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Does pelvic width influence patellar tracking? A radiological comparison between sexes

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ABSTRACT

Introduction: Pelvic width has been believed to affect patellar tracking by influencing the quadriceps angle (Q-angle). Anatomically, the upper arm of the Q-angle does not closely match the orientation of the quadriceps femoris. The pelvis is often considered wider and the Q-angle larger in female than in male individuals. The purpose of this retrospective study was to investigate the accuracy of such an assumption by using a radiologic comparison, which might be more objective.

Materials and methods: One hundred consecutive adult patients (50 men and 50 women) aged 18–30 years with unilateral injury to the lower extremity were studied. Full-length standing X-rays of these patients were used to analyze the relationship between the pelvis and the uninjured lower extremity and compare it between the sexes. The pelvic width was defined as the distance between the centers of the bilateral femoral heads.

Results: The pelvic width did not differ statistically between male and female ($P=0.74$). The femur length and sum of the lengths of the femur and tibia differed between the sexes (both $P<0.001$). Normalization of the pelvic width to the femur length or sum of the lengths of the femur and tibia resulted in a significant difference between male and female ($P<0.001$). The angle formed by the femoral and tibial mechanical axes correlated strongly with the angle formed by the femoral anatomic and tibial mechanical axes (Pearson correlation coefficient $=0.89$).

Discussion: Pelvic width does not differ with respect to gender. The pelvis may appear relatively wider in women due to the difference in body height. However, this difference may not increase Q-angle. Patellar mal-tracking may stem from other, more critical predisposing factors.

Level of evidence: Level IV. Anatomic study.

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1. Introduction

Patellar mal-tracking is a common issue [1,2]. Three groups of critical predisposing factors have been proposed: imbalance of peripatellar soft tissue tension, bony anomalies, and abnormal lower extremity alignment [3,4]. The quadriceps angle (Q-angle) is considered as an important determinant of patellar mal-tracking because it imposes a lateral traction force [5,6]. Female individuals are generally considered to have a wider pelvis and a larger Q-angle than male individuals [7], and female patients may consequently have a greater tendency to develop patellar mal-tracking. The Q-angle is determined clinically by measuring the angle of intersection between two lines, one connecting the anterior superior iliac spine (ASIS) and the center of the patella and another connecting the tibial tubercle and the center of the patella [5–8].

Clinical measurement of the Q-angle is not always straightforward. Lateral subluxation of the patella may decrease the Q-angle [9]. Moreover, the current method of measurement of the Q-angle is also questionable from the perspective of human anatomy. The orientation of the four muscular components of the quadriceps femoris (rectus femoris, vastus medialis, vastus lateralis, and vastus intermedius) does not correspond well to the upper arm of the Q-angle [10,11]. The choice of the ASIS as the origin of the upper arm is for convenience of measurement only [7]. Therefore, the use of the Q-angle to determine the magnitude of the lateral traction force is not always convincing [5–7]. The effect of the Q-angle on the severity of patellar mal-tracking is therefore difficult to quantify. A clinical technique for direct measurement of the pelvic width effect on the patellar alignment has been described [8]. Because clinical measurement of the Q-angle is not always convincing, direct measurement of the pelvic width may be a more reliable method to clarify the difference between genders and determine its relationship to lower extremity alignment. This retrospective study aimed to use a radiological technique to investigate whether

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the pelvis is truly wider in female than in male individuals and consequently disproportionately affects patellar tracking in the former.

2. Materials and methods

One hundred consecutive adult patients (50 men and 50 women) — (18–30 years [mean, 25 years]) examined from January 2001 to September 2011 were included in this study. All of whom had been admitted for treatment of unilateral lower extremity injury, e. i. unilateral nonunion or malunion (angular or rotational deformity or shortening) of the femur or tibia. All patients could ambulate with or without aids. All patients had been grossly healthy before these injuries, and no lower extremity abnormalities were noted. The exclusion criteria were any congenital or developmental abnormality and any metabolic bone disease that might have affected the normal growth of the pelvis and lower extremity.

Radiographs of the injury and a full-length standing scanogram (FLSS) X-ray were obtained (Fig. 1). No computed tomography (CT) scan was taken.

All FLSS images were stored using picture archiving and communication systems software (PACS; GE Healthcare, Waukesha, WI, USA) [12]. Data from the intact lower extremities were selected for analysis.

3. Data taken from the FLSS

PW (pelvic width) represented by the distance between centers of the bilateral femoral heads (Figs. 1 and 2).

FL (femur length): the length from the center of the femoral head to the center of the tibial articular surface.

TL (tibial length): the length from the center of the tibial articular surface to the center of talar articular surface.

LE-L (lower extremity length): the sum of the femoral and tibial lengths.

PW-NF (pelvic width normalized to the femur length): the pelvic width divided by the femur length (PW/FL).

PW-NL (pelvic width normalized to the lower extremity length): the pelvic width divided by the lower extremity length (PW/LE-L).

F-MA (femoral mechanical axis): a line from the center of the femoral head to the center of the tibial articular surface.

T-MA (tibial mechanical axis): a line from the center of the tibial articular surface to the center of the talar articular surface.

