Original Article

Absolute and Normalized Normative Torque Values of Knee Extensors and Flexors in Healthy Trained Subjects: Asymmetry Questions the Classical Use of Uninjured Limb as Reference

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Purpose: To provide normative values of maximal isometric torque of knee extensors and flexors measured at 80° of knee flexion and to characterize the results in healthy subjects practicing activities at risk of anterior cruciate ligament rupture. **Methods:** Seventy-four trained volunteers (35 male and 39 female) aged 18 to 41 years were recruited. They alternately performed 3 maximal voluntary isometric contractions of knee extension and flexion. The maximal voluntary isometric contraction net torque was computed as the mean value of the peak torques recorded over the 3 trials. **Results:** For women, the absolute torque for extensors was 143.5 ± 34.4 N•m (range, 87.7-253.1 N•m) and 66.8 ± 13.8 N•m (range, 37.5-93.1) for flexors. For men, the absolute torque for extensors was 199.8 ± 47.3 N•m (range, 99.3-311.5 N•m) and 89.8 ± 21.0 N•m (range, 51.8-137.2 N•m) for flexors. For women, the body mass normalized torque for extensors was 2.20 ± 0.51 N•m.kg^{-1} (range, 1.22-3.74 N•m.kg^{-1}) and 1.04 ± 0.26 N•m.kg^{-1} (range, 0.41-1.50 N•m.kg^{-1}) for flexors. For men, the normalized torque for extensors was 2.74 ± 0.58 N•m.kg^{-1} (range, 1.51-4.08 N•m.kg^{-1}) and 1.24 ± 0.30 N•m.kg^{-1} (range, 0.64-2.05 N•m.kg^{-1}) for flexors. **Conclusions:** This study provides absolute and normalized normative values of maximal isometric torque measured at 80° of knee flexion for extensors and flexors in a series of healthy trained subjects practicing activities at risk of anterior cruciate ligament rupture. The considerable level of interlimb asymmetry and the weak association between dominance and strength observed in uninjured subjects call into question the classical use of contralateral side as reference for injured patients. **Clinical Relevance:** Patients with anterior cruciate ligament (ACL) injuries are the most represented subjects using isokinetic dynamometers in many sport medicine and rehabilitation departments. Clinicians need reference values to compare patients with ACL injuries with comparable healthy subjects. This study may provide this information.

A patient's rehabilitation during the treatment of musculoskeletal injuries is essential for an adequate functional recovery and return to daily or sports activities. Strength evaluation throughout the rehabilitation process is therefore commonly performed to better assess the functional evolution of the patient during conservative treatment or following surgery.[1] The gold standard for that purpose remains isokinetic torque measurement, which is performed during anisometric contractions.[2] However, other modalities of assessment may present strong advantages for clinicians in order to evaluate their patients with a better level of confidence and time-to-benefit ratio.

Advanced health care institutions or physiotherapy centers have access to such high-level measurement devices, although they remain challenging to use with the risks to obtain irrelevant results. Despite the high reliability level of dynamometers in experimental

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settings,[3] the validity of strength measurement in clinical practice depends on the real capacity to obtain maximal voluntary contractions (MVCs) from our patients. It is noting that maximal voluntary torque production depends on the contraction mode (isometric, concentric, eccentric)[4] with different specificities of neural control[5] and requiring different levels of patient skills.[6] To counteract such limitations, isometric evaluation can be performed to ensure both the reproducibility and validity of the maximal strength measurement. Although this evaluation is not dynamic, the fact that it is performed at a selected angle and less affected by patient pain or biomechanical restrictions greatly facilitates patient MVC. In addition, it allows a strength measurement at a time point during which an isokinetic evaluation would have been impossible (e.g., shortly after anterior cruciate ligament [ACL] reconstruction for knee extensors). Isometric measurements may be performed at several angles. With the aim of protecting the graft during extensors MVC,[7] but also to provide comfort, limit pain, and to enhance the reliability of MVCs,[8] a knee flexed position may be recommended.

To guide the clinician in the rehabilitation process, patient strength capacities of the involved limb can be evaluated and compared with either the contralateral "healthy" side or to published normative values. The first approach is potentially limited, since it implies that the contralateral limb strength should be the real target for the involved side,[9] and the second requires strength normative values at the same selected knee angle on a population representative to concerned patient.

The purposes of this study are to provide normative values of maximal isometric torque of knee extensors and flexors measured at 80° of knee flexion and to characterize the results in healthy subjects practicing activities at risk of ACL rupture. We hypothesized that beyond providing normative values that should be useful in clinical practice, a considerable strength asymmetry between lower limbs would exist in healthy subject and that men would reach greater maximal isometric torque, even when normalized by body mass.

Methods

Seventy-four volunteer trained subjects, including 35 men (47%) and 39 women (53%) aged 24.1 ± 5.7 years (range, 18-41 years) with no neurologic or knees, hips, and muscles trauma history participated in the present study. Average Tegner score was 6.8 ± 1.1 (range 5-9) (Table 1). All of the subjects were athletic, practicing activities with a high risk of ACL injury such as collective sports, racket sports, combat sports, skiing, or on-loading activities with changing of directions.[10] A minimum of 2 sessions of training per week and a continuity in the practice during the 8 weeks preceding the evaluation were required. All subjects signed an informed consent form. Approval for the project was obtained from the local ethics committee (RCB#2021-A01414-37, CPP#2021/56), and all procedures were in conformity with the Declaration of Helsinki.

A subject's lower-limb dominance was evaluated using 5 items of subject-reported preference to perform motor actions: kicking a ball, picking up a marble with toes, tracing shapes with foot, digging with a spade and arm dominance: the writing hand. Recommendations from Schneiders et al.[11] were followed in order to select the more reliable criteria.

For each subject, the testing session lasted 1 hour and included anthropometric measurements and isometric maximal contractions. Subjects started the testing session with the assessment of weight and height using a calibrated weighing scale and a measuring rod.

