Research

Correlation of Knee Joint Stabilization Force with Anterior and Mediolateral Rotational Laxity Using the Arthrometer

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Abstract:
Knee joint laxity is commonly evaluated using instrumented arthrometers; however, the relationship between externally applied stabilization force and measured anterior and rotational laxity remains insufficiently explored. This study aimed to examine the correlation between knee joint stabilization force and both anterior and mediolateral rotational knee laxity in healthy adults. Methods: A cross-sectional study was conducted on 100 healthy participants (50 males and 50 females; aged 18–29 years). One randomly selected knee per participant was assessed using the DYNEELAX arthrometer. Anterior knee laxity was measured at loading forces of 134 N, 150 N, and 200 N. Mediolateral rotational laxity was assessed during medial and lateral rotation at torques of 3 Nm and 5 Nm. Stabilization force was recorded during standardized limb fixation. Associations were analysed using Spearman's correlation coefficient r_s. No meaningful correlations were observed between stabilization force and anterior knee laxity at any loading condition (r_s = -0.055 to -0.061). In contrast, moderate, statistically significant negative correlations were identified between stabilization force and mediolateral rotational laxity across all tested conditions (medial 3 Nm: $r_s = -0.455$; medial 5 Nm: $r_s = -0.554$; lateral 3 Nm: $r_s = -0.554$; lateral 5 Nm: $r_s = -0.553$; all $p < 0.001$). Conclusion: Stabilization force shows no meaningful correlation with anterior knee laxity but demonstrates a moderate inverse correlation with mediolateral rotational laxity. These findings indicate that rotational laxity is more sensitive to testing conditions, emphasizing the importance of standardized stabilization procedures in instrumented knee joint assessment.

Keywords: Knee biomechanics; Ligamentous stability; Tibiofemoral kinematics; Stabilization force; Stability; Healthy adults

1. Introduction

The knee joint, consisting of the tibiofemoral and patellofemoral articulations, is a complex and dynamic structure responsible for load transmission and mobility during activities of daily living (Paterno & Hewett, 2008). It allows a wide range of motion, primarily in flexion–extension and axial rotation, while maintaining joint stability under substantial mechanical demands (Hirschmann & Müller, 2015).

Biomechanically, the knee is classified as a modified hinge joint (trochoginglymus), where motion results from a coordinated interaction of rolling, gliding, and rotational movements. Its kinematics are described by six degrees of freedom. These include rotational components (flexion–extension, internal–external rotation, varus–valgus) and translational components (anterior–posterior, medial–lateral, compression, and distraction). These components interact to maintain joint stability while allowing physiological motion (Hirschmann & Müller, 2015; Noyes et al., 1991).

Knee joint motion differs between open and closed kinetic chain conditions. In open kinetic chain movements, flexion is characterized by posterior rolling and gliding of the tibial plateaus relative to the femoral condyles, accompanied by medial rotation of the tibia, particularly during the initial phase of flexion (approximately the first 30°). During extension, the tibia translates anteriorly through a combination of rolling and gliding, with the terminal phase (last 30°) associated with lateral rotation. In contrast, in closed kinetic chain movements, the kinematic pattern is reversed. Extension involves anterior rolling and posterior gliding of the femoral condyles on the tibial plateaus, together with medial rotation of the femur in the final degrees of motion, commonly referred to as the "screw-home" mechanism. During flexion, posterior rolling and anterior gliding of the femoral condyles occur, accompanied by lateral rotation of the femur at the onset of movement (McGinty et al., 2000).

Joint laxity is an inherent characteristic of physiological joint motion and is assessed passively in clinical settings (Schmitt et al., 2008). Anterior knee laxity is defined as the anterior displacement of the tibia relative to the femur (Shultz et al., 2009), whereas mediolateral rotational laxity refers to the rotational movement of the tibia in relation to the femur (Vassalou et al., 2016).

Increased knee laxity has been associated with a higher risk of ligamentous injury, particularly involving the anterior cruciate ligament (Myer et al., 2008; Pasanen et al., 2025), as well as other knee ligaments (Kim et al., 2010). Quantitative analyses indicate that each additional millimetre of anterior knee laxity increases the likelihood of traumatic knee injury by approximately 30% (odds ratio 1.3) (Vauhnik et al., 2008). Moreover, elevated joint laxity has been linked to the development of osteoarthritis (Heidari, 2011), and individuals with excessive physiological laxity have been shown to exhibit movement patterns associated with non-contact anterior cruciate ligament injury mechanisms (Mouton et al., 2016).

Given these associations, assessment of knee laxity plays an important role in clinical diagnosis, rehabilitation, and injury prevention screening. Traditionally, anterior and rotational laxity are evaluated using manual clinical tests, including the Lachman test, anterior drawer test, dial test, and pivot-shift test (Mouton et al., 2016). However, these assessments are limited by their dependence on examiner experience and their inability to provide precise and reproducible quantitative measurements (Seil et al., 2017).

