data.

In both assessments, the ADROM group showed higher values of ADROM in comparison to the control group (p<0.0001) for the examiners 01 and 02 (Figure 1 and 2).

Figure 2 - Comparison of ADROM means measured by the examiner 02 (Student's t-test for independent samples; "*" p<0.0001).



Source: Research data.

The application iHand Level proved to be valid and reliable for measuring the ankle dorsiflexion amplitude. The results of this study corroborate with the high reliability found by Vohralik et al.[31] when comparing the *iHand Level* with another application *TiltMeter* in the ankle dorsiflexion measurement. The *iHand Level* was initially developed, using the smartphone accelerometer, for use in carpentry and after the work of Salamh and Kolber[32] was validated to measure the spinal column mobility.

The use of applications is an attractive alternative for clinical evaluation, due to its low cost and availability in a variety of smartphones and, in comparison with goniometry, its ease and speed of use. There are the problems of hygiene and these are similar to those found using an inclinometer, but it is believed that in smartphones with smoother external parts cleaning is more easily performed with paper and alcohol.

The intra examiner and inter examiner reliability was excellent in the present study, this fact can be explained by the standardization of the smartphone positioning in the participant's TAT, rather than being placed with the narrowest point of the smartphone[31], the longest portion was allocated, favoring the stability even during the test execution. There are several pieces of equipment, nowadays designed to measure ADROM, such as Larsen et al.[33] created a new assessment tool, demonstrating inter and intra-examiner high reliability (0.989), but the tool is not commercialized, was tested only for purposes of research, which would make its clinical applicability difficult.

Following the line of equipment available for ADROM analysis in 2015 Calatayud et al.[34] tested the reliability and validated a system of leg mobility (Leg Motion System) evaluating 26 college students obtaining the equipment validation, affirmed also to be an easy applicability and portable device, but quite costly, when compared to a smartphone application with the same function.

In the present study, high correlation can be observed between the reduction of ADROM in individuals with PFP when compared to the asymptomatic group. The reduction in ADROM is associated to increase in the hip and knee movement in the frontal and transverse plane respectively and reduction of knee mobility in the sagittal plane during a squat movement [22]. This altered kinematics has been observed in malfunctions of the lower limbs (1,2) and it is believed that the ADROM limitation plays an important role in the PFP pathogenesis[28]. The knee flexion during the squat is important to reduce the center of mass and its limitation can result in a compensation of the hip and knee in the frontal plane[35].

It is believed that a limitation in ADROM can contribute to increased adductor moment in the hip, favoring the large vectors of lateralization force of the patella and reducing the patellofemoral contact contributing to the increased patellofemoral pressure and consequently the pain[29]. This can be observed in studies of Nakagawa et al.[7] and Wilson and Davis[36] when analyzing the increase of the hip adductor moment during the mini-squatting.

People with low ADROM exhibited greater torque peak of lateral rotation of the knee during squatting movement. The increase in the knee lateral rotation is also likely to raise the quadriceps vector force more to the lateral , and therefore this changes the load on the patellofemoral joint and possibly leads to knee pain over time[22], the authors observe a peak of torque of the knee lateral rotation in people with DFT of DFT reduced of 7,7º when compared with healthy individuals[4].

The low DFT of ADROM can be explained by capsular restrictions of the talocrural joint or also by the loss of flexibility of the gastrocnemius and soleus muscles associated with loss of flexibility of the Achilles tendon. It is suggested that future studies can assess the application of techniques to gain mobility and flexibility as an attempt to increase the DFT of ADROM and consequently assist in reducing the PFP.

The authors of this study suggest that the DFT of ADROM using smartphone app should be assessed and considered when there is presence of PFP. There is still no explanation in the literature of exact and ideal values of DFT of ADROM, but there are works that support ADROM acceptable to 45º in WB and 22º without load discharge (NWB)[37].

The study herein has limitations that should be taken into consideration for future studies, such as: it was not performed the comparison with other forms of measuring the DFT of ADROM; there is a need to compare also what is the etiological factor of loss of ADROM, trying to enlighten if there is a loss of joint mobility or restriction of soft tissues flexibility. And finally, search for other options of correlation of limitation DFT of ADROM with PFP in different functional tasks or with more precise biomechanical assessments.

4 Conclusion

It is concluded that the use of app smartphone has proved reliable for clinical application in the assessment of ADROM with WB and that there is a relationship between low DFT of ADROM with the presence of patellofemoral pain.

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