The subjects sat on a calibrated isokinetic dynamometer (Biodex S4, Shirley, NY) with the hip flexed at 85° (0 = anatomical position) during the testing session. The lateral condyle of the knee was aligned with the dynamometer motor axis using a visual inspection and manual palpation. The chairback receding was adjusted in order to let the width of 3 fingers between the seat cushion and the calf on the outside of the knee, relaxed and flexed around 80° to 90° (0 = anatomical position). Shoulders, pelvis, and distal part of the femur were firmly strapped to the chair using belts. The accessory used for knee measurements was set up with a length corresponding to the width of 3 fingers between the lateral malleolus and the accessory foam for each participant.

With the hands holding the handles, subjects started to realize 5 to 8 submaximal isokinetic contractions of extensors and flexors before having set up the stops, in order to activate quadriceps and hamstrings on the entire range of motion and verify the settings. Intensity was progressively increased without any feedback. Then, extension electronic stop was adjusted. Subjects were asked to fully activate the quadriceps at knee extension position and the experimenter progressively pressed the distal part of the tibia with his hand. This increased the produced torque and already deformed the foam of the chair while having a maximal participation of the quadriceps and all the involved muscle groups. This soft pressure permitted to produce a maximal isometric contraction at 0° of knee flexion and to set up the stops in the same condition as during recorded quadriceps MVCs.

Knee flexion angle is frequently 90° for maximal strength assessment. However, in this position, extensors muscles are particularly stretched, which do not permit to produce high level of strength.[12,13] Furthermore, for some subjects, the direction of produced force is slightly vertical (directed to the bottom and forward), which leads to more verticalization of the femur during extensors contraction and may imply less comfort and

Table 1. Demographic Data for Men and Women

	Women (n = 39)				Men (n = 35)					
	N (%)				N (%)					
	Mean ± SD	Median	IQR Range	(Min-Max)	Mean	±SD	Median	IQR Range	(Min-Max)	*P* Value
Age, y	24.1 ± 6.2	22.0	(20.0-26.5)	(18.0-41.0)	24.1	± 5.2	22.0	(20.0-27.0)	(18.0-38.0)	n.s.
Weight, kg	66.0 ± 11.3	63.8	(58.5-68.7)	(47.4-97.4)	73.1	± 9.9	74.9	(64.8-78.4)	(57.9-94.4)	.003
Height, cm	166.1 ± 6.5	167.0	(162.0-170.5)	(151.0-178.0)	178.7	± 5.1	180.0	(175.5-182.0)	(165.0-188.0)	<.001
BMI	24.0 ± 4.2	23.5	(20.5-26.9)	(17.8-34.9)	22.9	± 2.7	23.2	(20.8-24.2)	(18.1-29.3)	n.s.
Tegner score	6,9 ± 1.2	7.0	(6.0-7.5)	(5.0-9.0)	6.7	± 0.9	7.0	(6.0-7.0)	(5.0-9.0)	n.s.
Dominance										n.s.
Left	4 (10.3)				2 (5.7)					
Right	35 (89.7)				33 (94.3)					

BMI, body mass index; IQR, interquartile range; max, maximum; min, minimum, n.s., not significant; SD, standard deviation.

availability to produce MVC in comparison with more opened angles. On the opposite side, knee flexion at 60° or 70° may implicate more apprehension because of the femoropatellar joint biomechanics. Because of the better comfort and stability at this angle of measurement, subjects performed isometric contractions at 80° of knee flexion in this study as well as in our common clinical practice. Despite the good conditions offered for the contraction of extensors, torque measurements performed at 80° of knee flexion may not be clinically relevant for flexors. However, given that measurements are performed for extensors, it is very time saving to add measurements for flexors. Furthermore, it may present useful information about the torque production in shorten position which is of particular interest for patients who underwent an ACL reconstruction with hamstring graft.

Both for warming up and for motor learning, subjects realized a progressive isometric contractions protocol in terms of intensity. The intensity of the contractions was self-evaluated and visual feedback online was given using a computer display. Subjects were asked to produce 3-second isometric contractions with a regular plateau. Before recording, they realized 2 contractions at 50% of maximal intensity, 2 contractions at 75%, 2 contractions at 90%, and 2 contractions at 100%. Extensions and flexions were systematically alternated. During warm up, 10 to 15 seconds of rest was allowed between each trial.

After the warm-up phase, a 1-minute rest period was given and the subjects alternately performed 3 MVCs of extension and flexion. A timer gave an auditive and visual feedback to start contracting every 20 seconds, which permitted a relative rest of each muscle group of 35 seconds between each contraction. During maximal recorded contractions, no visual feedback was given in order to prevent any implication of the feedback on torque production. Each contraction started at the end of the 20-second countdown and was given at the same time by the experimenter. Strong verbal encouragements were given since the last submaximal trials until the end of the session for each contraction, from the start to the end (approximately situated 4 seconds after), to ensure that a 3-second torque plateau was performed. After recording the torque of the first limb (randomly chosen), a strictly identical experimental protocol was applied on the second limb.

For all experiments, net isometric torques retained were maximal values extracted from each MVC trial. The torque due to any element foreign to the voluntary torque, particularly the weight of the limb and the accessories, named baseline torque, was systematically subtracted. The mechanical data (i.e., torque and angular position) were recorded at 2 kHz using a NI USB-6001 and DAQExpress software (National