To address these limitations, several instrumented devices have been developed to standardize the evaluation of knee laxity and replicate manual testing procedures under controlled conditions (Mouton et al., 2016). Commonly reported devices include the KT-1000, KT-2000, GNRB, Rolimeter, and Telos systems (Magdič et al., 2023). More recently, the DYNEELAX® arthrometer has been introduced, enabling sequential assessment of sagittal and axial laxity within a single device without repositioning the tested limb (Mihalinec et al., 2024).

Beyond enabling standardized quantification, instrumented measurements also allow controlled application of stabilization forces during testing. The magnitude of posteriorly directed stabilization force applied at the patella and ankle has been shown to influence measured knee laxity values (Nascimento et al., 2024). Although stabilization force has been suggested to influence measured knee laxity, its direct relationship with anterior and rotational laxity has not yet been specifically examined. Therefore, the purpose of this study was to investigate the relationship between knee joint stabilization force and both anterior and mediolateral rotational laxity, as assessed using the DYNEELAX® arthrometer.

2. Material and Methods

2.1. Ethical approval and study setting

Ethical approval was obtained from the National Medical Ethics Committee of the Republic of Slovenia (No. 0120-436/2024-2711-3). Institutional permission was granted by the Faculty of Health Sciences, University of Ljubljana. All participants provided written informed consent before participation and were informed about the study aims and procedures both verbally and in writing.

The study was conducted at the Biomechanics Laboratory, Faculty of Health Sciences, University of Ljubljana, between June and September 2025. All measurements were performed by a physiotherapist newly trained in the use of the DYNEELAX® arthrometer, who completed a structured training program before data collection. Measurement reliability was confirmed in a pilot study demonstrating acceptable reliability.

2.2. Study design

A cross-sectional study design was used. A total of 100 healthy adults were included (50 males and 50 females). One randomly selected knee from each participant was assessed once. Demographic and anthropometric data were collected, including age, sex, lower limb dominance, body height, and body mass, from which body mass index (BMI) was calculated. In female participants, additional data were collected regarding menstrual cycle regularity, oral contraceptive use, and premenstrual symptoms, due to the potential influence of sex hormones on ligament laxity (Shultz et al., 2004). Lower limb dominance was determined using a standardized question (“If you were to kick a ball toward a target, which leg would you use?”) and verified with a practical ball-kicking task. In cases of inconsistency, the assessment was repeated (van Melick et al., 2017).

2.3. Participants

Participants were recruited using a convenience sampling approach through social media and personal invitations. Eligibility criteria included being 18–30 years old, having no history of lower limb injury or disease, no prior lower extremity surgery, not participating in other studies on the day of testing, and being in good general health. Exclusion criteria were current or previous lower limb pain, history of injury, disease, or surgery affecting the lower extremities, neurological or systemic musculoskeletal conditions, BMI greater than 35 kg/m², pregnancy, and inability to follow instructions or comply with the protocol.

2.4. Measurement instrument

The DYNEELAX® arthrometer is an automated device used to quantify knee joint laxity by measuring anterior–posterior tibial translation and mediolateral tibial rotation. It applies controlled translational and rotational loads to the tibia and records the mechanical response of structures (Genourob, n.d.).

Anterior tibial translation is assessed using forces ranging from 0 to 300 N, applied to the proximal posterior tibia. Displacement is recorded with a sensor placed over the tibial tuberosity, with a resolution of 0.1 mm, enabling quantification of laxity (mm/N). Results are presented as force–displacement curves, where the slope reflects ligament stiffness (Genourob, n.d.; Guegan et al., 2024). Rotational laxity is assessed using torques between 1 and 10 N·m. Tibial rotation is recorded in degrees (°) with a precision of 0.1°, and results are presented as torque–angle curves.

Previous studies have reported moderate reliability for anterior laxity (ICC 0.578–0.71 inter-rater; 0.631–0.71 intra-rater) and good to excellent reliability for rotational laxity (ICC 0.822–0.94 inter-rater; 0.916–0.94 intra-rater) (Mihalinec et al., 2024). Excellent intra-rater reliability for anterior laxity has also been reported in healthy adults (ICC 0.91–0.96) (Nascimento et al., 2024).

The testing protocol followed previously published procedures and manufacturer guidelines.

2.5. Testing protocol

Participants were instructed to avoid high-intensity activities involving rapid directional changes on the day of testing. They received standardized instructions and were encouraged to remain relaxed throughout the procedure. Participants lay in a supine position on a customized examination table, with the trunk flexed to approximately 30°. The tested limb was positioned at 20° of knee flexion and neutral rotation using an adjustable support aligned with the knee joint line. The lower limb was secured using standardized strapping, applied from distal to proximal. Strap tension ranged from 80 to 150 N and was adjusted to participant tolerance. For anterior translation, the sensor was placed over the tibial tuberosity perpendicular to the skin. For rotational measurements, the sensor was positioned on the anterior tibia approximately 2 cm distal to the translation plate. Calibration was performed according to manufacturer guidelines. Anterior laxity was assessed first, followed by rotational laxity. The anterior protocol included one trial at 134 N, one at 150 N, and three trials at 200 N. Rotational testing included one trial at 3 N·m and three trials at 5 N·m for both medial and lateral rotation. The total testing time was approximately 20 minutes.

