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*original research*

# Sex Differences and Representative Values for 6 Lower Extremity Alignment Measures

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***Context:*** A discrepancy in anterior cruciate ligament (ACL) injury rates exists between men and women. Structural differences between the sexes often are implicated as a factor in this discrepancy. Researchers anecdotally assume that men and women tend to display different normative values for certain lower extremity alignments, but published information about these values is limited.

***Objective:*** To evaluate the effect of sex on 6 measures of lower extremity alignment and to report representative values of these measures from a sample of active adults and elite athletes.

***Design:*** Descriptive cohort design.

***Setting:*** University research laboratory.

***Patients or Other Participants:*** A total of 118 healthy adults (57 men: age = 21.1 ± 3.0 years, height = 179.1 ± 7.3 cm, mass = 79.8 ± 13.0 kg; 61 women: age = 20.0 ± 1.6 years, height = 167.7 ± 6.7 cm, mass = 62.7 ± 5.5 kg) volunteered.

***Main Outcome Measure(s):*** Six common measures of lower extremity posture (navicular drop, tibial varum, quadriceps angle, genu recurvatum, anterior pelvic tilt, femoral anteversion) were collected using established methods. One measurement was taken for each participant for each lower extremity alignment. We measured the right lower extremity only.

***Results:*** Compared with men, women demonstrated larger quadriceps angles, more genu recurvatum, greater anterior pelvic tilt, and more femoral anteversion.

***Conclusions:*** We observed differences between men and women for 4 of the 6 lower extremity alignments that we measured. Future researchers should focus on identifying how sex and skeletal alignment affect biomechanical performance of functional tasks and what these differences specifically mean regarding the discrepancy in anterior cruciate ligament injury rates between the sexes.

***Key Words:*** malalignment, femoral anteversion, genu recurvatum, anterior pelvic tilt, quadriceps angle

**Key Points**

- Women demonstrated larger quadriceps angles, more genu recurvatum, greater anterior pelvic tilt, and more femoral anteversion compared with men.
- We found no sex difference for navicular drop or tibial varum.
- Because the sex differences for 4 measures of alignment were small, we cannot decisively conclude that alignment contributes to lower extremity injury.
- Further investigation is needed to determine how lower extremity alignment affects the rate of lower extremity injuries.

A discrepancy in anterior cruciate ligament (ACL) injury rates exists between men and women.[1–6] Researchers have examined several intrinsic and extrinsic factors to explain this discrepancy; however, no specific sex difference has been identified to explain the greater incidence of ACL injuries in women.[5,7] One intrinsic factor with clinically observable differences between men and women is lower extremity alignment.

Considerable discussion has focused on how lower extremity alignments may be related to sex and injury.[5,7,8] It is commonly accepted that men and women tend to display different normative values for certain lower extremity alignments. For example, investigators believe that women tend to demonstrate larger quadriceps angles (Q angles),[5,9,10] more genu recurvatum,[10] greater anterior pelvic tilt,[10] and more femoral anteversion[10] compared with men. Although it is typically believed that men and women demonstrate these alignment differences, limited published data are available to substantiate these claims and to show whether these differences are statistically significant.

Authors of prospective studies,[11] retrospective studies,[5,7,8,12,13] recommendation reports,[14–16] and systematic reviews[4,17–20] have examined lower extremity alignments. In each study, certain factors were reported to potentially increase the risk of either acute or chronic injuries; across studies, however, the authors did not agree about whether a particular alignment was actually a risk factor. Lower extremity alignments are often cited as risk factors for injury, but how they may affect injury rates and patterns is unclear.[17] In particular, the lower extremity alignments of navicular drop, tibial varum, Q angle, genu recurvatum, anterior pelvic tilt, and femoral anteversion are often implicated in both acute and chronic injuries and are commonly measured as part of a lower-quarter screening.[12,15,21] Clinicians often attempt to alter these alignments when they are considered excessive (malalignment). A visual inspection may reveal an obvious malalignment, but the lack of normative data in the literature regarding these measures makes it difficult to define a "normal" range.