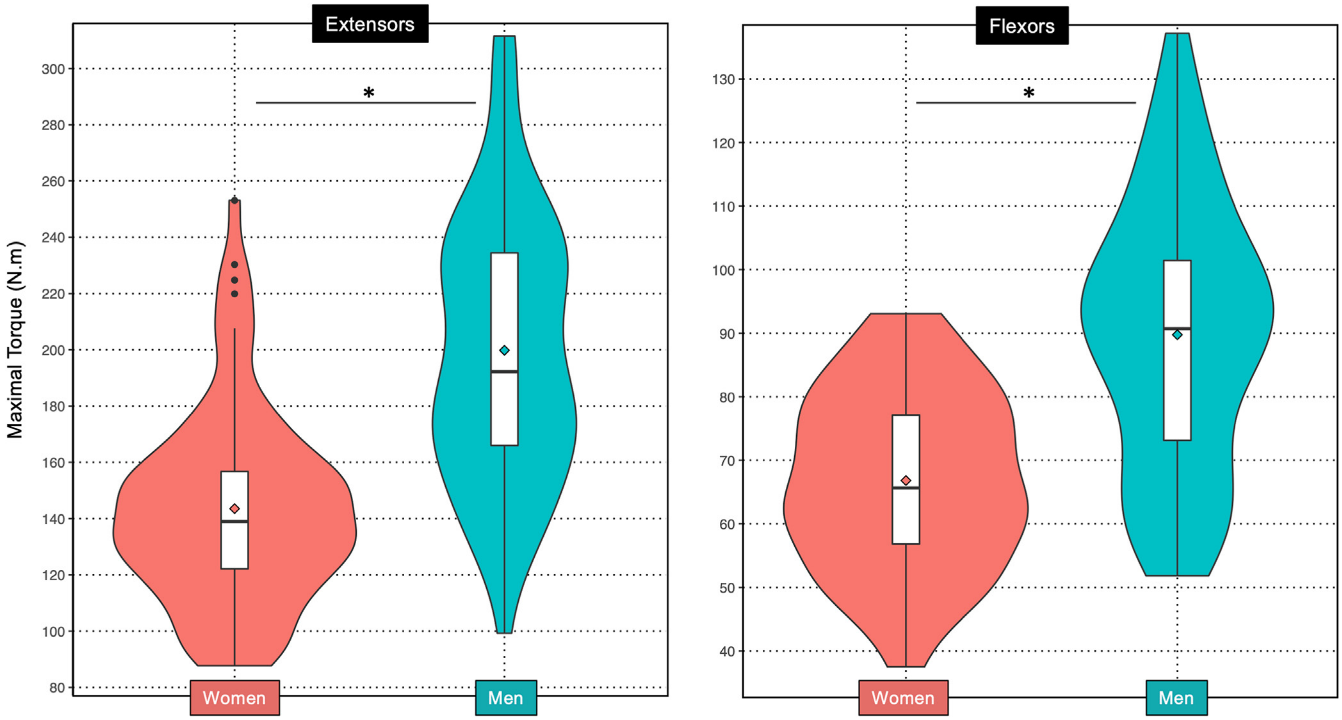

Fig 1. Distribution of absolute extensors and flexors torque values for men and women.

Instruments Crop., Austin, TX). The MVC torque was computed as the mean value recorded over the 3 trials for each muscle group using a custom-made Matlab script (The MathWorks Inc., Natick, MA). The ratio between stronger and weaker limb torque was calculated and expressed as a percentage of asymmetry (stronger − weaker / stronger). A leg was considered as stronger/weaker than the contralateral side if the difference exceeded the standard error of measurement (SEm).

For baseline characteristics, variables were reported as mean ± standard deviation, median, interquartile range, and range (minimum − maximum) for continuous data and proportions for categorical data. The normality of distributions was assessed using Shapiro−Wilk tests. For non-Gaussian continuous data, differences between men and women were evaluated using Wilcoxon rank-sum tests (Mann−Whitney *U* test). For Gaussian continuous data, differences between men and women were evaluated using an unpaired Student *t*-test. Limb differences (dominant vs nondominant) were evaluated using the Wilcoxon signed-rank test for non-Gaussian continuous data and using the paired Student *t*-test for Gaussian continuous data. Statistical analyses were performed using R, version 3.6.2 (R Foundation for Statistical Computing, Vienna, Austria). *P*-values $< .05$ were considered statistically significant.

The relative (intraclass correlation coefficient [ICC]) and absolute (SEm) repeatability of strength measurements were evaluated. The ICC (ICC3,3; model: 2-way, type: absolute agreement, unit: average) was interpreted as follows: 0-0.2 indicates poor agreement: 0.3-0.4 indicates fair agreement; 0.5-0.6 indicates moderate agreement; 0.7-0.8 indicates strong agreement; and >0.8 indicates almost perfect agreement. Mean ICCs obtained in the present study were between 0.93 and 0.96, depending on sex and muscle groups.

The SEm was calculated using the following formula: $SEm = SDw \times \sqrt{1 - ICC}$ and expressed in percentage of the mean: $\text{SEm}_{(\%)}$. SDw is the standard deviation within-subjects. $\text{SEm}_{(\%)}$ was between 4.5% and 6.6%, depending on sex and muscle groups.

For sample size calculation, the ICC value used for the calculation of SEm was not mean ICC. Since strength assessment in clinical practice may not be as much reliable as it is during research experimentations, the authors retained the lower limit of the 95% confidence interval of the ICC (men extensors 0.951; men flexors 0.931; women extensors 0.964; women flexors 0.947). The minimum sample size needed for this study was calculated using the following formula:

$$n = \frac{(1.96 \times SDb)^2}{E^2}$$

E is the margin of error and *SDb* is the standard deviation between subjects. The authors decided to use a margin error corresponding to the SEm of strength evaluations for each muscle group and sex group. For

Table 2. Men and Women Knee Absolute Muscle Strength (Nm)

	Men (n = 35)				Women (n = 39)				
	Mean ±SD	Median	IQR Range	(Min-Max)	Mean ± SD	Median	IQR Range	(Min-Max)	*P* Value
Extensors	199.8 ± 47.3	192.2	(166.0-234.5)	(99.3-311.5)	143.5 ± 34.4	138.9	(122.1-156.7)	(87.7-253.1)	<.001
Flexors	89.8 ± 21.0	90.7	(73.1-101.5)	(51.8-137.2)	66.8 ± 13.8	65.6	(56.8-77.1)	(37.5-93.1)	<.001

IQR, interquartile range; max, maximum; min, minimum, n.s., not significant; SD, standard deviation.

women, the greatest SD was found when testing the extensors (34.4 N•m), which gives a total sample size of 71. For men, the greatest SD was found when testing the extensors (47.3 N•m), which gives a total sample size of 53 subjects. Since the authors tested both limbs for each healthy subject, a minimum of 36 women and 27 men were needed.

