

## Ultrasound Measurements of Patellar Tendon Differences Depending on Previous Training

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### ABSTRACT

**AIM:** to evaluate if the lack of experience in musculoskeletal ultrasonography generates measuring errors based on patellar tendon measurements. Ultrasound is recognized as an outstanding tool

in musculoskeletal pathology diagnosis, despite being physician-dependent in knowledge as much as in experience.

**METHODS:** Six donated knees (ages 58-71 years old) were chosen for the present study. Four observers performed the measurements, which were length, thickness and width of the patellar tendon; an expert in musculoskeletal ultrasonography (gold standard), an obstetric sonographer, an orthopedic surgeon and a third-year medical student. An external participant collected all data and analyzed results.

**RESULTS:** regarding length, an 8% mean decrease with respect to the gold standard's mean was observed. With respect to the width, the evaluators showed lower measurements with respect to the gold standard, (less than 5% difference) with no constant systematic error, although a trend of a proportional systematic error was observed (0.59). Third, measurements from observers were an 8% higher than the gold standard's regarding thickness. The evaluator that most approximated measurements to the gold standard performed was the obstetric sonographer.

**CONCLUSION:** The present paper represents an approach to learning systems in musculoskeletal ultrasound and counseling courses to focus on ultrasound technique knowledge rather than anatomical domains.

**Key words:** Musculoskeletal ultrasound; Patellar tendon; Training; Learning systems; Gold standard

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### INTRODUCTION

Ultrasound is recognized as an outstanding tool in musculoskeletal pathology diagnosis, despite being physician-dependent in knowl-

edge as much as in experience<sup>[1]</sup>. Patellar tendon pathology is especially frequent within several sports practice, such as athletics or soccer<sup>[2]</sup>. Previous studies show a frequency of appearance of 0.12 lesions per 1000 hours of sports, being 1.5% of all lesions in sports such as soccer<sup>[2]</sup>.

Patellar tendon tendinopathies regarding donor site in anterior cruciate ligament reconstructions have been reported reaching high percentages, ranging from 4 to 60%<sup>[3]</sup>. Moreover, the gap left behind during this surgery has been defined as cause of pain in the donor site for months<sup>[4]</sup>.

A correct diagnosis and treatment require evaluating systems that are reproducible such as the ultrasonography, which Fornage defended back in 1984 as being useful in tendon pathologies including patellar tendon<sup>[5]</sup>. This reproducibility has been endorsed by series such as O'Connor's<sup>[6]</sup> or more recent studies<sup>[4]</sup>.

Ultrasonography is used as a diagnosis tool and several authors support their use even in less-trained physicians, describing shorter learning curves<sup>[7-9]</sup>.

The aim of the present work was to evaluate if the lack of experience in musculoskeletal ultrasonography generates measuring errors based on patellar tendon measurements. The present hypothesis is that the lack of experience in musculoskeletal ultrasonography generates measurement errors regarding patellar tendon.

## METHODS

Six donated knees belonging to the Anatomy Department of our Medicine School were chosen for the present study. Ages ranged from 58 to 71 years old and only knees with no previous knee surgery were selected.

Six knees belonging to the service of donors' bodies 'Laboratory of Surgical and Functional Anatomy' of the International University of Catalonia were used for the present study. Knees were sectioned lower limbs and were cryopreserved instead of embalmed. The range of age of the donors' knees used for this research was 58 to 71 years old.

Cause of death was cirrhosis, renal failure, coronary artery disease, cardiac arrest, metastatic adenocarcinoma and pneumonia. An exclusion criterion for knees was previous knee surgery. The samples were stored frozen at -20°C up to 12 hours before the test. The limbs were removed and placed in a refrigerator at 4°C for 10 hours and then completely thawed in the laboratory at 18°C.

Specimens were placed in a 30°-flexion position over a support. The University's Ethical Committee approved the present study. Different measurements were performed by four people with the ultrasound equipment Aloka SSD- Prosound C37 C3cv Tokyo (Japan) with a linear multi-frequency linear transducer that has a frequency range of 7.27 to 11.43 MHz. Registered measurements were length, thickness and width of the patellar tendon. The four evaluators were an expert in musculoskeletal ultrasonography (MR), an obstetric sonographer with no experience in musculoskeletal ultrasonography (JLH), an orthopedic surgeon expert in knee surgery and especially in patellar tendon but with no ultrasound experience (RS), and a third-year medical student with no surgical or ultrasound experience. The musculoskeletal sonographer gave a 30-min explanation of how to measure patellar tendon to the remaining evaluators prior to measurements.