With the exception of studies on Q angle, only 1 study that was specifically designed to describe sex differences between men and women for these measures has been published.[10] Without information on normative values, objectively determining who falls within and outside normal limits is impossible. To truly establish normative values, a very large single sample or multiple studies using

**Figure 1. Measurement of navicular drop in centimeters. The change in height of the navicular tuberosity from unweighted to weighted position.**

similar methods must be performed to verify the generalizability of these norms to the population of young, active adults.

The purpose of our study was to evaluate the effect of sex on 6 alignment measures of the lower extremity from a sample of active adults and elite collegiate athletes aged 18 to 32 years and to develop representative values for these measures. Based on anecdotal and published evidence, we hypothesized that certain lower extremity alignments in our study would differ between men and women. Specifically, we hypothesized that women would demonstrate greater Q angle, genu recurvatum, pelvic tilt, and femoral anteversion compared with men.

## METHODS

### Participants

A total of 118 active adults (n = 49) and collegiate athletes (n = 69) aged 18 to 32 years were recruited from 1 central Pennsylvania and 2 central Virginia academic institutions to participate in this study (57 men: age = 21.1 ± 3.0 years, height = 179.1 ± 7.3 cm, mass = 79.8 ± 13.0 kg; 61 women: age = 20.0 ± 1.6 years, height = 167.7 ± 6.7 cm, mass = 62.7 ± 5.5 kg). Collegiate athletes were active members of National Collegiate Athletic Association Division I varsity sports teams. Active adults were included if they participated in physical activity at least 30 minutes, 3 times per week, and had a history of participation in competitive sports at the scholastic or collegiate level. Exclusion criteria included orthopaedic injury to the back or lower extremity within 1 month before testing and a history of lower extremity surgical realignment. Participants provided informed consent, and the study was approved by the institutional review boards of the 3 institutions at which this study was conducted.

### Lower Extremity Alignment Data Collection

The 6 measures of lower extremity alignment (navicular drop, tibial varum, Q angle, genu recurvatum, anterior pelvic tilt, femoral anteversion) were collected by a certified athletic trainer (J.M.M.) with 6 years of experience who regularly and consistently used these measures of static alignment in clinical and research practice. The investigator was not blinded to the purposes of this study. All measures were collected using previously established methods.[22–28] For testing, participants were clothed in shorts that allowed exposure of all bony landmarks needed for testing and were barefoot. For all bony landmarks, the central point was palpated and marked with a fine-point marker. To minimize error from skin movement, all landmarks were located with the participant in the position for measurement. For each participant, a single measurement was taken for each lower extremity alignment. Because it has been reported that side-by-side differences do not exist,[10] statistical analysis of these measures was performed for each participant's right lower extremity only.

**Navicular Drop.** Navicular drop was determined as the difference in height of the navicular tuberosity from the floor during sitting and standing (Figure 1). An initial measurement was taken with the participant seated, both feet on the floor, unweighted, and in subtalar neutral. The unweighted navicular position was the distance from the floor to the marked point on the navicular tuberosity. The participant then stood and was instructed to keep equal pressure on both feet while the measurement was repeated. Navicular drop was calculated as the difference between the 2 measurements. This method recently has been reported to have an intraclass correlation coefficient (ICC) of 0.91 to 0.97 for intratester reliability.[21]

**Tibial Varum.** This measure was performed with the participant in a weight-bearing, double-limb stance. Each participant was instructed to maintain equal weight on each foot. The posterior aspect of the shank was bisected at two-thirds of the length of the tibia from the medial joint line of the knee to the medial malleolus. A second point was marked at the point bisecting the widest point from the medial malleolus to the lateral malleolus. Tibial varum is the angle at which the distal third of the tibia diverges from the perpendicular as measured with a standard goniometer[23] (Figure 2). This measurement was taken without controlling for subtalar neutral. This method has been reported to have an ICC of 0.83 for intratester reliability with sufficient practice by the clinician.[29]

**Quadriceps Angle.** Quadriceps angle was determined with the participant standing (a functional position) and was measured as the acute angle created by the line of pull of the quadriceps from the anterior-superior iliac spine to the insertion on the central point of the patella and from the central point of the patella to the tibial tuberosity in the frontal plane (Figure 3). To standardize the measure among participants, each participant stood so that the feet were positioned with the toes pointed straight forward. Special care was taken to ensure that the participant's quadriceps were in a relaxed position, because contraction of the quadriceps would affect the position of the patella. This method of assessing Q angle has been reported to have an ICC of 0.89 to 0.98 for intratester reliability.[21]

