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Original Scientific Paper

REPEATIBILITY AND RELIABILITY OF KNEE JOINT ROTATIONAL LAXITY MEASUREMENTS WITH DOUBLE GONIOMETRY

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SUMMARY – The results of existing studies on the range of motion in the knee joint rotation are contradictory. The best method for measuring knee rotation has not yet been found. The purpose of this study was to investigate the repeatability and reliability of knee joint rotational laxity measurement using two magnetic goniometers. Thirty healthy subjects (15 males and 15 females) aged between 20 and 32 years participated in the study. Internal and external rotation of the left and right knee joints were measured with double goniometry in the sitting position with 90° flexion of the knee. There was no statistically significant difference in measurements between first and second session. The intraclass correlation coefficient (ICC) for repeatability ranged from 0.812 to 0.858 and for reliability from 0.655 to 0.837. Within-subject coefficient of variation was less than 10%, standard error of measurement was between 1.4° and 2.0°, minimal detectable change was between 2.5° and 3.8°. The measured values of internal and external rotation did not completely agree with those reported by other authors. The ICC values indicated good to very good repeatability and reliability of the double goniometry measurement of rotational knee laxity. Technical improvements will be required before translation into clinical practice.

Key words: *Rotational laxity; Knee joint; Double goniometry; Range of motion*

Introduction

There are inconsistencies in the literature regarding the terminology used to describe knee instability. The terms instability, laxity and disability are often misused. Laxity can be physiological or pathological. Pathological laxity is defined as the excessive movement of a joint within the constraints of its ligaments and other structures; instability is defined as the inability to maintain position because the joint subluxations due to pathological laxity; and instability is defined as the instability that interferes with required function. The stability of the knee joint is maintained by the shape of the condyles and menisci in combination with passive support structures. These are the four main ligaments, the anterior cruciate ligament, the posterior cruciate ligament, the medial collateral ligament, and the lateral collateral ligament. The posteromedial and posterolateral capsular components and the iliotibial tract also have an important contribution. Muscles acting above the joint provide dynamic stability. Knee instability has a high incidence rate and affects both young[1,2] and older individuals[3,4]. The impact of knee instability can be severe and is associated with an increased risk of falls[4] and a long period of rehabilitation[5]. Knee rotation

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plays an important role in weight bearing in the lower limbs, for example, changing direction during walking, running and jumping[6]. There are several types of rotational instability of the knee joint, including posterolateral rotational instability due to injury to the posterolateral corner, medial rotational instability due to injury to the anterolateral ligament, and anteromedial instability[7]. Obliquely reconstructed anterior cruciate ligaments could also affect rotational instability and long-term outcome[8]. Therefore, measuring tibia rotation is important to evaluate these knee joint problems.

Knee laxity measurements usually describe how the proximal part of the tibia can move away from its normal equilibrium position relative to the distal part of the femur. Laxity refers to the ability of the knee to translate or rotate in a specific direction and can be measured as either translation or rotation caused by the applied force or torque required for the said movements in the knee joint. Measurements or tests can be static or dynamic. Static clinical tests must have good measurement properties and be quick, simple, easy and inexpensive to perform.

The literature has not yet defined how to measure rotation in the knee joint in the most objective way[9]. There is no simple, commercially available device for measuring knee rotation[10]. Different protocols and methods have been used to measure rotation in the knee joint, so it is difficult to determine normative values[11]. There are several reasons for such obvious differences in rotation values. Noninvasive measurement of rotation in the knee joint with a device is not accurate due to movement between soft tissue and bone[11]. Differences in research results may also be the result of different neutral or starting positions[12]. Mossberg and Smith[12] state that maximum rotation is possible at 90° of flexion at the knee joint, and increases proportionally with flexion. The problem in measuring the active rotation of the knee joint is the fact that movements occur simultaneously in adjacent joints[12]. Movements in the hip, ankle and foot[12] influence rotation in the knee joint. It is easy to stabilize the hip, but it is very difficult to completely prevent movements in the ankle joints and in the foot[12]. The sitting position is good for measuring isolated knee rotation because it provides stabilization of the hip, thigh, and ankle, but it is not functional because the knee is not under load as in everyday life[13]. For this reason, some authors measured it actively and under load, similar to real life conditions[14].