2.6. Statistical analysis

Data were exported and checked for accuracy before analysis. Statistical analyses were performed using jamovi (version 2.7.12) and Microsoft Excel. Normality was assessed with the Shapiro–Wilk test. Normally distributed data are presented as mean ± standard deviation, while non-normally distributed data are presented as median and interquartile range. Categorical variables are expressed as percentages. For anterior knee laxity assessment, values obtained at 134 N, 150 N, and the final repetition at 200 N were analysed, while for mediolateral rotational laxity, values obtained at 3 N·m and the final repetition at 5 N·m were analysed.

Between-group comparisons were performed using the Mann–Whitney U test or independent samples t-test, as appropriate. The Wilcoxon signed-rank test was used for repeated measures. Categorical variables were analysed using the chi-square or Fisher's exact test. Associations between anterior and rotational laxity were assessed using Spearman's correlation coefficient r_S. Correlation strength was interpreted as negligible (0.00–0.09), weak (0.10–0.39), moderate (0.40–0.69), strong (0.70–0.89), or very strong (0.90–1.00) (Schober et al., 2018). Statistical significance was set at $\alpha = 0.05$.

3. Results

3.1. Participant characteristics

The study included 100 healthy adult participants, 50 males and 50 females, aged 18–29 years. In both sexes, 25 left and 25 right knee joints were assessed. Age and body height were not normally distributed (p-values < 0.001 and 0.026). Body mass and body mass index were normally distributed (p-values 0.082 and 0.144). Within each sex, there were no statistically significant differences between participants whose left or right knee joint was assessed (p-values between 0.437 and 1).

Anthropometric data and other participant characteristics are presented in **Table 1**.

3.2. Correlation of knee joint stabilization force with anterior laxity

Table 2 presents descriptive statistics for knee joint stabilization force and anterior knee laxity measured at 134 N, 150 N, and 200 N. The mean stabilization force was 135.33 N (median 137 N; IQR 13 N). Mean anterior laxity values were 2.92 mm at 134 N, 3.21 mm at 150 N, and 4.52 mm at 200 N, with corresponding medians of 2.85 mm, 3.05 mm, and 4.28 mm. The observed ranges increased with higher loading levels, with maximum values of 6.22 mm, 6.63 mm, and 8.11 mm at 134 N, 150 N, and 200 N, respectively. All variables deviated significantly from normal distribution (Shapiro–Wilk, $p \leq 0.001$)

Figures 1–3 present scatter plots showing the relationship between knee joint stabilization force and anterior laxity at 134 N, 150 N, and 200 N. Spearman's correlation coefficients (r_s) between knee joint stabilization force and anterior laxity were negative under all three loading conditions (134 N: $r_s = -0.055$; 150 N: $r_s = -0.061$; 200 N: $r_s = -0.058$).

Table 1. Anthropometric data of participants by sex and side of the assessed knee joint.

	Men			Women			
	n = 50			n = 50			
	Left	Right		Left	Right		All
Number	25	25	/	25	25	/	100
(%)	(25)	(25)		(25)	(25)		(100)
Age (years)							
Me	22	22	†p = 0.505	22	21	†p = 0.708	22
IQR	3	3		3	2.75		3
Body height (cm)							
Me	180	180	†p = 0.915	166	167	†p = 0.437	175
IQR	11	13		7	7		15
Body mass (kg)							
$\bar{x}$	25	25	*p = 0.480	23	23	*p = 0.810	24
SD	2	2		3	3		3
Dominant leg – n (%)	4	6		2	2		14
Left – n (%)	(16)	(24)		(8)	(8)		(14)
Dominant leg	21	19	‡p = 0.480	23	23	§p = 1	
Right – n (%)	(84)	(76)		(92)	(92)		(86)
RMC - n				19	21	/	40
(%)				(76)	(8)		(12)
O.C. - n	/	/	/	4	2	/	6
(%)				(16)	(8)		(12)
PMS - n	/	/	/	4	5	/	9
(%)				(16)	(20)		(18)

BMI = body mass index; IQR = interquartile range; Me = median; O. C. = oral contraceptives; PMS = premenstrual symptoms; p = p-value; RMC = regular menstrual cycle; SD = standard deviation; $\bar{x}$ = mean; * = independent samples t-test (comparison between left and right side within the same sex); † = Mann–Whitney U test (comparison between left and right side within the same sex); ‡ = χ^2 test (comparison of distribution between left and right side and lower limb dominance in males); § = Fisher's exact test (comparison of distribution between left and right side and lower limb dominance in females)

Table 2. Descriptive statistics of knee joint stabilization force and anterior knee laxity measured at 134 N, 150 N, and 200 N.