**Genu Recurvatum.** While standing, each participant was instructed to extend the knee as fully as possible. In some cases, participants reached hyperextension. Genu recurvatum (Figure 4) was measured as the angle created in the sagittal plane by the femur (from the central point of the greater trochanter to the central point of the lateral

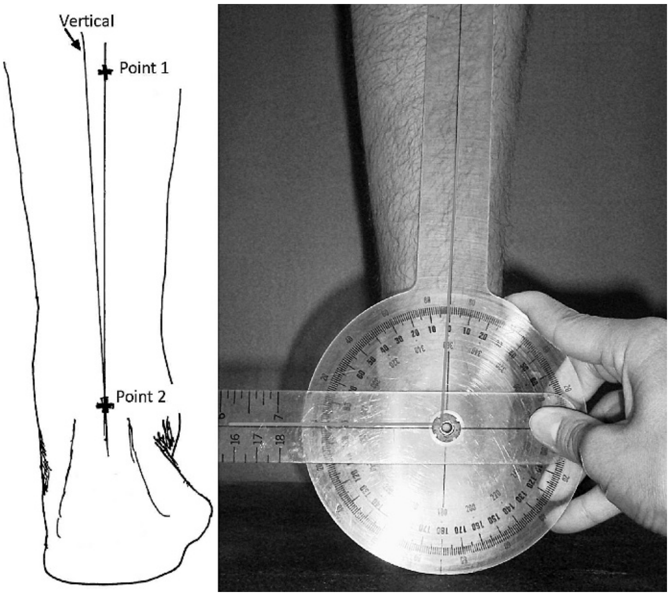


**Figure 2. Measurement of tibial varum in degrees. Lateral divergence of the tibia from an imaginary vertical line from distal to proximal in the frontal plane.**

epicondyle) and the shank (from the most lateral point of the proximal joint line of the knee through the lateral malleolus). This method has been reported to have an ICC of 0.88 to 0.97 for intrarater reliability.[21,26]

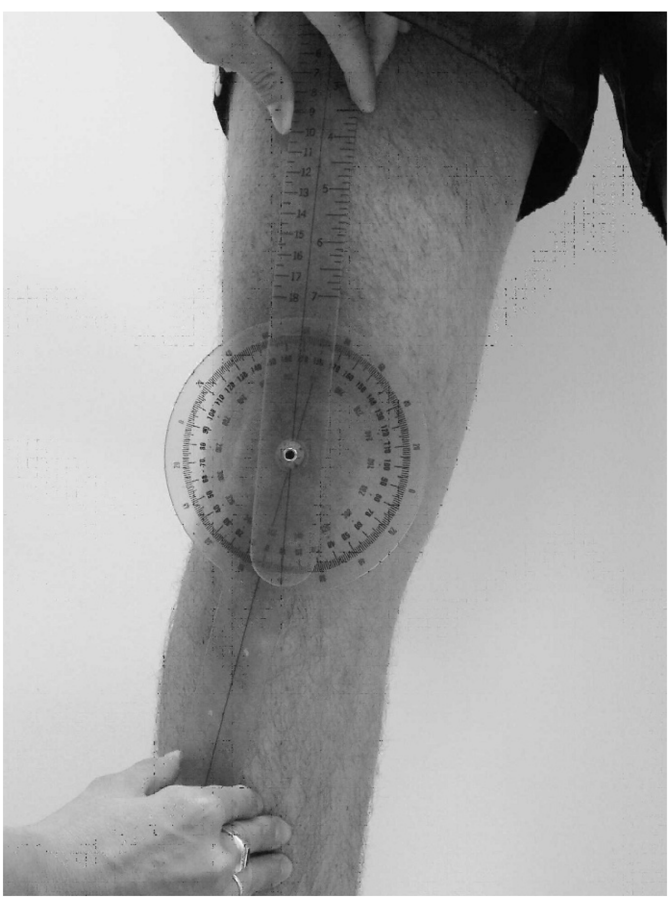

**Figure 3. Measurement of quadriceps angle in degrees. Angle of pull of the quadriceps in the frontal plane.**

**Figure 4. Measurement of genu recurvatum in degrees. Hyperextension of the knee greater than 0° in the sagittal plane.**

