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Normative data of frontal plane patellar alignment in athletes

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ABSTRACT

Objective: The objective of this study was to provide normative data of frontal plane patellar alignment according to McConnell and Arno angles, verify the association between theses angles and identify the presence of patellar rotation in different sports.
Design: Cross-sectional.
Participants: Nine participants (18 knees) were assessed in a preliminary study to verify the intra and inter-examiner reliabilities of the patellar alignment measures. In the main study, 230 volleyball, basketball, gymnastics and soccer athletes (460 knees) were evaluated in order to obtain normative data of patellar alignment.
Main outcome measures: Frontal plane patellar alignment (McConnell and Arno angles) measured in standing position by means of photogrammetry.
Results: The standardized method demonstrated intra and inter-examiner reliability coefficients varying from .85 to .98. The mean McConnell and Arno angles were 2.05° (±5.9) and 2.89° (±7.57), respectively. A low association was observed ($r = .189$, $p < .0001$) between these angles. There was a difference in distribution of medial and lateral rotations, according to the McConnell angle, between different sports ($p < .014$).
Conclusions: The proposed procedure for measuring patellar alignment according to McConnell and Arno angles proved to be highly reliable. This made possible the establishment of normative data in a large sample of healthy athletes.

1. Introduction

Alterations of frontal plane patellar alignment (i.e. patellar rotation) may contribute to development of clinical conditions, such as patellofemoral pain syndrome and patellar tendinopathy (Barton, Bonanno, Levinger, & Menz, 2010; Draper et al., 2010; Lin et al., 2010; Mendonça, Macedo, Silva, & Fonseca, 2005; Powers, 2003; Powers, 2010; Souza, Draper, Fredericson, & Powers, 2010; Wilson, Press, Koh, Hendrix, & Zhang, 2009). The proposed contribution of patellar rotation to development of these conditions is associated with changes in dynamic patellar alignment on the femoral trochlear groove during knee flexion and extension (Draper et al., 2010; Lin et al., 2010; Souza et al., 2010; Wilson, Mazahery, Koh, & Zhang, 2010), and to asymmetrical force distribution on the medial and lateral retinaculum and on the medial and lateral portions of the patellar tendon (Elvin, Elvin, Scheffer, Arnoczky, Dillon, & Erasmus, 2009; Lin et al., 2010; Wen, 2007; Zachazewski, Magee, & Quillen, 1996). These asymmetries may result in overload to specific regions of the patella and its tendon. Therefore, the presence of patella rotation may be considered a factor that may contribute to the development or aggravation of musculoskeletal dysfunctions (Barton et al., 2010; Diederichs,

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Köhlitz, Kornaropoulos, Heller, Vollnberg, & Scheffler, 2013; Draper et al., 2010; Powers, 2010; Reiman, Bolgla, & Lorenz, 2009).

The classification of biomechanical factors as relevant or not depends on the comparison with normative data. Although the literature describes frontal plane changes in patellar alignment (Arno, 1990; Mendonça et al., 2005; Wilson et al., 2009; Zachazewski et al., 1996), there is no reported normative data of this alignment to identify which values could be expected as normal and those that could characterize the presence of excessive patellar rotation. The existence of normative values for patellar rotation would allow clinicians to characterize patellar alignment in a specific population to help determine what could be considered clinically relevant.

Some measurements have been proposed to evaluate frontal plane patellar alignment (Diederichs et al., 2013; Draper et al., 2010; MacIntyre, McKnight, Day, & Wilson, 2008). Magnetic resonance imaging and computed tomography, for example, are methods that could be used to measure patellar rotation (Diederichs et al., 2013; Draper et al., 2010; MacIntyre et al., 2008). MRI and CT allow a tridimensional analysis of patellar alignment, on the other hand, they have low applicability in a clinical context due to high costs (Draper et al., 2010; Wilson, 2007) and to the non-functional information they provide as a result of the patient positioning during examination (Diederichs et al., 2013). Thus, in clinical settings, some methods involving visual estimation and palpation have been proposed to evaluate patellar alignment (Diveta & Vogelbach, 1992; Ehrat, 1994; Zachazewski et al., 1996). However, these methods have low reliability (Diveta & Vogelbach, 1992; Tomsich, Nitz, Threlkeld, & Shapiro, 1996; Wilson, 2007), preventing the establishment of normative values.