	Force (N)	134 N (mm)	150 N (mm)	200 N (mm)
Mean	135	2.92	3.21	4.52
Median	137	2.85	3.05	4.28
IQR	13	1.06	1.19	1.22
Minimum	103	1.41	1.59	2.83
Maximum	149	6.22	6.63	8.11
Shapiro-Wilk p	< 0.001	0.001	<0.001	<0.001

IQR = interquartile range

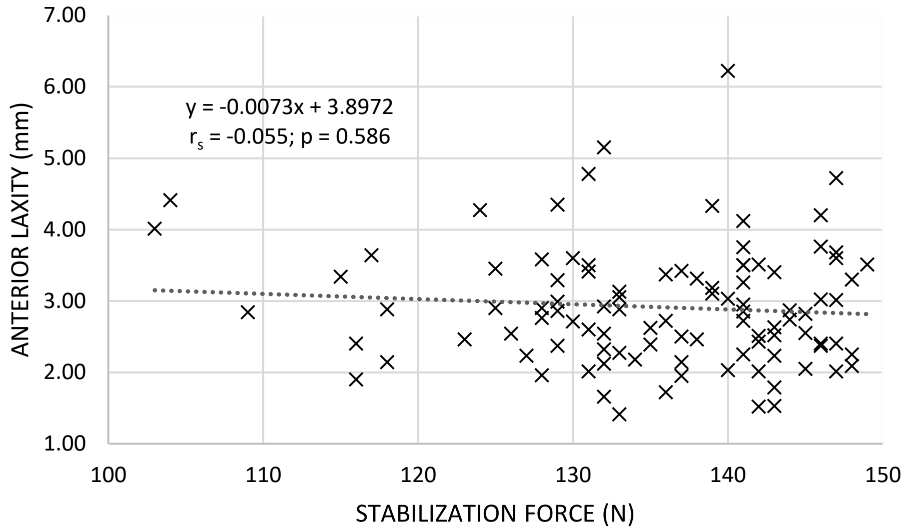

Figure 1. Correlation of knee joint stabilization force with anterior laxity at 134 N. The dotted line represents the fitted regression line; the corresponding equation, r_s, and p-value are shown within the figure.

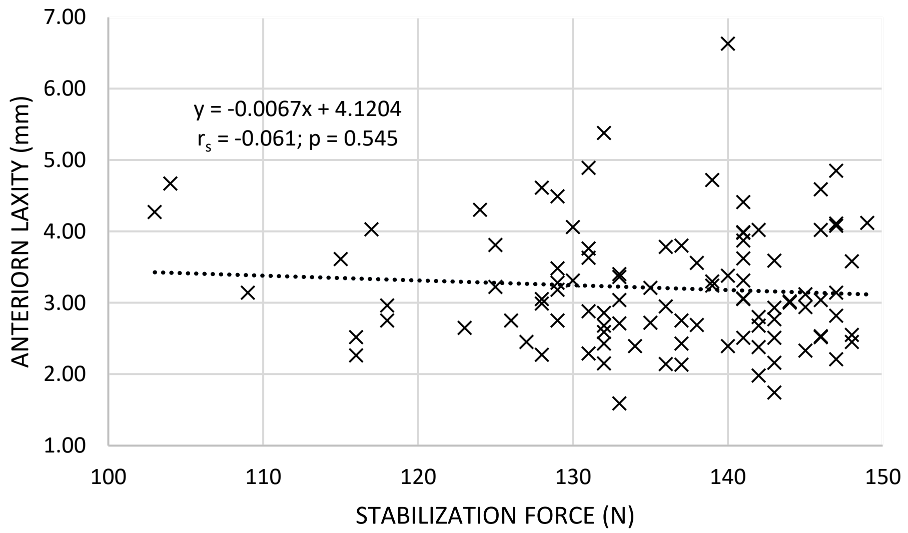

Figure 2. Correlation of knee joint stabilization force with anterior laxity at 150 N. The dotted line represents the fitted regression line; the corresponding equation, r_s, and p-value are shown within the figure.

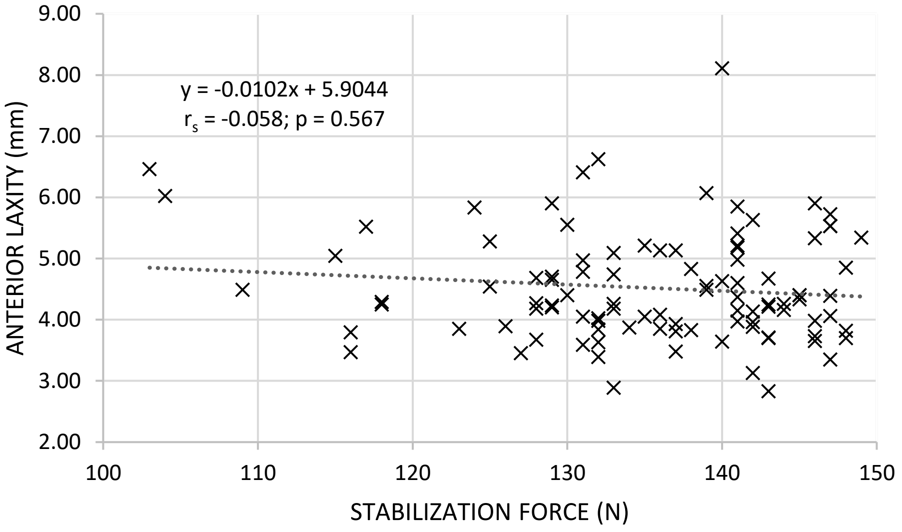

Figure 3. Correlation of knee joint stabilization force with anterior laxity at 200 N. The dotted line represents the fitted regression line; the corresponding equation, r_s, and p-value are shown within the figure.