**Anterior Pelvic Tilt.** Anterior pelvic tilt was measured using previously described methods.[27] We used a skeletal alignment and leg-length discrepancy instrument (PALM; Performance Attainment Associates, St Paul, MN) to determine the angle created by an imaginary line from the anterior-superior iliac spine to the posterior-superior iliac spine as it diverged from the horizontal (Figure 5). Pelvic tilt was measured as the degree of anterior tilt of the pelvis in the sagittal plane. This method has been reported to have an ICC of 0.77 to 0.99 for intratester reliability.[21,27]

**Femoral Anteversion.** The measure of femoral anteversion was performed with the participant positioned prone and the knee flexed to 90°. The greater trochanter was palpated, and the femur was moved passively into internal rotation until the greater trochanter could be palpated at its most lateral position. Femoral anteversion was determined as the acute angle formed by the tibia and an imaginary vertical line (Figure 6). This technique of measuring femoral anteversion has been demonstrated to be superior to radiologic techniques for determining femoral anteversion in children having hip surgery.[28] This method has been reported to have an ICC of 0.77 to 0.97 for intratester reliability.[21]

## Statistical Analysis

A multivariate analysis of variance was performed to determine the effect of sex on the static lower extremity alignment measures for this sample. In the event of a significant general linear model, between-subjects univariate

**Figure 5. Measurement of pelvic tilt in degrees. Anterior tilt of the pelvis from an imaginary horizontal line in the sagittal plane.**

analyses of variance were performed to identify the specific effect of sex on lower extremity alignment. Means, SDs, and 95% confidence intervals (CIs) were calculated to describe representative measures and specific sex differences.

Pooled effect sizes were calculated for each alignment to evaluate the magnitude of the difference between the means by sex. Pooled effect sizes were calculated as the difference between the means divided by the pooled SDs. This calculation was used in preference to standard effect-size calculation (difference between the means divided by the SDs of the control) to account for the fact that neither group was a control group. We interpreted effect sizes that were less than 0.4 as small, 0.4 to 0.7 as moderate, and more than 0.7 as large.[30]

Coefficient of variation (CV) was calculated as the dividend of the SD of each measure divided by the mean. This calculation represents the normalized dispersion of the values for each alignment.

All statistical analyses were conducted in SPSS (version 14.0 for Windows; SPSS Inc, Chicago, IL). The $\alpha$ level was set a priori at .05. Pooled effect sizes were calculated in MATLAB (version 6.0 [R2007b]; The MathWorks, Inc, Natick, MA). One investigator (J.M.M.) wrote the code for these calculations.

## RESULTS

Results of the statistical comparison between men and women for the effect of sex on lower extremity alignment are presented in Table 1. Results of the multivariate analysis of variance revealed an effect of sex on the linear combination of all 6 lower extremity measures ($F_{5,91}$ = 15.4, Wilks $\Lambda$ = 0.479, $P < .001$). Further univariate analysis of variance revealed sex differences for 4 of the 6 measures of lower extremity alignment. Women demonstrated greater Q angle ($F_{1,91}$ = 28.5, $P < .001$), genu recurvatum ($F_{1,91}$ = 15.6, $P < .001$), anterior pelvic tilt ($F_{1,91}$ = 11.0, $P$ = .003), and femoral anteversion ($F_{1,91}$ = 25.7, $P < .001$) compared with men. We did not find a difference between the sexes for the lower extremity measures of tibial varum or navicular drop.