Results

For women, the maximal isometric torque for extensors was 143.5 ± 34.4 N•m (range, 87.7-253.1 N•m) and 66.8 ± 13.8 N•m (range, 37.5-93.1 N•m) for flexors (Fig 1, Table 2). Men demonstrated a significantly greater ($P < .001$) maximal isometric torque with 199.8 ± 47.3 N•m (range, 99.3-311.5 N•m) for extensors and 89.8 ± 21.0 N•m (range, 51.8-137.2 N•m) for flexors. Different levels of absolute isometric torque have been created for a better use in clinical practice.

For women, the normalized maximal isometric torque for extensors was 2.20 ± 0.51 N•m.kg^{-1} (range, 1.22-3.74 N•m.kg^{-1}) and 1.04 ± 0.26 N•m.kg^{-1} (range, 0.41-1.50 N•m.kg^{-1}) for flexors (Fig 2, Table 3). Men demonstrated a significantly greater ($P < .001$) normalized maximal isometric torque with 2.74 ± 0.58 N•m/kg (range, 1.51-4.08 N•m/kg) for extensors and 1.24 ± 0.30 N•m/kg (range, 0.64-2.05 N•m/kg) for flexors. Different levels of normalized isometric torque have been created for a better use in clinical practice (Appendix Figs 1 and 2, available at www.arthroscopyjournal.org).

Sixty-nine percent (69%) of the women were stronger on their dominant side for the extensors and 62% for the flexors. Likewise, 57% of the men were stronger on their dominant side for the extensors and 60% for the flexors (Fig 3).

For women, the interlimb torque asymmetry was of 14.1 ± 10.0% (range, 1.2%-35.7%) for the extensors and 15.4% ± 10.4% (range, 0.4%-40.7%) for the flexors (Fig 4). Men exhibited comparable interlimb torque asymmetry with 14.8 ± 10.9% (range, 1.0%-41.0%) for the extensors and 19.1% ± 12.9% (range, 0.1%-45.2%) for the flexors.

Discussion

The present study provides normative values of normalized and non-normalized maximal isometric torque measured at 80° of knee flexion for extensors and flexors in a series of healthy subjects practicing activities at risk of ACL rupture, stratified by sex. Our results furthermore highlighted a considerable interlimb strength asymmetry and a greater normalized maximal isometric torque for men, thereby confirming our hypothesis.

Strength normative values of knee extensors and flexors are published in many previous studies.

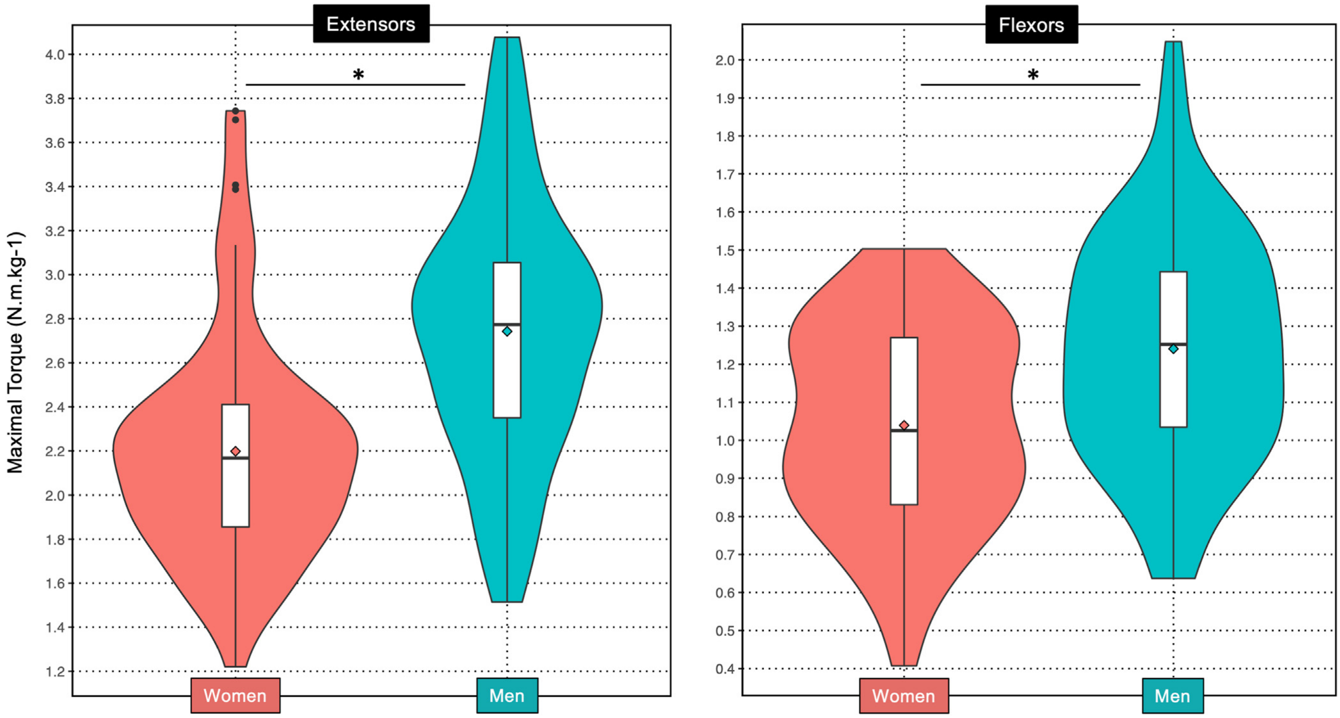

Fig 2. Distribution of body weight-normalized extensors and flexors torque values for men and women.