3.3. *Correlation of knee joint stabilization force with mediolateral rotational laxity*

Table 3 presents descriptive statistics for knee joint stabilization force and mediolateral rotational knee laxity measured during medial and lateral rotation at 3 Nm and 5 Nm. Median medial rotation laxity was 4.67° at 3 Nm and 7.65° at 5 Nm, while median lateral rotation laxity was 6.22° at 3 Nm and 10.44° at 5 Nm. The interquartile ranges increased with higher torque levels, with the greatest variability observed for lateral rotation at 5 Nm (IQR 9.33°). Maximum values were 12.37°, 19.61°, 16.17°, and 25.83° for medial 3 Nm, medial 5 Nm, lateral 3 Nm, and lateral 5 Nm, respectively. Shapiro–Wilk test results showed that all variables significantly deviated from normal distribution ($p \leq 0.05$).

Table 3. Descriptive statistics of knee joint stabilization force and mediolateral rotation knee laxity measured at 3 and 5 Nm.

	Medial rotation (Nm)	Medial rotation (Nm)	Lateral rotation (Nm)	Lateral rotation (Nm)
	3 Nm	5 Nm	3 Nm	5 Nm
Median	4.67	7.65	6.22	10.44
IQR	3.42	5.82	6.54	9.33
Minimum	0.24	2.6	1.18	2.97
Maximum	12.37	19.61	16.17	25.83
Shapiro-Wilk p	0.026	<0.001	<0.001	<0.001

IQR = interquartile range

Figures 4 and 5 present scatter plots showing the relationship between knee joint stabilization force and mediolateral rotational laxity at 3 and 5 N·m. Spearman's correlation coefficients between knee joint stabilization force and rotational laxity were negative under all conditions (medial 3 Nm: $r_s = -0.455$; medial 5 Nm: $r_s = -0.554$; lateral 3 Nm: $r_s = -0.554$; lateral 5 Nm: $r_s = -0.553$), and all correlations were statistically significant ($p < 0.001$).

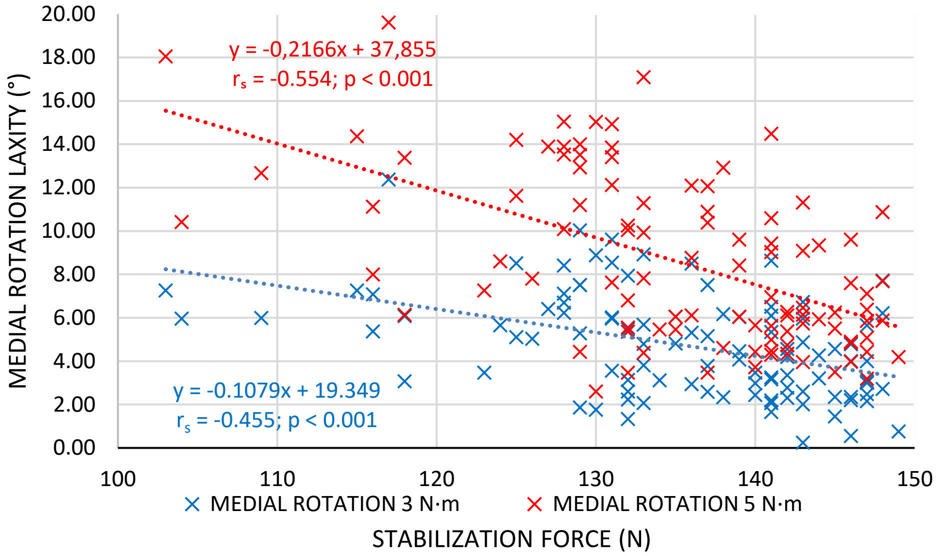

Figure 4. Correlation of knee joint stabilization force with medial rotation laxity at 3 and 5 Nm. The dotted line represents the fitted regression line; the corresponding equation, r_s, and p-value are shown within the figure.

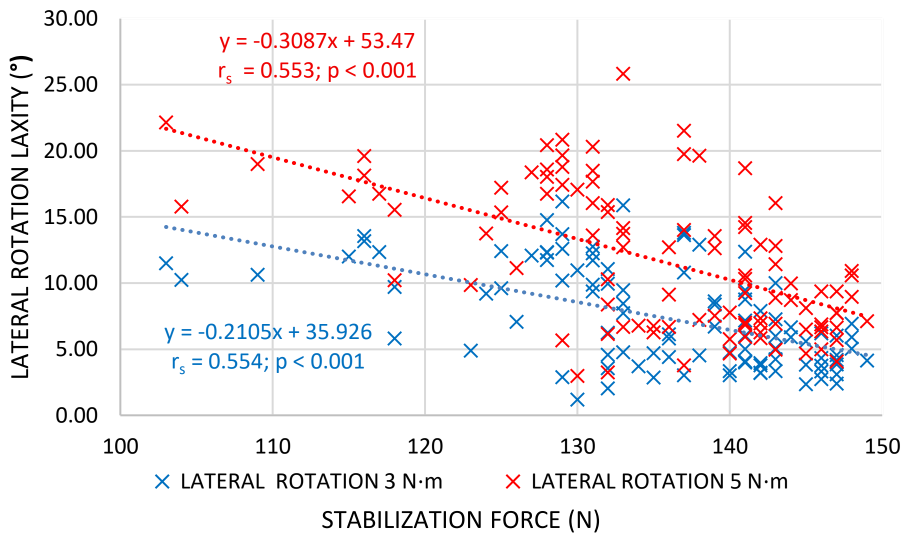

Figure 5. Correlation of knee joint stabilization force with lateral rotation laxity at 3 and 5 Nm. The dotted line represents the fitted regression line; the corresponding equation, r_s, and p-value are shown within the figure.