Complete results of effect size and 95% confidence interval (CI) calculations are provided in Table 2. Pooled effect-size calculation revealed large effect sizes for the magnitude of the difference between the means for the measures of Q angle,

**Figure 6. Measurement of femoral anteversion in degrees. Positional rotation of the femur in the transverse plane.**

**Table 1. Sex Comparisons of Lower Extremity Alignments**

| | Men | | | Women | | | Difference Between Sexes | |
|---|---|---|---|---|---|---|---|---|
| | Mean ± SD | 95% Confidence Interval | Range | Mean ± SD | 95% Confidence Interval | Range | Mean | 95% Confidence Interval |
| Navicular drop, cm | 0.9 ± 0.03 | 0.8, 1.0 | 0.4 to 1.5 | 0.8 ± 0.3 | 0.7, 0.9 | 0.1 to 1.7 | 0.1 | −0.01, 0.24 |
| Tibial varum, ° | 5.9 ± 2.8 | 5.1, 6.7 | 1.0 to 12.0 | 6.6 ± 2.5 | 6.0, 7.2 | 1.0 to 12.0 | −0.7 | −1.7, 0.3 |
| Quadriceps angle, ° | 11.5 ± 2.4 | 10.8, 12.2 | 5.0 to 16.0 | 13.9 ± 2.6[a] | 13.2, 14.6 | 11.0 to 23.0 | −2.4 | −3.3, −1.4 |
| Genu recurvatum, ° | 3.1 ± 2.5 | 2.4, 3.8 | 0.0 to 10.0 | 5.7 ± 3.2[a] | 4.9, 6.5 | −5.0 to 12.0 | −2.5 | −3.8, −1.3 |
| Anterior pelvic tilt, ° | 9.6 ± 3.5 | 8.6, 10.6 | 3.0 to 18.0 | 11.7 ± 3.8[b] | 10.7, 12.7 | 2.0 to 19.0 | −1.9 | −3.5, −0.7 |
| Femoral anteversion, ° | 8.3 ± 3.5 | 7.3, 9.3 | 1.0 to 16.0 | 11.5 ± 3.3[a] | 10.7, 12.3 | 5.0 to 21.0 | −3.2 | −4.5, −2.0 |

[a] Indicates $P < .001$.
[b] Indicates $P = .003$.

**Table 2. Effect Sizes and 95% Confidence Intervals for the Magnitude of the Differences Between Men and Women**

| | Effect Size | 95% Confidence Interval |
|---|---|---|
| Navicular drop, cm | 0.25 | −0.41, 0.91 |
| Tibial varum, ° | 0.17 | −0.38, 0.72 |
| Quadriceps angle, ° | 1.15 | 0.63, 1.78[a] |
| Genu recurvatum, ° | 0.85 | 0.24, 1.46[a] |
| Anterior pelvic tilt, ° | 0.72 | 0.33, 1.11[a] |
| Femoral anteversion, ° | 1.10 | 0.36, 1.84[a] |

[a] Indicates significant confidence interval that does not encompass zero.

**Table 3. Comparison of Calculated Coefficient of Variation Between Our Study and Previously Reported Data[a]**

| | Men | | Women | |
|---|---|---|---|---|
| | Our Study, % | Nguyen and Shultz,[10] % | Our Study, % | Nguyen and Shultz,[10] % |
| Navicular drop, cm | 33 | 47 | 38 | 49 |
| Tibial varum, ° | 47 | —[b] | 38 | —[b] |
| Quadriceps angle, ° | 21 | 45 | 19 | 37 |
| Genu recurvatum, ° | 81 | 94 | 56 | 70 |
| Anterior pelvic tilt, ° | 36 | 48 | 32 | 40 |
| Femoral anteversion, ° | 42 | 59 | 29 | 38 |

[a] Calculated coefficients of variation from data reported by Nguyen and Shultz.[10]

[b] No comparable measure to Nguyen and Shultz.[10]

genu recurvatum, anterior pelvic tilt, and femoral anteversion (range, 0.72–1.15). Calculated 95% CIs did not encompass zero for any of these measures. For the measures of navicular drop and tibial varum, effect sizes were small (range, 0.17–0.25), and 95% CIs encompassed zero.

Calculation of the CV revealed a range of 21% to 81% across the 6 measures for men and a range of 19% to 56% for women. These values are presented in Table 3 and are compared with CVs calculated from previously reported data for 5 of the 6 measures of alignment.[10]

## DISCUSSION

The purpose of our study was to quantitatively assess the effect of sex on 6 lower extremity alignments often identified as risk factors for injury, to develop representative values for each measure from a sample of active adults and elite athletes and to compare men and women for these measures. Our study was an explicit look at structural differences between men and women in a sample of healthy young adults with no lower extremity injuries. We can conclude that these values for the 6 measures are reasonable representations for this sample.