However, the context and conditions of measurement such as the population studied and the joint angle chosen have a strong impact on the collected data which can render the comparison of different results challenging in clinical practice. First of all, the studied population has a major impact on strength production. Previous studies focused on specific populations (e.g., athletes, children, older adults)[14,15] and some others performed measurements on more general profiles of participants.[16] Targeting a too-specific or a too-large population may lead to useless data for clinicians who aim at comparing their patients. In absence of reference values, analysis of strength testing would be reduced to the analysis of interlimb symmetry and potentially overestimate involved knee function.[17] Given that strength assessments in a clinical context are largely performed for ACL-deficient or ACL-reconstructed patients, including an uninjured sportive population at risk of ACL injury in our study seems to be more appropriate.[10] With the goal of offering clinicians an overview of strength values distribution that concerns this specific but heterogenous population, the present study aims to propose the finest inclusion criteria given the scale is neither too large nor too specific. Second, the contraction type used for strength assessment highly modulates the values obtained. Indeed, due to the physiological torque—angle velocity relationship, we know that for a constant angle of measurement, increasing speed during concentric contractions leads to torque reduction. For eccentric contractions, more variability between subjects has been observed, and we know that individual characteristics and level of expertise may influence the torque production, which may be greater or lower than isometric values.[18] In clinical practice, isokinetic dynamometers are mainly used with isokinetic contractions even if dynamometers are enabled to record during isometric contractions. This may explain why normative values published in previous studies are mainly recorded during isokinetic contractions, as underlined by the recent scoping review of van Melick et al.[19] Isometric assessment using isokinetic dynamometers may present strong

Table 3. Men and Women Knee Relative Muscle Strength (N•m.kg^{-1})

	Men (n = 35)				Women (n = 39)				
	Mean ± SD	Median	IQR Range	(Min-Max)	Mean ± SD	Median	IQR Range	(Min-Max)	*P* Value
Extensors	2.74 ± 0.58	2.77	(2.35-3.06)	(1.51-4.08)	2.20 ± 0.51	2.17	(1.86-2.41)	(1.22-3.74)	<.001
Flexors	1.24 ± 0.30	1.25	(1.03-1.44)	(0.64-2.05)	1.04 ± 0.26	1.03	(0.83-1.27)	(0.41-1.50)	<.001

IQR, interquartile range; max, maximum; min, minimum, n.s., not significant; SD, standard deviation.

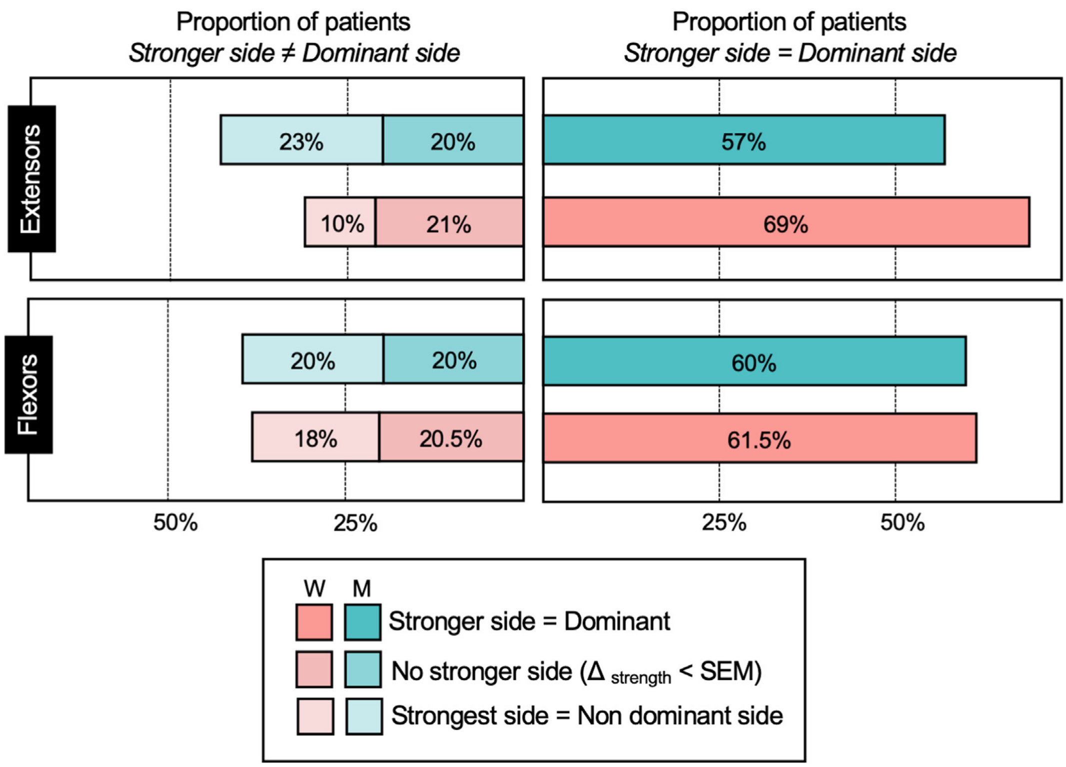

Fig 3. Representation of stronger side depending on subjects' dominance. (SEm, standard error of measurement.)

advantages for clinicians owing to (1) its high reliability, (2) less patient practice time needed in terms of motor learning to produce MVC in comparison with isokinetic contractions, (3) the possibility to realize strength assessments in patients at a time point at which dynamic MVCs are not authorized, and (4) because isometric contractions potentially generate less articular pain and inflammatory reaction in patients due to the lack of motion. Furthermore, for example, after ACL reconstruction, it is known that shear forces are produced on the graft by contracting quadriceps with open kinetic chain between 0° and 38°.[7] This reason implicates that maximal isokinetic contractions on the entire range of motion are not permitted in the first phases after surgery. In this particular case, isometric measurements performed at 80° of knee flexion may be realized without any restriction and allows patient evaluation much more earlier during the rehabilitation process, thereby providing helpful information to guide clinicians and optimize the treatment strategy.