4. Discussion

The aim of this study was to investigate the relationship between knee joint stabilization force and both anterior and mediolateral rotational knee laxity in healthy young adults using the DYNEELAX® arthrometer. The principal finding was that stabilization force showed no meaningful relationship with anterior knee laxity, while moderate, statistically significant negative correlations were observed with mediolateral rotational laxity. These findings suggest that the influence of stabilization during instrumented knee testing differs depending on the type of laxity being assessed.

The absence of a significant association between stabilization force and anterior laxity across all three loading conditions (134 N, 150 N, and 200 N) indicates that anterior laxity measurements may be relatively robust to variations in external fixation force within the tested range. Although weak negative correlations were observed, their magnitude was negligible, suggesting that increased stabilization does not substantially alter anterior translation values in healthy knees. This may be explained by the biomechanical characteristics of sagittal plane knee stability. At approximately 20° of knee flexion, as used in the present protocol, anterior tibial displacement is primarily restrained by the anterior cruciate ligament (Kreder & Hawker, 2010), with additional support from secondary passive stabilizers such as the iliotibial band, collateral ligaments, menisci, and surrounding capsuloligamentous structures (Rahnemai-Azar et al., 2017). Therefore, suggesting that anterior laxity measurements primarily reflect intrinsic ligamentous behaviour, with minimal influence of externally applied stabilization force within the tested range.

This finding is consistent with previous work using the DYNEELAX® system, which reported high intra-rater reliability for anterior translation under standardized stabilization conditions, indicating that anterior measurements are relatively stable, reliable and reproducible (Cojean et al., 2023). The present results build on these observations by suggesting that even when stabilization force varies between participants, anterior laxity values remain largely unaffected.

In contrast, the results showed moderate negative correlations between stabilization force and rotational laxity under all tested torque conditions. The strongest association was observed for medial rotation at 5 N·m (r_s = -0.554), with similar values for lateral rotation. These findings indicate that greater stabilization force is associated with lower measured rotational displacement. From a biomechanical perspective, this result is plausible, as greater stabilization likely increases patellofemoral joint compression and enhances joint stability, thereby limiting mediolateral rotational freedom (Cojean et al., 2023).

Rotational knee laxity is known to be more sensitive to testing conditions (Mouton et al., 2016), as axial rotation is influenced not only by intra-articular ligamentous structures but also by periarticular soft tissues (Mayr et al., 2024; Vap et al., 2017), skin movement (Gimm et al., 2026) and the effectiveness of limb fixation during testing (Musahl et al., 2010). Greater stabilization likely reduces accessory motion of surrounding soft tissues and minimizes unintended movement of the entire limb segment, thereby decreasing the measured rotational excursion. This suggests that part of the measured rotational laxity may represent non-articular motion rather than true tibiofemoral rotation. In other words, part of the observed rotational displacement may reflect soft tissue compliance or slight limb movement rather than pure joint motion.

This interpretation is particularly important in the context of instrumented arthrometry, where the precision of rotational measurements depends on fixation of the lower limb (Gimm et al., 2026). Previous literature has emphasized that rotational laxity is highly variable and influenced by measurement setup, flexion angle, and sensor location (Mouton et al., 2016). The present findings further support the need for rigorous standardization of stabilization procedures, especially when rotational parameters are used for clinical decision-making or research comparisons.

From a clinical perspective, these findings may have direct implications for the use of the DYNEELAX® arthrometer and similar devices. While minor variations in stabilization force may not substantially affect anterior laxity outcomes, they appear to have a measurable effect on rotational assessments. This suggests that clinicians and researchers should pay particular attention to maintaining consistent stabilization force during rotational testing to improve measurement validity, reliability and comparability between sessions and examiners. This may be especially relevant in the evaluation of ligamentous injuries involving rotational instability, such as anterior cruciate ligament insufficiency or combined anterolateral complex injuries.

Although the present study does not permit determination of an optimal stabilisation force threshold, the observed inverse association between stabilisation force and rotational laxity suggests that greater stabilisation may improve the precision and consistency of rotational measurements. During testing, participants were instructed to remain relaxed, while stabilisation forces were standardised between 80 and 150 N according to participant tolerance. In functional conditions, however, muscular forces acting around the knee joint are substantially greater than the externally applied stabilisation forces used during arthrometry. Therefore, insufficient fixation may allow additional accessory movement of the limb and surrounding soft tissues, potentially contributing to increased measured rotational displacement. From a methodological perspective, these findings suggest that higher and well-standardised stabilisation forces may be preferable when assessing rotational knee laxity.