Based on anecdotal evidence, we hypothesized that women would demonstrate greater Q angle, genu recurvatum, anterior pelvic tilt, and femoral anteversion compared with men. The results of our study support our hypothesis. Women demonstrated larger measures for all 4 of these measures compared with men.

As expected, we found no sex difference for navicular drop or tibial varum. The mean navicular drop (both measures) for both sexes in our study fell within minimum[26] and maximum[31] reported averages (7 and 9 mm, respectively). We did not observe a sex difference for the measure of tibial varum. Average values for tibial varum vary greatly even when similar methods are used. The range of averages reported for tibial varum for healthy limbs is 4.0° to 8.7° in studies with methods similar to ours.[23,29,32] The means and SDs of tibial varum in our study fell within this range.

The reported range of average values for Q angle varies from 5° to 14° for men and 10° to 18° for women,[31,33–35] which is a fairly large range. Our Q angle values of 13.8° ± 2.6° for women and 10.9° ± 2.4° for men fell within these ranges and were lower than the Q angle values that Woodland and Francis reported[34] for a large sample size (n = 526; 17.0° ± 1.2° for women and 13.6° ± 1.2° for men). It is commonly believed that a Q angle of 15° in men and 20° in women is excessive and may lead to disorders at the knee.[36] However, these values have been disputed as being somewhat arbitrary.[9] Nonetheless, the means and SDs of the Q angle values in our sample were less than those values.

The general assumption is that women demonstrate more genu recurvatum than men. In 1 study,[26] women averaged 5.8° ± 4.2° of genu recurvatum and men averaged 3.2° ± 1.5°, values that are very close to our genu recurvatum values of 5.7° ± 3.2° (women) and 3.1° ± 2.5° (men). More than 10° of knee hyperextension has long been considered abnormal, a potential indicator of hyperlaxity in children with congenital hip dysplasia, and a risk factor for overuse injuries in the lower extremity.[37,38] Our average values for genu recurvatum, as measured in healthy participants, fell well below that mark.

The method used for measuring pelvic tilt angle in our study is relatively new, and limited data for the measurement of pelvic tilt have been reported. Hertel et al[8] reported that pelvic tilt for women was 3.50° ± .04° and for men was 1.5° ± 0.4°. These values are considerably lower than the values for our participants (11.7° ± 3.8° for women and 9.6° ± 3.5° for men). In contrast, Shultz et al[21] noted that average values for pelvic angle ranged from 10.8° ± 4.6° to 15.3° ± 4.1°, with no sex specification for these values.

Using the Craig test measurement technique, Magee[33] gave the range for femoral anteversion as 8° to 15° with no sex specification. Using ultrasound as the method of measurement, Braten et al[39] found that women demonstrated more femoral anteversion compared with men. Our values for femoral anteversion fell within these previously reported ranges, with women displaying more femoral anteversion than men.

Previously reported ranges generally correspond with our ranges for all alignment measures used in our study; however, the range may not fully describe the distribution of values for each measure. For each alignment measure, it is important to note that the ranges of maximum and minimum values were much larger than the 95% CIs associated with the means of each alignment measure, which were very narrow. Based on the size of the CIs for all reported measures, the measures derived from our sample most likely represent measures for the population of men and women similar to those in our study. The relatively narrow CIs indicate that we found true differences between men and women based on their lower extremity alignment profiles. A newly drawn sample of similar participants likely would exhibit measures within these CIs, and very few (less than 5%) would be likely to fall into a much wider range outside these intervals. This indicates that, although the variation among individuals is large, healthy men and women within this age range are very likely to fall within the normal distribution around the respective mean alignment measure.

A particular problem with the measurement of static alignment measures is that intertester reliabilities typically are not consistently high.[21,26,40] We have attempted to avoid that problem by using a single tester, thereby maximally standardizing the measurement techniques. In our study, observed values fell within the ranges of average values reported in previous studies.