In order to allow the quantification of frontal plane patellar alignment, two clinically feasible methods have been proposed: McConnell and Arno angles (Arno, 1990; Diveta & Vogelbach, 1992; Ehrat, 1994; Mendonça et al., 2005; Watson, Propps, Galt, Redding, & Dobbs, 1999). The former considers the patellar alignment relative to the femur and the latter relative to the tibia. The first point to be raised is that, since each angle considers patellar alignment relative to different references (segments), do they measure exactly the same aspect of patellar alignment? The second point is relative to the patient positioning during the test. Traditionally, the patient position during the evaluation of both angles is in relaxed supine lying. However, as distal (e.g. shank and foot) and proximal body segments (e.g. hip and thigh) may influence patellar alignment through retinaculum tensioning (Barton et al., 2010; Mendonça et al., 2005; Reiman et al., 2009), the angles of patellar rotation obtained with traditional positioning (supine with knee extension) may not represent the real patellar position in functional situations. Therefore, the measurement of patellar alignment has to consider a more functional position in order to take into account these biomechanical influences. A position that considers the influence of the tensioning of the patellar retinaculum is standing with semi flexed knees (in a position around 30°) (Draper et al., 2010; Souza et al., 2010; Wilson et al., 2009).

The use of normative data in clinical practice, especially in sports, is facilitated when the method chosen is fast and easily applied, in order to allow the evaluation of a large number of individuals in a short period (e.g. athletes preseason screening). In addition, standardization and adequate reliability of the method is a precondition to the test to be used. Thus, the main purposes of this study were (1) to generate normative data to characterize frontal plane patellar alignment in athletes (2) verify the association between McConnell and Arno angles, and (3) verify the distribution of the types of frontal plane patellar alignments in different sports. To achieve this aim, a preliminary study was carried out to evaluate the reliability of the proposed standardized method to measure the McConnell and Arno angles.

2. Methods

Two studies were carried out in order to attain the objectives. First, a study was performed to develop a method to measure the McConnell and Arno angles in a standing position and to determine the inter and intra examiner reliability. Second, the main study was carried out with a larger number of athletes, in order to obtain normative data on frontal plane patellar alignment. In both studies, the procedures to measure the patellar alignment were the same. Participants with history of injuries or surgery in the lower limbs in the previous six months were not included in either of the studies. Informed consent was obtained for all participants and the rights of subjects were protected in both studies.

2.1. Reliability study

Nine volunteers (18 knees) who practiced sports activities five times a week took part in this study. The sample was comprised of 3 men and 6 women (mean age of 22.66 ± 2.54 years; mean height of 1.68 ± .79 m; and mean body mass of 64.88 ± 8.32 kg). Two examiners assessed the participants. In order to allow the intra-examiner reliability assessment, each examiner measured the same participant twice with an interval of three days. In the same evaluation session, the measures were done with 15-min intervals between examiners in order to avoid fatigue of the lower limb muscles. The examiners could not access the results obtained by each other. A third examiner removed all marks on the athlete's skin (more details in patellar alignment measurement description) during the interval between the evaluations of each examiner to make sure that they could not see the marks made by each other. The second measurement of each examiner was used for inter-examiner reliability analysis.

2.2. Normative data study

After the reliability investigation, the two examiners evaluated two hundred and thirty athletes (460 knees) of different sports: volleyball ($n = 68$), basketball ($n = 50$), gymnastics ($n = 59$) and soccer ($n = 53$). Demographic data of each modality are presented in Table 1.

2.2.1. Patellar alignment measurement

To evaluate the frontal plane patellar alignment, reflective markers were attached bilaterally to the anterior superior iliac spine (ASIS), femoral epicondyles, midpoint of the patellar base (determined with a measuring tape), inferior pole (apex) of the patella and tibial tuberosity. The markers' placements and photographic records were determined with the subject in bipedal standing with the knees flexed at 30° (measured with universal

Table 1
Demographic data for volleyball, basketball, gymnastics and soccer athletes.

	Female/male	Age (years)[a]	Body mass (kg)[a]	Height (cm)[a]
Volleyball	27/41	18.27 (6.73)	71.13 (17.04)	179.15 (14.35)
Basketball	0/50	14.46 (2.38)	66.94 (18.68)	176.85 (16.91)
Gymnastics	17/42	13.91 (3.53)	55.67 (18.34)	165.94 (23.03)
Soccer	24/29	17.09 (3.36)	59.94 (10.23)	168.59 (7.46)

kg = kilograms, cm = centimeters.
[a] values indicate mean (standard deviation).