F-AA (femoral anatomic axis): a line connecting the centers of the upper third and lower third of the femoral shaft.

A-FAA (angle between femoral mechanical and anatomic axes): the angle of intersection between F-MA and F-AA.

DMA-K (deformed mechanical axis of the knee): the angle of intersection between F-MA and T-MA.

DAA-K (deformed anatomic angle of the knee): the angle of intersection between F-AA and T-MA.

4. Statistical analysis

Values were compared between genders using the unpaired Student’s t-test performed with Microsoft Office Excel 2010 (Microsoft Corporation, Taipei, Taiwan). A P-value of <0.05 was considered indicative of statistical significance. The degree of relationship between two parameters was evaluated using the Pearson product-moment correlation coefficient calculated with Microsoft Office Excel 2010.

5. Results

Data are summarized in Table 1.

No significant difference was found in comparison of the pelvic width (PW), mean angle between the femoral mechanical and anatomic axes (A-FAA), deformed mechanical angle of the knee (DMA-K), and deformed anatomic angle of the knee (DAA-K). The P-value was 0.74, 0.41, 0.40, and 0.34, respectively.

Significant difference was found in comparison of the femur length (FL), tibial length (TL), lower extremity length (LE-L), pelvic width normalized to the femur length (PW-NF), and pelvic width normalized to the lower extremity length (PW-NL). All comparisons were P = 0.001.

Among all 100 patients, the Pearson correlation coefficient between PW and FL was 0.34 and the correlation coefficient between PW and LE-L was 0.31. Among the 50 male patients, the coefficients were 0.44 and 0.35, respectively. Among the 50 female patients, the coefficients were 0.57 and 0.57, respectively.

Among all 100 patients, the Pearson correlation coefficient between DMA-K and DAA-K was 0.89. The value was 0.92 among the 50 male patients and 0.87 among the 50 female patients.

Among all 100 patients, the Pearson correlation coefficients between DMA-K and PW, PW-NF, and PW-NL were −0.06, −0.03, −0.17, respectively. Among the 50 male patients, the coefficients were 0.12, −0.02, and −0.29, respectively. Among the 50 female patients, the coefficients were −0.27, −0.21, and −0.19, respectively.

6. Discussion

It is difficult to persuade healthy young volunteers to undergo FLSS for pure research use, when a large sample population is needed. Therefore, FLSS images were used from patients with various disorders. All of the patients included in this study were between 18 and 30 years of age. This allowed us to disregard the possibility that degenerative changes in the hip and knee joints might affect the axis of the lower extremity. All of the patients had had intact motor function in both lower extremities prior to the unilateral lower extremity injury. The injury had occurred within three years before FLSS imaging and the contralateral lower extremity could be assumed to have been minimally affected. Therefore, all...
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Table 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Total patients (n = 100)</th>
<th>Male patients (n = 50)</th>
<th>Female patients (n = 50)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PW (cm)</td>
<td>18.1</td>
<td>18.1</td>
<td>18.2</td>
<td>0.74</td>
</tr>
<tr>
<td>FL (cm)</td>
<td>43.4</td>
<td>45.5</td>
<td>41.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TL (cm)</td>
<td>35.7</td>
<td>37.6</td>
<td>33.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LE-L (cm)</td>
<td>79.1</td>
<td>83.1</td>
<td>75.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PW-NF (cm)</td>
<td>0.42</td>
<td>0.40</td>
<td>0.44</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PW-NL (cm)</td>
<td>0.23</td>
<td>0.22</td>
<td>0.24</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>A-FMA</td>
<td>6.3°</td>
<td>6.2°</td>
<td>6.4°</td>
<td>0.41</td>
</tr>
<tr>
<td>DMA-K</td>
<td>Valgus 4.3°</td>
<td>Valgus 3.9°</td>
<td>Valgus 4.5°</td>
<td>0.34</td>
</tr>
</tbody>
</table>

PW: pelvic width; FL: femur length; TL: tibia length; LE-L: lower extremity length; PW-NF: pelvic width normalized to the femur length; PW-NL: pelvic width normalized to the lower extremity length; A-FMA: angle between the femoral mechanical and anatomic axes; DMA-K: deformed mechanical angle of the knee; DAA-K: deformed anatomic angle of the knee.

* Statistical significance.
patients were suitable for study of the pelvis and the uninjured lower extremity.

The Q-angle is defined with the upper arm originating from the ASIS. From the anatomic perspective, this arm lies between the vector of the rectus femoris (originating from the anterior inferior iliac spine [AIIS]) and that of three other muscles (the vastus medialis, vastus intermedius, and vastus lateralis, all originating from the upper femur) [6, 10, 11]. The pelvis is supposed to be wider and the Q-angle larger in female than in male individuals [7], which is assumed to explain the greater frequency of patellar mal-tracking among female patients. However, Grelsamer et al. report no difference in the PW and a mild difference of 2.3° of the Q-angle between male and female according to their clinical measurements [8]. The current study is a radiographic comparison and finds no difference in pelvic width between male and female. The significantly shorter length of the lower extremity among female individuals (P < 0.001) may produce an optical illusion of a wider pelvis. Grelsamer et al. demonstrate a similar Q-angle in case of equal height among male and female [8].