In our study, we found a sex difference for 4 of the 6 measures; however, the differences were less than 4° in all cases, which is a relatively small amount when considered alone. We cannot determine how these individual angles may affect other joints; the effect of an individual's height and mass on joint angles may affect forces at a particular joint. Extremes of alignment (malalignments) often are implicated in certain overuse injuries, and they are frequently the first item addressed when treating these conditions. Although often related to injury, excessive lower extremity malalignment is not necessarily a cause of injury. Individuals with any particular alignment may or may not experience an injury. Likewise, an individual may develop an injury that is normally associated with malalignments but may not exhibit any of these structural problems.

We still do not know if the typical sex-related alignments contribute to the discrepancy in injury rates. Although the alignment characteristics of larger Q angles, genu recurvatum, pelvic tilt, and femoral anteversion are displayed more often in women than in men, these sex differences will not be seen by all individuals, and, additionally, these measures overlap between the sexes.

## Clinical Relevance

The range for each measure was quite large, but the 95% CIs around the means for men and for women were relatively narrow. We believe we have captured a representative sample within which we are 95% likely to estimate the true population mean for both men and women for each measure. In addition, we observed significant and clinically meaningful differences between the sexes for the measures of Q angle, genu recurvatum, anterior pelvic tilt, and femoral anteversion. Finally, the CIs for each of these 4 measures did not overlap when making comparisons across the sexes. This indicated that the alignment profile was different between men and women for those measures.

As expected, we also observed differences between men and women for the measures of Q angle, genu recurvatum, pelvic tilt, and femoral anteversion. Although significance may be accounted for by our large sample size, we also observed a strong effect for the magnitude of the difference between the sexes for these measures. The CIs around these large effect sizes were narrow and did not encompass zero (Table 2). We are very confident that a true difference exists between men and women for these 4 measures, although the average difference is only a few degrees. This difference of 3° to 4° in these 4 measures is not only significant but also appears to be clinically meaningful. Measures that exceed this value will have a stronger effect, but the true influence of lower extremity alignment on biomechanics and injury is unknown at this time. Our results demonstrate that continued investigation into lower extremity alignment is needed and that malalignment might still be a risk factor to consider. Further research is warranted to determine how lower extremity alignment might contribute to injury.

## Limitations

A limitation to this study is that the alignment measures were obtained only once per participant. Calculation of intraclass coefficients, which is a typical method of determining reliability of the measure, was not possible with this study design. In an attempt to infer the reliability of our measures, we compared the means, SDs, and CVs for 5 of the measures with these values reported by Nguyen and Shultz,[10] who used similar methods and found similar results. Our results for the means, SDs, and ranges for all measures were consistent with their results; however, our CVs were slightly lower than but still comparable with their values.[10] We did not directly assess reliability in our study, but, based on the similarities and normal variations in the measures between our study and their study,[10] we are confident that our measures are accurate estimates of participants' lower extremity alignment profiles.

Because large CVs were reported for both studies, we must consider that the magnitudes for all of these measures are relatively small in relation to zero. In fact, for each of these measures, having a mean of zero is conceivable. As the mean of a measure approaches zero and the SD remains constant, the CV is inflated dramatically.[41] Notably, if the same distribution of measures was scaled higher (away from zero) and the SD remained constant, the CV would be much lower.[41] In particular, the CV for genu recurvatum was quite high in both our study and the study by Livers.[41] The mean of genu recurvatum in both studies was close to 0, with SDs that indicate a wide range across participants. The high CV values[41] do not indicate that these measurement techniques were not reliable or valid; rather, the interpretation of the CV is dubious when the mean of a measure is near zero.

## CONCLUSIONS

In our study, we attempted to generate representative values for specific anatomic lower extremity alignments that are often implicated as risk factors for injury in healthy, active adults and elite athletes. The observed differences by sex in certain lower extremity alignments corroborated previous anecdotal statements, because the female group in our study demonstrated larger Q angles, genu recurvatum, anterior pelvic tilt, and femoral anteversion compared with the male group. No sex differences were revealed for navicular drop and tibial varum. Although the sex differences for these 4 measures of alignment were significant, the differences between men and women were relatively small and, regardless of the size of the differences, direct implications for injury cannot be generated. Future researchers should target how sex-related structure may affect movement patterns and forces rather than implicate sex alone.

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