Isometric normative values have already been published in previous publications. Despite a similar contraction type used in the current study, several elements complicate our capacity to compare the data between studies. At first, because of the physiological torque–angle relationship, torque production depends on the angle of measurement. To our knowledge, maximal isometric torque data have already been provided for knee angles 45°, 70°, and 90° but not at 80° for knee extensors and flexors in men and women at risk of ACL injury. In a recent meta-analysis comprising 411 studies, Sarabon et al.[20] presented reference torque values for knee extensors and flexors by different knee angle ranges (e.g., extended, mid-range, and flexed). Our results compare well with those reported by Sarabon et al.[20] for both extensors torque (women, 1.22-3.74 vs 2.04-2.71 $N\cdot m.kg^{-1}$; men, 1.51-4.08 vs 2.50-3.06 $N\cdot m.kg^{-1}$) and flexors torque (women, 0.41-1.50 vs 0.46-1.69 $N\cdot m.kg^{-1}$; men, 0.64-2.05 vs 0.96-1.54 $N\cdot m.kg^{-1}$). Second, comparison between studies is challenging because of the measurement tool or the units chosen. Strength values are recorded and expressed as forces by some of them,[16] whereas some others published torque values.[21] Furthermore, for torque measurements, some studies published absolute torque values, expressed in N•m,[22] whereas some others also presented normalized torque values by weight, expressed in $N\cdot m.kg^{-1}$, particularly during anisometric contractions.[14] This limitation encouraged the authors to provide both raw and normalized torque values for the same set of data in this publication.

For both knee extensors and flexors, the results obtained in the present study confirm that sex stratification is necessary to provide useful normative values, even when the torque is normalized by weight. In comparison with women, men exhibited greater absolute torque values (+37.5% for extensors and +30.8% for flexors) and normalized-torque values (+25.1% for

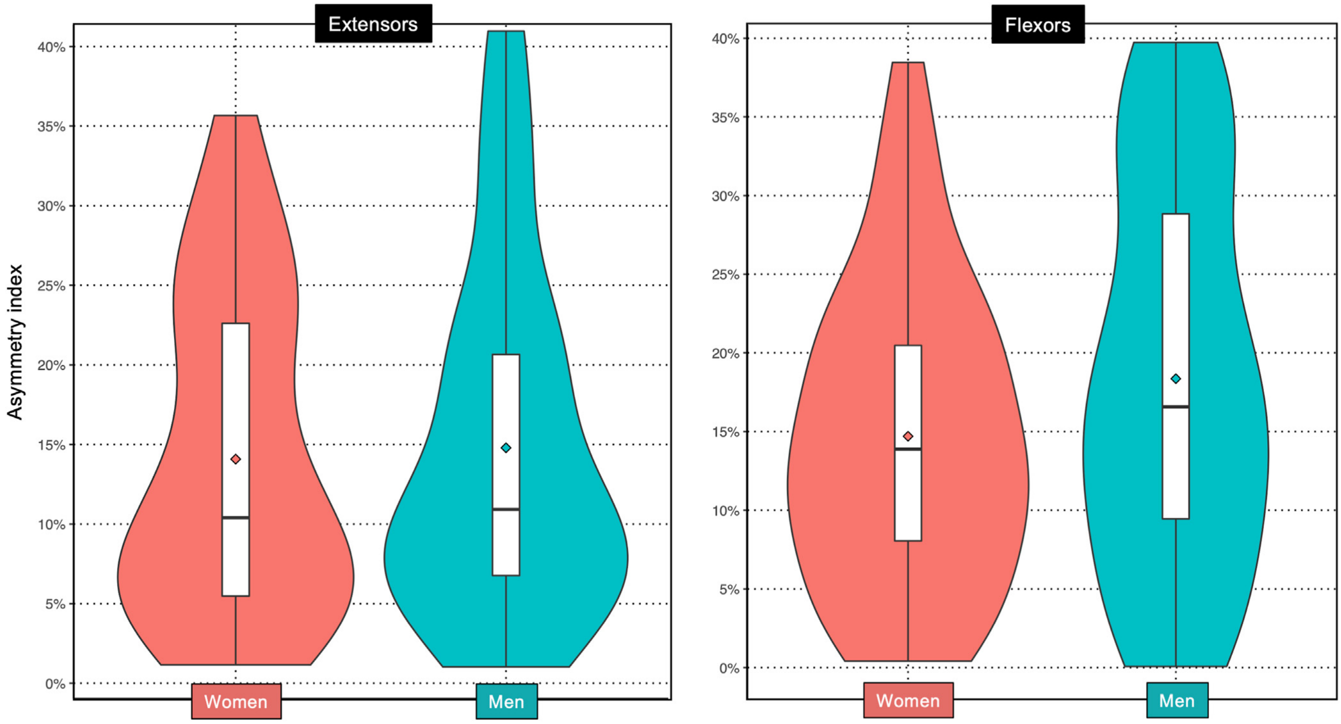

Fig 4. Distribution of extensors and flexors asymmetry indexes for men and women.

extensors and +20.0% for flexors), which is widely reported in the scientific literature.[21,23,24]

For a 70° knee flexion angle, Dalgaard et al.[25] reported a normalized knee extensors torque of 3.0 ± 0.17 N•m.kg^{-1} for a specific population of young women. Those values are greater than our results (2.20 ± 0.51 N•m.kg^{-1}) since a 70° knee flexion angle is closer from the angle of peak torque than 80°. Furthermore, subjects may highly deform the seat foam at 70° compared with 80° during maximal contractions (due to more vertical applied forces), which decreases in experimental settings the knee anatomical flexion angle towards the knee peak torque angle.