Several limitations of this study should be acknowledged. First, the cross-sectional design precludes causal inferences. Second, the sample consisted exclusively of healthy young adults, limiting generalizability to injured and older populations. Third, although measurements followed standardized procedures, all assessments were conducted by a single examiner, which may reduce external validity despite prior training and pilot reliability testing. Fourth, electromyography (EMG) was not used to verify whether participants were fully relaxed during the assessments.

Future studies should investigate whether the observed relationship between stabilization force and rotational laxity is also present in individuals with ligamentous injuries, particularly anterior cruciate ligament-deficient knees, where rotational instability is often clinically relevant. Furthermore, establishing an optimal and standardized stabilization force range may contribute to improved reproducibility of rotational knee laxity measurements across different arthrometers and clinical settings.

In conclusion, the present study demonstrated that knee joint stabilization force is moderately and inversely associated with mediolateral rotational laxity, while no meaningful relationship was observed with anterior laxity. These findings underscore the importance of standardized stabilization procedures, particularly for rotational knee laxity assessment, and provide clinically relevant information for improving the precision of instrumented knee joint evaluation.

5. Conclusions

This study examined the relationship between knee joint stabilization force and anterior and mediolateral rotational knee laxity in healthy young adults using the DYNEELAX® arthrometer. The results showed no significant association between stabilization force and anterior knee laxity, indicating that anterior laxity measurements are relatively robust to variations in external fixation within the tested range. In contrast, mediolateral rotational laxity showed consistent moderate inverse associations with stabilization force, indicating that higher stabilization is associated with lower measured rotational displacement.

These findings suggest that rotational laxity is more sensitive to testing conditions than anterior laxity, likely reflecting the greater contribution of periarticular soft tissues and the dependence of rotational measurements on effective limb fixation. From a clinical and methodological perspective, this underscores the importance of maintaining consistent and well-controlled stabilization procedures, particularly when assessing rotational knee laxity.

Overall, stabilization force appears to be a relevant factor associated with rotational, but not anterior, knee laxity. Ensuring standardized testing conditions may therefore improve the accuracy, validity, and comparability of instrumented knee joint measurements in both research and clinical practice.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the National Medical Ethics Committee of the Republic of Slovenia (No. 0120-436/2024-2711-3). All procedures were performed in accordance with relevant guidelines and regulations, and informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Cojean T, Batailler C, Robert H, Cheze L. Sensitivity, repeatability and reproducibility study with a leg prototype of a recently developed knee arthrometer: The DYNEELAX®. Med. Nov. Technol. Devices. 2023; 19: 100254. DOI: 10.1016/J.MEDNTD.2023.100254
2. Genourob. (n.d.). Dyneelax knee arthrometer. Available at: Https://Arthrometer.Com/Dyneelax-Knee-Arthrometer/. Access 28.05.2026
3. Gimm G, Park S, Kim MS, Han HS, Kim S. Validation and reliability of a novel portable automated knee arthrometer: a cadaveric study bridging the skin-to-bone gap and suggesting medial pivotal rotation as a superior marker for ACL deficiency. J Orthop Surg Res. 2026; 21:98. DOI:10.1186/s13018-025-06627-w
4. Guegan B, Drouineau M, Common H, Robert H. All the menisco-ligamentary structures of the medial plane play a significant role in controlling anterior tibial translation and tibial rotation of the knee. Cadaveric study of 29 knees with the Dyneelax® laximeter. J Exp Orthop. 2024; 11:e12038. DOI:10.1002/jeo2.12038