The existing methods for measuring rotation in the knee joint require expensive equipment, or the equipment and accessories are still large, making them unsuitable for clinical use. For this reason, we developed a new method that requires the use of a clamp, two magnetic needle goniometers, a universal goniometer, a fixation strap, and some washers. The aim of the research was to evaluate the measurement characteristics of a new method for measuring rotation in the knee joint that is simple, inexpensive, and applicable in all environments.

Subjects and Methods

Subjects

Healthy subjects between the ages of 20 and 35 who had no knee injuries and/or surgeries participated in the study. Subjects with knee pain or conditions for which rotational measurement could exacerbate symptoms, who experienced pain during measurement, who did not want to participate in the study, or who changed their mind during the study were not included in the study.

Some demographic (sex, decimal age) and anthropometric data (limb dominance, body height, and body weight) were collected from the subjects.

Measuring devices and accessories

For the measurement of knee joint rotation, we used two magnetic needle goniometers (OB goniometer Myrin FOLLO A/S, Norway), a goniometer with telescopic arms (Lafayette Instrument Co., USA), ergonomic inserts for epicondyles made with a 3D printer that we placed on the clamp, and an insert made with a 3D printer to place a second magnetic goniometer perpendicular to the clamp above the knee.

Measurement method

When measuring rotation in the knee, the axis of motion was vertical and the plane of motion was horizontal. The measurement was performed by an examiner (first author) squatting in front of the subject. Before starting the measurement, he marked

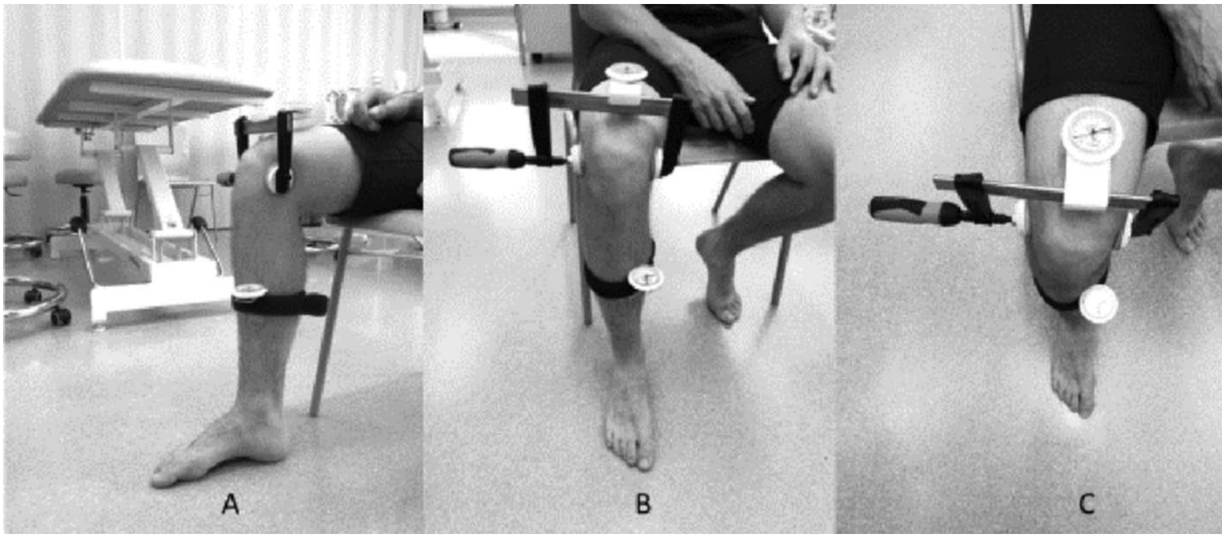

Fig. 1. Starting position for measuring knee rotation with dual goniometry: medial (A), anterior (B), and superior (C) views.

the medial and lateral femur epicondyles of both legs. Before measuring rotations in the knee joint, one goniometer was placed on a clamp perpendicular to the femur and attached to the epicondyles of the femur. The second goniometer was attached with an elastic Swedish zipper tie in the middle of the medial part of the tibia, where the body of the tibia is highlighted just under the skin (Fig. 1).