The four assistants separately performed measurements, and once they had performed and recorded their measurements, they could stay in the room to observe the other participants. The measurements were systematically performed in length, from the patellar tip to its inser-

tion in the tibia; thickness and width, which were measured at a 15-mm distance from the patellar tip. These three measurements were directly performed and repeated two more times. An external participant (OA) collected all data and analyzed results. The used measurements were a mean of the three measurements in length, thickness and width of the patellar tendon.

The musculoskeletal sonographer performed the measurements first of all and assisted the remaining participants within technical doubts, without conditioning their measurements.

## Statistical analysis

Each participant's results have been compared to the results obtained by the musculoskeletal ultrasound expert, considering this as gold standard of the measurements. The ultrasound expert was chosen as gold standard as he was the most experienced in this type of measurements, with an over 20-year experience in ultrasonography performing over 5,000 musculoskeletal ultrasound per year. Therefore, linear regressions estimates from the observers in comparison to the gold standard's have been performed, working out type 1 beta error or proportional systematic error, type 0 beta or constant systematic error and Total Deviation Index (TDI) indicating below what value are 90% of the differences.

Furthermore, a factor analysis was performed, aiming to visualize the relative positions of the four participants taking into consideration all measurements (12 variables measured). This factor analysis allows us to evaluate more accurately all aspects within measurements. Factor extraction was carried out with the principal component analysis method without performing any axis factoring, as the purpose was not to explain but to visualize the relative position of all four explorers.

A cluster analysis was used to quantify the relative distances between these four participants and, as abovementioned with the factor analysis, was performed with all measurements. Euclidean distance and Ward's criterion was used for this analysis in order to evaluate distances between individual and group or between groups.

## RESULTS

Mean results from the three measurements of the patellar tendon, length, thickness and width, from all four observers, are shown in Table 1 as descriptive data.

Comparison between the three observers regarding the observer 1 or gold standard is shown in Table 2.

Regarding the measurement length, an 8% mean decrease with respect to the gold standard's mean was observed, specifically regarding Observer 2 (obstetrics ultrasound), who individually showed a difference of 20% decrease with respect to the gold standard (Tables 1 and 3). Mean differences do not include 0 in length measurements and would therefore be categorized as constant systematic error or type 0 beta.

Regarding variable width, the evaluators showed lower measurements with respect to the gold standard, being less than 5% difference observed. When performing the regression analysis it can be statistically observed that there was no constant systematic error, although a trend of a proportional systematic error was observed (0.59), is that measurements tend to be 59% of the gold standard for variable width.

Thirdly, regarding the variable thickness, measurements from observers were an 8% higher than the measurements by the gold standard, although the proportional systematic error was 0.85, meaning that all measurements were 85% of gold standard. TDI showed an error margin of 1.7 mm within this measurement.

As can be observed, the evaluator that most approximated measurements to the gold standard performed was Observer 2. On the other hand, the observers that most similar measurements performed between them were Observers 3 and 4.

The cluster analysis confirms, from a different analysis perspective point of view, the results observed with the factor analysis. The cluster analysis provided the dendrogram observed in Figure 1.

When both analyses were used (Factor and Cluster), we can observe that Observer 1 (gold standard) has more similar measurements with Observer 2, taking into account all measurements (12 variables).

## DISCUSSION

Data analysis allows us to observe a clear correlation between the observers within the thickness measurement of the patellar tendon, where the statistical error margin can be placed at 90% confidence interval in less than 1.7 mm.

The main statistical difference showing a constant systematic error is for the length measurement, especially in Observer 2 (obstetrics ultrasound), constantly measuring significant lower measurements than the gold standard. This constant error could be explained by two possible causes. First of all is the less acknowledgment of the anatomical margins by the obstetrics ultrasound expert, and secondly, by the difficulty that entails this measurement in particular. Given the tendon's length, it is possible not to take the measurement through the shortest measurement of the transducer and thus performing a less precise measurement.

This same cause could explain the trend within width measurements where we observed a 59% decrease of all estimations with respect to the gold standard. This error with a trend to be a proportional systematic error is increased by Observer 3 (orthopedic surgeon), who unknowing the ultrasound technique performs a proportional error to the measurements magnitude, and not a constant error such as in Observer's 2 case.