5. Heidari B. Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part I. Caspian J Intern Med. 2011; 2:205-212.
6. Hirschmann MT, Müller W. Complex function of the knee joint: the current understanding of the knee. Knee Surg Sports Traumatol Arthrosc. 2015 ;23:2780-2788. DOI:10.1007/s00167-015-3619-3
7. Kim SJ, Kumar P, Kim SH. Anterior cruciate ligament reconstruction in patients with generalized joint laxity. Clin Orthop Surg. 2010; 2:130-139. DOI:10.4055/cios.2010.2.3.130
8. Kreder HJ, Hawker G.A. (2010). The Knee. Fam's Musculoskeletal Examination and Joint Injection Techniques. Ed.Mosby. Second Edition. 2010, pp. 65–88. https://doi.org/10.1016/B978-0-323-06504-7.10006-5
9. Magdič M, Dahmane RG, Vauhnik R. Intra-rater reliability of the knee arthrometer GNRB® for measuring knee anterior laxity in healthy, active subjects. J Orthop. 2023; 39:7-10. DOI:10.1016/j.jor.2023.03.016
10. Mayr HO, Rosenstiel N, Prakash KS, et al. Internal Rotation Measurement of the Knee with Polymer-Based Capacitive Strain Gauges versus Mechanical Rotation Measurement Taking Gender Differences into Account: A Comparative Analysis. Life (Basel). 2024; 14:142. DOI:10.3390/life14010142
11. McGinty G, Irrgang JJ, Pezzullo D. Biomechanical considerations for rehabilitation of the knee. Clin Biomech (Bristol). 2000; 15:160-166. DOI:10.1016/s0268-0033(99)00061-3
12. Mihalinec K, Martinez-Cepa CB, Zuil-Escobar JC, Kejžar N, Vauhnik R. Intra-rater and inter-rater reliability of robotic arthrometer DYNEELAX®. J Exp Orthop. 2024; 11:e70026. DOI:10.1002/jeo2.70026
13. Mouton C, Theisen D, Seil R. Objective measurements of static anterior and rotational knee laxity. Curr Rev Musculoskelet Med. 2016; 9:139-147. DOI:10.1007/s12178-016-9332-0
14. Musahl V, Voos J, O'Loughlin PF, Stueber V, Kendoff D, Pearle AD. Mechanized pivot shift test achieves greater accuracy than manual pivot shift test. Knee Surg Sports Traumatol Arthrosc. 2010; 18:1208-1213. DOI:10.1007/s00167-009-1004-9
15. Myer GD, Ford KR, Paterno MV, Nick TG, Hewett TE. The effects of generalized joint laxity on risk of anterior cruciate ligament injury in young female athletes. Am J Sports Med. 2008; 36:1073-1080. DOI:10.1177/0363546507313572
16. Nascimento N, Kotsifaki R, Papakostas E, et al. DYNEELAX Robotic Arthrometer Reliability and Feasibility on Healthy and Anterior Cruciate Ligament Injured/Reconstructed Persons. Transl Sports Med. 2024; 2024:3413466. DOI:10.1155/2024/3413466
17. Noyes FR, Cummings JF, Grood ES, Walz-Hasselfeld KA, Wroble RR. The diagnosis of knee motion limits, subluxations, and ligament injury. Am J Sports Med. 1991; 19:163-171. DOI:10.1177/036354659101900212
18. Pasanen K, Seppänen A, Leppänen M, et al. Knee laxity, joint hypermobility, femoral anteversion, hamstring extensibility and navicular drop as risk factors for non-contact anterior cruciate ligament injury in female athletes: A 4.5-year prospective cohort study. Knee Surg Sports Traumatol Arthrosc. 2025; 33:4120-4127. DOI:10.1002/ksa.12625
19. Paterno MV, Hewett TE. Biomechanics of Multi-ligament Knee Injuries (MLKI) and Effects on Gait. N Am J Sports Phys Ther. 2008; 3:234-241.
20. Rahnemai-Azar AA, Zlotnicki J, Burnham JM, Guenther D, et al. (2017). Secondary Stabilizers of the Anterior Cruciate Ligament—Deficient Knee. Oper. Tech. Orthop. 2017; 27:107–112. DOI:10.1053/J.OTO.2017.02.005
21. Schmitt LC, Fitzgerald GK, Reisman AS, Rudolph KS. Instability, laxity, and physical function in patients with medial knee osteoarthritis. Phys Ther. 2008; 88:1506-1516. DOI:10.2522/ptj.20060223
22. Schober P, Boer C, Schwarte LA. Correlation Coefficients: Appropriate Use and Interpretation. Anesth Analg. 2018; 126:1763-1768. DOI:10.1213/ANE.0000000000002864
23. Seil R, Robert H, Theisen D, & Mouton C. Instrumented Static Laxity Evaluation. In Controversies in the Technical Aspects of ACL Reconstruction (pp. 413–428). Springer Berlin Heidelberg. 2017. DOI: 10.1007/978-3-662-52742-9_38
24. Shultz SJ, Kirk SE, Johnson ML, Sander TC, Perrin DH. Relationship between sex hormones and anterior knee laxity across the menstrual cycle. Med Sci Sports Exerc. 2004; 36:1165-1174. DOI:10.1249/01.mss.0000132270.43579.1a
25. Shultz SJ, Nguyen AD, Levine BJ. The Relationship Between Lower Extremity Alignment Characteristics and Anterior Knee Joint Laxity. Sports Health. 2009; 1:54-60. DOI:10.1177/1941738108326702
26. van Melick N, Meddeler BM, Hoogeboom TJ, Nijhuis-van der Sanden MWG, van Cingel REH. How to determine leg dominance: The agreement between self-reported and observed performance in healthy adults. PLoS One. 2017; 12:e0189876. DOI:10.1371/journal.pone.0189876
27. Vap AR, Schon JM, Moatshe G, et al. The Role of the Peripheral Passive Rotation Stabilizers of the Knee With Intact Collateral and Cruciate Ligaments: A Biomechanical Study. Orthop J Sports Med. 2017; 5:2325967117708190. DOI:10.1177/2325967117708190

28. Vassalou EE, Klontzas ME, Kouvidis GK, Matalliotaki PI, Karantanas AH. Rotational Knee Laxity in Anterior Cruciate Ligament Deficiency: An Additional Secondary Sign on MRI. AJR Am J Roentgenol. 2016; 206:151-154. DOI:10.2214/AJR.15.14816
29. Vauhnik R, Morrissey MC, Rutherford OM, Turk Z, Pilih IA, Pohar M. Knee anterior laxity: a risk factor for traumatic knee injury among sportswomen?. Knee Surg Sports Traumatol Arthrosc. 2008; 16:823-833. DOI:10.1007/s00167-008-0559-1