When measuring rotations in the knee joint, the subject sat in a chair with the knee and hip joints in 90° flexion and the foot on the floor (Fig. 1A and 1B). Flexion at the knee and hip was determined with a telescopic goniometer. In the starting position, the second toe was aligned with the center of the patella and the center of the thigh (Fig. 1C). The position and weight of the body were sufficient for the stabilization conditions. The examiner maintained maximum dorsiflexion in the upper ankle joint over the distal part of the foot with one hand and on the mid-tibia with the other hand. Then, the examiner rotated the tibia outward and inward with both hands until the end of motion was felt. The sensation of the end of motion was firm during internal and external rotation due to soft tissue tension, as internal rotation was primarily limited by tension in both cruciate ligaments and medial collateral ligaments, and external rotation was primarily limited by tension in the posterior portion of the posterior cruciate ligaments and lateral collateral ligaments. The investigator read the measurements on both goniometers. From the values measured with the distal goniometer, he subtracted the values of the proximal goniometer and obtained the range of motion in the selected direction. The total range of motion was equal to the sum of the range of motion of the external rotation and internal rotation of the knee joint.

Ethics

The Medical Ethics Committee of the Republic of Slovenia approved the study (No.: 0120-309/2017-5). Before the test was performed, the subjects were informed about the purpose and procedure of the examination. Based on the text they read, they were able to sign a consent form for voluntary participation in the investigation.

Statistics

Results were presented using descriptive statistics (mean ($\bar{X}$) and standard deviation (SD)). The Kolmogorov-Smirnov test was used to check normal distribution of the data. The difference between the means of three consecutive measurements was tested using one-way analysis of variance for repeated measures. If the mean measurements were statistically significantly different, post hoc t-test with Bonferroni correction was performed. Statistical significance was set at $p \leq 0.05$.

The accuracy of the measurements was assessed in terms of the percentage coefficient of variation (CV (%) = SD/X̄*100) between individuals and within an individual. When CV was less than 10%, accuracy was excellent, 10% to 20% it was good, 20% to 30% it was acceptable, and greater than 30% it was unacceptable.

Repeatability and reliability were evaluated using the intraclass correlation coefficient (ICC, (2.1)). ICC values below 0.50 indicate poor reproducibility and reliability, between 0.50 and 0.75 indicate moderate reproducibility and reliability, between 0.75 and 0.90 indicate good reproducibility and reliability, and above 0.90 indicate excellent reliability[15].

We also calculated the standard error of measurement (SEM=SD×√1-ICC) and the minimal detectable change (MDC95=1.96×√2×SNM). It serves as a complement to the reliability coefficient and is an estimate of the measurement accuracy. When the test is completely reliable, the SEM is equal to zero, and when the test is completely unreliable, the SEM is largest and is equal to the standard deviation of the observed results. MDC95 can be interpreted as the level of change within which there is a greater than 95% probability that no real difference occurred[16].

Data were processed using MedCalc Statistical Software version 14.12.0 (MedCalc Software bvba, Ostend, Belgium) and Microsoft Excel (version 2013, Microsoft Corporation, Redmond, USA).

Results

Thirty healthy young subjects participated in the study. Males were significantly taller, heavier, and had a higher body mass index. Subjects did not differ in age and lower limb dominance (Table 1).

Table 1. Characteristics of study subjects

	Age (years) X̄ (SD)	**Body height (m) X̄ (SD)**	**Body mass (kg) X̄ (SD)**	**BMI (kg/m²) X̄ (SD)**	**Dominance (R/L)**
All (N=30)	23.8 (2.5)	1.74 (0.10)	68.4 (12.2)	22.4 (2.0)	24/6
Female (n=15)	24.4 (2.9)	1.67 (0.05)	58.9 (5.7)	21.1 (1.6)	13/2
Male (n=15)	23.1 (1.7)	1.81 (0.07)	77.9 (9.0)	23.7 (1.4)	11/4
p	0.1593	**<0.0001**	**<0.0001**	**<0.0001**	0.3995

BMI = body mass index; X̄ = mean; SD = standard deviation; R/L = right/left

Table 2. Measured values of internal rotation, external rotation and full range of motion of rotation for three consecutive measurements and means of three measurements in the first and second session for both knees

Movement	**Session**	**Measurement X̄ (SD)**				
		1	**2**	**3**	**p**	**Mean**
Internal rotation (°)	First	10.9 (2.6)	10.8 (2.8)	10.7 (2.5)	0.311	10.8 (2.5)
	Second	10.6 (2.4)	10.9 (2.4)	10.7 (2.5)	0.466	10.7 (2.3)
p		1.000	1.000	1.000		0.774
External Rotation (°)	First	21.9 (3.4)	21.4 (3.5)	21.6 (3.9)	0.306	21.7 (3.4)
	Second	22.3 (3.7)	22.3 (3.8)	22.1 (3.7)	0.590	22.2 (3.6)
p		1.000	0.712	1.000		0.129
Total rotation (°)	First	32.9 (4.7)	32.2 (4.8)	32.3 (5.1)	0.165	32.5 (4.6)
	Second	32.8 (5.2)	33.2 (5.3)	32.8 (5.4)	0.968	32.9 (5.0)
p		1.000	0.872	1.000		0.323