This information could make us think that the constant systematic error from the obstetrics ultrasound expert is favored by a less acknowledgement of the anatomy, whereas the proportional systematic error from the orthopedic surgeon could be favored by a lesser acknowledgement of the ultrasound technique.

However, this error is predictably improved with a relatively fast learning curve, where both anatomic knowledge and ultrasound tech-

nique can be improved. In this line, the study by Kim *et al* regarding learning curve in anesthesia with ultrasound-guided nerve block affirmed that students with only 5 trials could achieve a high rate of successes in ultrasound-guided nerve block<sup>[8]</sup>.

In the same line, García de Casasola *et al* observed that teaching programs of approximately 15 hours to students regarding abdomen ultrasonography could achieve success rates of over 90% for abdominal structures identification<sup>[7]</sup>. Even in one-week courses students could reach comparable rates to the experts<sup>[10]</sup>.

**Table 1** Observer 1 is the gold standard (musculoskeletal ultrasound expert), observer 2 is the obstetrics ultrasound expert, 3 is the orthopedic surgeon and 4 is the medical student. All measurements are expressed in mm.

|           | Observer | Mean   | SD    | Min    | Max    |
|-----------|----------|--------|-------|--------|--------|
| Length    | 1        | 318.33 | 35.08 | 287.00 | 375.00 |
|           | 2        | 253.83 | 52.86 | 182.00 | 313.00 |
|           | 3        | 303.67 | 64.25 | 231.00 | 382.00 |
|           | 4        | 320.00 | 34.38 | 257.00 | 355.00 |
|           | (2,3,4)  | 292.50 | 56.77 | 182.00 | 382.00 |
| Width     | 1        | 339.00 | 28.28 | 298.00 | 379.00 |
|           | 2        | 326.50 | 40.37 | 268.00 | 364.00 |
|           | 3        | 318.00 | 32.25 | 271.00 | 365.00 |
|           | 4        | 324.67 | 33.61 | 260.00 | 354.00 |
|           | (2,3,4)  | 323.06 | 33.64 | 260.00 | 365.00 |
| Thickness | 1        | 41.83  | 15.43 | 26.00  | 64.00  |
|           | 2        | 42.00  | 15.82 | 25.00  | 65.00  |
|           | 3        | 47.67  | 13.66 | 30.00  | 66.00  |
|           | 4        | 46.50  | 13.46 | 35.00  | 67.00  |
|           | (2,3,4)  | 45.39  | 13.72 | 25.00  | 67.00  |

SD: standard deviation. Min: minimum. Max: maximum.

**Table 2** Comparison between the observers in comparison to the gold standard.

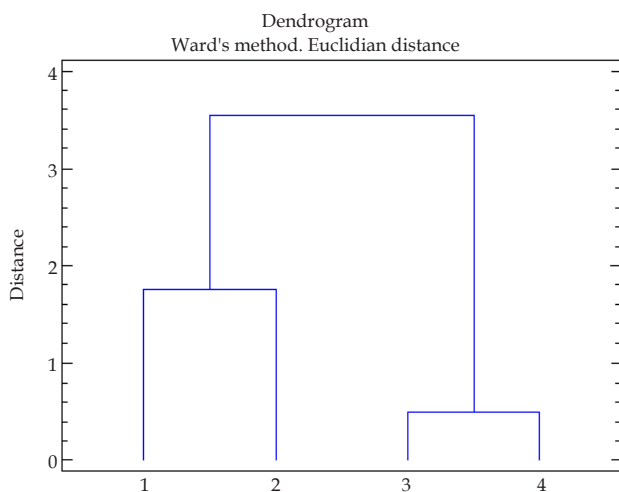
|           | Beta0  | Beta1 | 95% CI |      | Mean Dif. | 95% CI |       | SD Dif. | UPPER TDI 90% |
|-----------|--------|-------|--------|------|-----------|--------|-------|---------|---------------|
| Length    | -52.49 | 1.08  | 0.37   | 1.79 | -25.83    | -48.49 | -3.17 | 45.57   | 119.13        |
| Width     | 121.73 | 0.59  | 0.001  | 1.19 | -15.94    | -32.09 | 0.21  | 32.47   | 83.23         |
| Thickness | 9.89   | 0.85  | 0.63   | 1.07 | 3.56      | 0.26   | 6.86  | 6.63    | 17.19         |

Types 0 and 1 beta errors, 95% confidence intervals, mean differences with its confidence interval and standard deviation (SD), and finally Total Deviation Index (TDI) in its upper limit.