In the study from Harbo et al.[21] including a large sample of subjects (n = 178), maximal isometric and isokinetic torque were assessed to establish normative values of many muscle groups. Unfortunately, data reported are expressed only for extensors, as absolute values (N•m), not normalized by weight and without any clear description of the chosen knee angle for the measurements. Nevertheless, the values reported for extensors torque seems to be slightly greater but comparable with ours for both men (246.6 ± 56.3 vs 199.8 ± 47.3 N•m) and women (166.6 ± 38.2 vs 143.5±34.4 N•m). Finally, Spinoso et al.[26] obtained comparable values on a series of young women (18-25 years old) for normalized extensors torque (2.45 ± 0.52 vs 2.20 ± 0.51 N•m.kg^{-1}) and flexors torque (1.09 ± 0.23 vs 1.04 ± 0.26 N•m.kg^{-1}) at 60° knee flexion. Taken together, the results obtained in this study seem to be consistent with already-reported data and present an originality in the angle of measurement for the studied population. If sex stratification has been done to the present data, other criteria have been furthermore described in order to provide helpful information for clinicians.

In the present study, we only included healthy subjects with no previous injury on lower limbs and aimed to evaluate strength on both sides. Although the distinction between limbs in clinical practice is classically injured versus uninjured limb, different approaches have been described in the literature for healthy subjects.[27] Distinctions may be done as right versus left, stronger versus weaker, but it is often described as dominant versus nondominant. Determination of laterality is commonly done in clinical practice, particularly during strength assessment, but a self-reported question about handedness is often the only element used by clinicians even for lower-limb measurements. Because strength normative values are sometimes stratified by dominance, we decided to determine footedness using a valid and reliable clinical determination model, using the recommendation of Schneiders et al.[11] The dominant limb is commonly perceived as the stronger side, and this may implicate that the determination of laterality provides useful information for strength data analysis. In our study, the dominant side was the strongest (greater than the other side by > SEm) for only 57% to 69% of our subjects depending on sex and muscle group. Therefore, it seems that there is no good reason to stratify by dominance. Furthermore, given that injuries may occur randomly on the dominant or nondominant side, it seems that evaluating dominance during strength testing does not improve our interpretation of strength symmetry and this may be considered by practitioners. Athlete screening before injuries is the only case in which reference values can be correctly defined and allow to appropriately determine the rehabilitation objectives. Unfortunately, this ideal situation is not applicable for all patients because we do not know their preinjury neuromuscular performance level. If the determination of the stronger side is not feasible in clinical practice before strength testing for most patients, it remains important to note that interlimb differences may also be important for healthy subjects.

Strength assessment in clinical practice is classically based on 2 different approaches: the comparison of absolute values with reference normative data and the analysis of symmetry indices. Different methodologic processes are reported in the literature, and various indices are calculated to estimate strength symmetry between limbs.[27] Asymmetries may be calculated as a percentage of a reference limb[28] and it is typically considered that a goal of rehabilitation of unilateral knee injuries is to restore a level of strength similar to the uninjured side.[29] However, we have no evidence to consider that this target is clinically relevant. Furthermore, even if strength differences between limbs have been associated with an increased risk of prospective injury,[30] conflicting evidence suggest that asymmetry does not always lead to dysfunction[31,32] and would even be necessary for sport performance in some cases. Interpretation of asymmetry scores is hence questionable, and it is very common in clinical practice or in the literature to consider thresholds between 10% and 15% to identify abnormal inter-limb differences.[30,33] Interlimb symmetry indexes calculated in our study ranged from an average of 14% to 19% (confidence interval from 0% to 45%). This underlines a considerable interlimb difference for a healthy population, already reported for athletes,[34,35] and a great variability in the population studied. Considering the possible lack of symmetry before injury, clinicians need to be cautious in the comparison with the contralateral side. It seems that interlimb difference between injured and uninjured limb in clinical practice may be over or underestimated due to the pre-existing interlimb difference before injury, which is often not known. Those elements are supported by the study from Parkinson et al.,[27] which suggests that the use of predetermined arbitrary thresholds to distinguish "normal" and "abnormal" asymmetry scores, especially commonly used thresholds such between 10% and 15%, is not robustly supported by the literature, and that an individualized approach considering the use of sample-specific thresholds and individual variability is necessary. Taking into account these different elements, the authors of the present study suggest that clinicians (1) should perhaps give more importance to the comparison with normative values and a little less with symmetry indices; (2) may favor symmetry approach during early rehabilitation phases and absolute normative approach for later phases; (3) refrain from interpreting symmetry indices if the uninjured limb presents reduced values in comparison with reference data; and (4) might need to reconsider the necessary between-limb symmetry when no data recorded before injury are available for the patient.

Limitations

This study has several limitations. First, those normative values might not be applicable to patients who differ from our studied population in terms of age and sports activities. Second, the sample size calculated for this study allowed the authors to report normative values per sex only. Although being already useful in clinical practice, other studies with greater cohort sizes providing normative values per more specific subgroup (age, activity) would be needed. Finally, the normative values provided in this study can only be used by clinicians using isokinetic dynamometers and not directly by practitioners who are not equipped with such materials.

Conclusions

This study provides absolute and normalized normative values of maximal isometric torque measured at 80° of knee flexion for extensors and flexors in a series of healthy trained subjects practicing activities at risk of ACL rupture. The considerable level of interlimb asymmetry and the weak association between dominance and strength observed in uninjured subjects call into question the classical use of contralateral side as reference for injured patients.