X̄ = mean; SD = standard deviation

Table 3. Repeatability of consecutive measurements of rotation laxity

Movement	Session	ICC (2.1)	95% confidence interval
Internal rotation	First	0.812	0.729-0.875
	Second	0.812	0.729-0.875
External rotation	First	0.817	0.736-0.879
	Second	0.851	0.783-0.903
Total rotation	First	0.852	0.784-0.903
	Second	0.858	0.793-0.907

ICC = intraclass correlation coefficient

Table 4. Reliability of rotation laxity

Movement	ICC (2.1)	95% confidence interval
Internal rotation	0.655	0.420-0.794
External rotation	0.798	0.663-0.879
Total rotation	0.837	0.727-0.902

ICC = intraclass correlation coefficient

Table 5. Standard error of measurement and minimum detectable change of the mean value of three measurements

Movement	Session	SEM (°)	MDC (°)	Within group CV (%)	Within subject CV (%)
Internal rotation	First	1.5	3.3	22.9	9.7 (4.3)
	Second	1.4	3.3	21.2	9.0 (4.9)
External rotation	First	1.5	3.4	15.6	5.5 (3.9)
	Second	1.6	2.5	16.0	5.8 (3.6)
Total rotation	First	1.9	3.8	14.3	5.1 (2.8)
	Second	2.0	2.5	15,3	5.1 (3.6)

SEM = standard error of measurement; MDC = minimum detectable change; CV = coefficient of variation

Difference in the extent of internal and external rotation between the left and right sides was not statistically significant. Measurements of internal, external, and total rotation were not significantly different between consecutive measurements or between sessions. The range of motion of internal rotation was on average half that of external rotation (Table 2).

Repeatability of the test was good to excellent for all measurements obtained, as the ICC was above 0.800. The lowest ICC was calculated for the measurements of internal rotation and highest for the measurements of the total range of motion of rotation (Table 3).

The mean values of three consecutive measurements had the best reliability, as the ICC values were above 0.600. Reliability was poor to moderate for internal rotation, good to very good for external rotation, and good to excellent for total rotation (Table 4).

Standard error of measurement was highest for total range of motion measurements and approximately equal for external and internal rotation measurements. Minimal detectable change ranged from 2.5° (external rotation and total rotation) to 3.8° (total rotation). Overall, the MDC was lower on second measurement. Within group, CV was highest for internal rotation and lower for external rotation and total range of motion measurements. The accuracy of measurements for individual subjects was excellent, as all CV were less than 10% and did not differ significantly between sessions (Table 5).

Discussion

In the late 1960s and early 1970s, attention began to be paid to rotational laxity of the knee due to anterior cruciate ligament injuries[17]. Assessment of rotational laxity of the knee is becoming standard practice in most institutions, emphasizing the need of standardization and uniform documentation. It is important that measurement devices provide reliable measurements that allow confidence in reporting and interpretation of results[15]. The aim of our study was to test the method of measuring rotation in the knee joint using two goniometers on a magnetic needle. Rotation in the knee joint was measured in healthy subjects. In each subject, we paid attention to compliance with the test protocol and the determined position. In the literature, different authors[11-13,18-20] found a similar position of the subjects when measuring rotation in the knee joint, namely 90° flexion, since in this position the maximum rotation should be possible[12]. The values of CV, ICC, SEM, and MDC reported in this paper demonstrate the acceptable reliability of double goniometry in testing the rotational laxity of the knee joint in healthy young people.

Studies[21,22] have shown that the rotational laxity of the knee joint varies greatly among subjects and can range from 20° to 65° of rotation depending on the flexion range of the knee joint and the testing procedure. Therefore, to compare the measured values, we included studies[12,21,23] in which measurements were taken in a similar position, and the end of the range of motion was determined by the sensation at the end feel of the movement. The values we obtained for internal rotation were similar, but were different for external rotation and total range of motion. The highest values for both movements were measured by Mossberg and Smith[12], which is to be expected since only women participated in their study. Females have a greater range of motion than males[20,24,25]. In the aforementioned studies, dispersion of the measured values was higher, as they had larger standard deviations, indicating less accurate measurements or greater variability of the measured values among the subjects. As in our study, other authors[2,21] also showed that the range of internal rotation of the knee joint was smaller than the range of external rotation. However, Russel *et al.*[23] concluded that the range of internal rotation of the knee joint was larger than the range of external rotation.