The current study defines the pelvic width (PW) as the distance between the centers of the bilateral femoral heads. In normal anatomy, the AIIS is located at the ilium, closely proximal to the lateral wall of the acetabulum [13, 14]. Therefore, the orientation of the rectus femoris should be similar between male and female if the PW is similar. In our series, the A-FMA (angle between the femoral mechanical and anatomic axes) is similar between male and female (6.2° versus 6.4°, P = 0.41). Therefore, the orientation of the other three components of the quadriceps femoris should also be similar. Combining the above measurements reveals that the PW with Q-angle do not definitely differ between male and female. This finding is partially consistent with the report by Grelsamer et al. about similar PW [8]. Furthermore, the A-FMA measured in the current study is very close to that reported in the literature (5°–7°) [15–17].

Three groups of critical predisposing factors have been proposed to affect patellar tracking [3, 4]. The first is imbalance of peripatellar soft tissue tension, which includes tight lateral patellar soft tissues or weakening of the vastus medialis [18–20]. The second is bony anomalies, comprising trochlear or patellar dysplasia and patellar alta [21–24]. The third is abnormal lower extremity alignment, consisting of valgus knee, femoral anteverision, and external tibial torsion [25–27]. The current study suggests that these predisposing factors may be more important to patellar tracking than the pelvic width and Q-angle. For Wu et al., release of a snapping hip in the hip region could allow a patellar mal-tracking to return to a normal location [28], indicating the importance of peripatellar soft tissue tension. Dejour et al. emphasized trochlear dysplasia as the main determinant of patellar mal-tracking [29].

In the current study, the DMA-K (deformed mechanical angle of the knee) and DAA-K (deformed anatomic angle of the knee) do not differ between male and female. Moreover, these angles correlate highly with one another (correlation coefficient, 0.89). Both parameters indicate that the coronal alignment is similar between male and female. Therefore, in the normal population, both genders exhibit similar coronal alignment. The disproportionate number of female patients who develop varus knee after the age of 60 years and require surgery is more likely caused by acquired factors [30–32].

The Q-angle may be evaluated with the knee in full extension with the patient lying down or standing [7, 8, 33, 34]. The landmarks (ASIS, patellar center, and tibial tubercle) may be obscured and difficult to localize in patients with marked obesity. It is also unclear whether the center of the patella is located at the center of the knee on anteroposterior radiographs with the knee in full extension. Therefore, neither clinical nor radiological measurement of the magnitude of the Q-angle is always reliable [8], making the normal Q-angle values reported in the literature (<14° in female individuals and <14° in male individuals) somewhat questionable [6, 7, 35–37]. The current study suggests that reevaluation of the data in the literature may be imperative.

The literature states that the DMA-K should ideally be neutral (e.g., 0° varus) [38, 39]. The value in the current study is 2.1° varus without difference between male and female. Therefore, the current study confirms that a mechanical axis of the lower extremity of 0° varus in normal young individuals is believable and applicable.

The current study does not intend to rule out an effect of the Q-angle on patellar tracking. After all, a very large Q-angle due to a very wide pelvis or severe valgus knee is uncommon among the normal population [8, 40]. A lateral traction force could theoretically contribute to lateral patellar displacement [6, 8]. The findings of the current study show that the Q-angle is not ordinarily wider in female than in male individuals. Why, then, are patients with patellar mal-tracking disproportionately female [33]? Grelsamer et al. using a trigonometric technique demonstrate only 2.3° difference of the Q-angle between male and female [8]. In the current study, the upper arm length differed by only 10.2% between the sexes, and it is questionable whether such a small difference could truly induce patellar mal-tracking [7]. Therefore, some other factors may be more important causes of patellar mal-tracking [28, 29].

The limitations of the study include the use of the distance between the centers of the bilateral femoral heads to represent the PW. The PW measured from the ASIS is very difficult to clinically determine because of the thickness of the overlying soft tissues. Moreover, body size and body height may affect the value [8]. In a FLSS image, the ASIS is not always identifiable on both sides and the shape may be asymmetrical due to technical issues during image acquisition.

This study finds no definite PW difference between male and female, making the effect of the Q-angle questionable [7]. Because this represents a revolutionary change from traditional concepts, a larger data set may be necessary to validate these findings. The quantitative relationship between the PW and the Q-angle is another uncertainty. The current study confirms PW can be determined from a FLSS image. However, it remains unclear whether the Q-angle can be determined from a FLSS image. Therefore, this study used PW to investigate the relationship between the pelvis and the lower extremity. Finally, some orthopedists doubt the validity of the use of FLSS images for this type of study [41]. Nevertheless, FLSS currently remains widely used and is considered as the most reliable tool for study of the lower extremity [42, 43]. The use of FLSS images in this study is thus reasonable.

In conclusion, pelvic width does not differ between male and female. The pelvis may be relatively wider in women due to their typically shorter stature. However, this difference does not increase the Q-angle or affect patellar tracking. The disproportionately number of female individuals who develop patellar mal-tracking may be due to other more critical predisposing factors.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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