**Table 3** Measurements from the observers with respect to the gold standard.

|           | Observer         | Mean   | SD    | Min     | Max    | % regarding GS |
|-----------|------------------|--------|-------|---------|--------|----------------|
| Length    | Dif. (2-1)       | -64.50 | 35.59 | -112.00 | -32.00 | 20             |
|           | Dif. (3-1)       | -14.67 | 37.53 | -69.00  | 34.00  | 4              |
|           | Dif. (4-1)       | 1.67   | 33.46 | -43.00  | 38.00  | 0.5            |
|           | Dif. ((2,3,4)-1) | -25.83 | 44.21 | -112.00 | 38.00  | 8              |
| Width     | Dif. (2-1)       | -12.50 | 33.98 | -52.00  | 39.00  | 3.6            |
|           | Dif. (3-1)       | -21.00 | 28.77 | -67.00  | 15.00  | 6.1            |
|           | Dif. (4-1)       | -14.33 | 36.97 | -65.00  | 26.00  | 4.2            |
|           | Dif. ((2,3,4)-1) | -15.94 | 31.61 | -67.00  | 39.00  | 4.7            |
| Thickness | Dif. (2-1)       | 0.17   | 4.12  | -5.00   | 7.00   | 0.4            |
|           | Dif. (3-1)       | 5.83   | 8.23  | -3.00   | 21.00  | 14             |
|           | Dif. (4-1)       | 4.67   | 5.96  | -3.00   | 14.00  | 11             |
|           | Dif. ((2,3,4)-1) | 3.56   | 6.46  | -5.00   | 21.00  | 8.5            |

SD: standard deviation. GS: gold standard.



**Figure 1** Dendrogram showing how the observers 3 and 4 are those found at a shorter distance between them as to the results referes, whereas 1 and 2 are closer between them with respect to the results.

The medical student globally shows mean differences from the gold standard of 5.2%, remaining the observer that better similarity rates obtained regarding the gold standard (8% and 8.03% for Observer 2 and 3, respectively). These differences indicate that an increased knowledge does not provide an advantage in this assessment but favors a bias by the knowledge of both specialized physicians.

Studies by Ozçakar *et al* show how novice sonographers merely taking a course with 2 trials is enough to obtain correct measurements of the Achilles tendon and the supervision of an experienced sonographer is crucial for precision rates<sup>[1,11]</sup>.

Despite the ease of learning with such programs, different studies show a learning curve of approximately 100 measurements, such as the studies on injuries of the rotator cuff tendons of the shoulder<sup>[12-14]</sup>.

In contrast, other studies show excessive differences between expert sonographers in the calculation of cross sectional area in patellar tendon, which gives strength to the concept of the importance of sonographer dependent effect of ultrasound<sup>[15]</sup>.

The cluster analysis is a technique that evaluates relative positions of some points, observers in the present study, within a space of as many dimensions as variables are in the study (the above measures in the present study). Thus we can assess relative positions, distances between profiles. This analysis, graphically described by the dendrogram (Figure 1), provides the relative proximity of the observers through a proximity map. In the present work, Observers 3 and 4 were the first to be associated, thus being the most similar profiles. These were the orthopedic surgeon and the medical student, following the above-mentioned where it seems that the technical domain is more important than the anatomy's domain.

The following association is between Observers 1 and 2, i.e. the expert sonographers, in musculoskeletal and obstetrics respectively. As we can observe, two clear profiles were generated; one made up from both sonographers and a second one with the surgeon and student.

These data support a tendency to value the greater weight of the technical domain ultrasound regarding the anatomical domain. As the aforementioned studies, the different observers may be able to resemble with short-duration courses<sup>[1,7,8]</sup>.

The present paper represents an approach to learning systems in musculoskeletal ultrasound, delving into statistical analysis and in the present case counseling courses to focus on ultrasound technique knowledge rather than anatomical domains.

The research lines that are created as a result of the present study would be the evaluation of the rate of learning for different specialists, reaching to hypothesize different rates for different specialists.

Furthermore, from the curiosity of the error trends in both specialties (obstetric and orthopedic surgeon) in different errors, explicable by their lack of experience both in the anatomical area and in the image technique, it is important that the studies show a rapid adaptation of less-experienced personal, obtaining results that quickly approximate to the gold standard, in small-duration courses.

## INFORMED CONSENT

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

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