Disclosure

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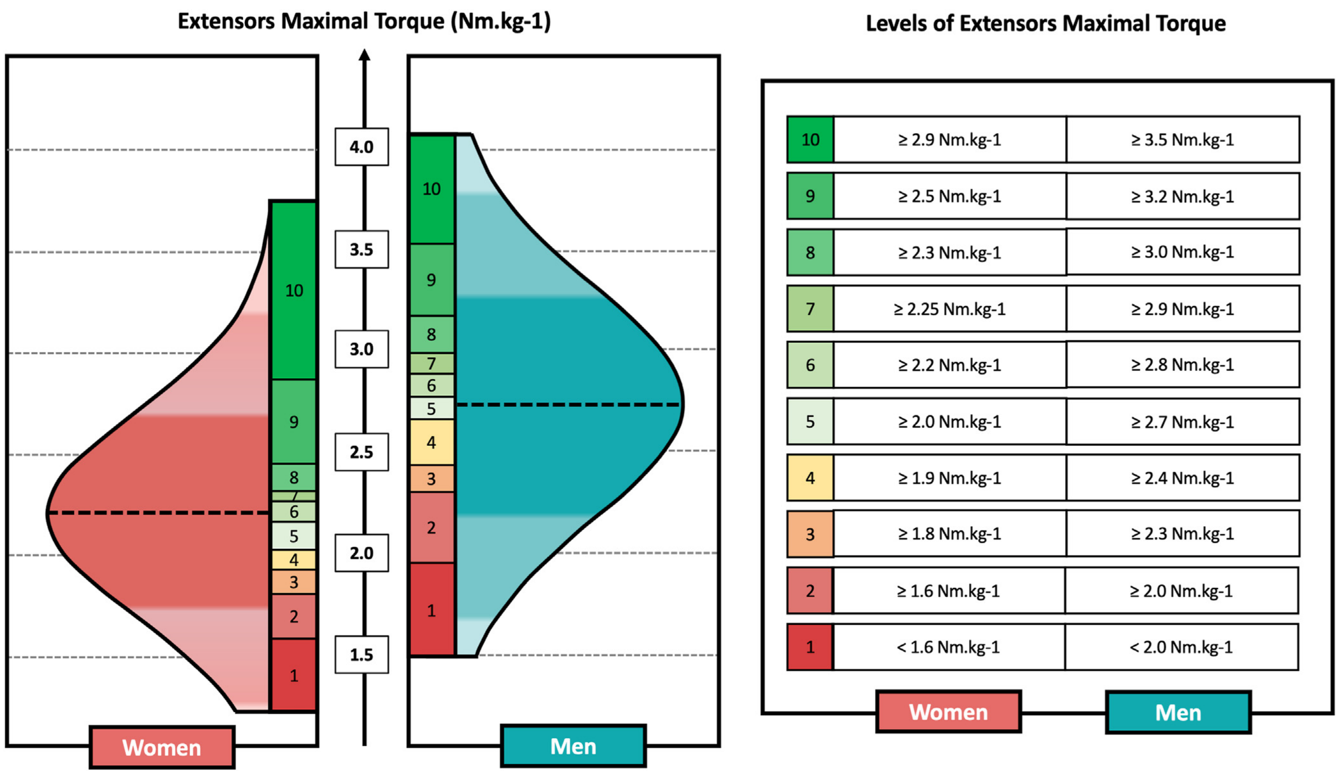
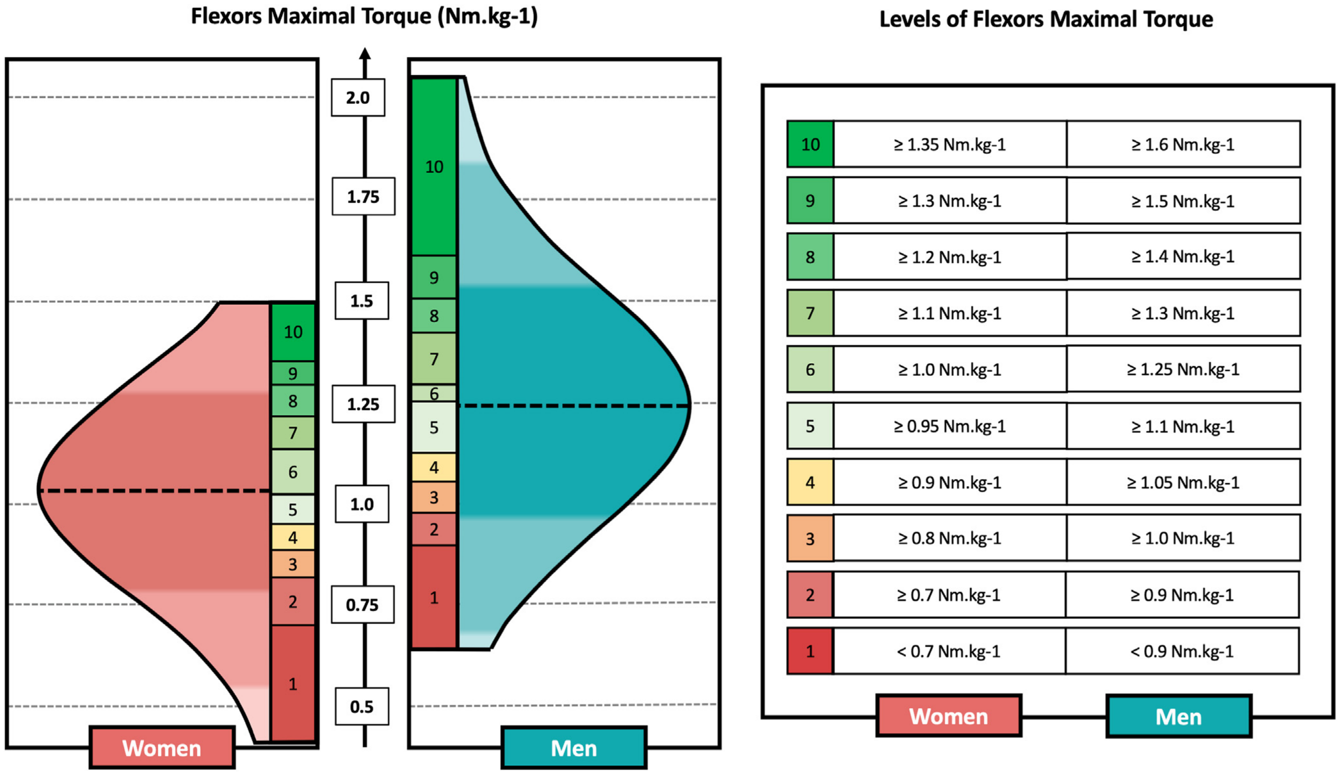


Appendix Fig 1. Normative values and levels of maximal normalized extensors torque.



Appendix Fig 2. Normative values and levels of maximal normalized flexors torque.