There are few repeatability data in the literature. Almquist *et al.*[20] found that repeatability was moderate for the total range of motion (ICC=0.66, 95% CI 0.33-0.85). Our results showed good repeatability of double goniometry in both the first and second sessions. A factor that certainly could have contributed to this was the learning effect of the examiner and subjects, who was more experienced in the second session, as he had already performed several measurements. For this reason, it is possible that the values of the second series of measurements were more reputable, as shown by the higher ICC values.

The repeatability and reliability of the developed double goniometry method for measuring rotational laxity was acceptable. However, further research and improvements in the method, equipment, and accessories are needed before the method can be transferred to the clinical setting. The advantages of the method were that we could measure the area in degrees to monitor the progress in the rehabilitation process. The method is also very time-saving, as it takes five minutes to measure a knee. We chose to place the goniometer on the tibia because this eliminates the risk that the inversion and eversion of the ankle will affect the range of rotation of the knee, as was the case in the study by Mossberg and Smith[12]. The limitation we found primarily relates to the perception of sensation at the end feel of the movement as determined by the examiner. Since the measurement of range of motion based on end feel sensation is biased, it would probably be better to perform the knee rotations with a standardized force (e.g., 10N, 20N, 30N). We had difficulty mounting the clamp so that the goniometer was oriented perpendicular to gravity on the magnetic needle as it was attached to the epicondyles of the thigh. This is because one condyle is longer and the other is shorter[26]. Compared to the medial condyle, the lateral condyle is displaced more anteriorly and distally. When measuring rotation in the knee joint *in vivo*, there are a number of factors that influence the variability of the measurement data. These originate from the subject (e.g., different elasticity and plasticity of the soft tissues due to the environment (e.g., time of day, temperature and humidity of the environment) or the effect of hormones or physical activity), the examiner (experience, skill), the measurement device (e.g., measurement accuracy), and the measurement procedure. Measurement in the sitting position is not functional for the knee[13], yet we chose this position with the knee in 90° flexion because maximum rotation is possible in this position[6,12]. On the other hand, magnetic needle goniometers do not allow any other position either. The last limitation we would like to mention is that with a noninvasive method such as double goniometry we used, the best accuracy of the measurements of the rotation range cannot be guaranteed due to the movement of the soft tissues during the execution of the movement[11].

Conclusion

In this study, we tested a new noninvasive method for measuring rotation in the knee joint and determined its reproducibility and reliability. The method we developed was compared with protocols and devices for measuring knee rotation used by other authors. We analyzed the advantages and limitations of the method and examined how it should be improved in further research so that it can be used in clinical practice. Thus, the method of measuring rotation in the knee using double goniometry has been shown to be potentially suitable for clinical practice because it is successful, simple, inexpensive, and takes little time.

The results of the research are promising, as we obtained good reproducibility and reliability of the method, but further research and improvements of the measurement device or methods are needed before we can introduce the method into clinical practice. Undoubtedly, it will be necessary to analyze the inter-rater reliability, to compare the rotation range of healthy subjects with a group of patients with a specific pathology, to modify the device, and to improve the measurement protocol. The results of the investigated studies on total knee rotation and separately measured internal and external rotation are not comparable.

Despite all these possible influencing factors, we believe that the described method has potential for use in a research and clinical setting due to its good measurement properties. It will also be possible to determine normal reference values of knee joint rotation in a larger sample of healthy individuals and to investigate the possible age or gender differences.

References

1. Noya Salces J, Gómez-Carmona PM, Gracia-Marco L, Moliner-Urdiales D, Sillero-Quintana M. Epidemiology of injuries in First Division Spanish football. J Sports Sci. 2014;32(13):1263-70. doi: 10.1080/02640414.2014.884720. Epub 2014 May 1. PMID: 24787731.
2. Rahnama N, Bambaeichi E, Daneshjoo A. The epidemiology of knee injuries in Iranian male professional soccer players. Sport Sci Health. 2009;5(1):9-14. doi: 10.1007/s11332-009-0070-1.
3. Kellis E, Mademli L, Patikas D, Kofotolis N. Neuromuscular interactions around the knee in children, adults and elderly. World J Orthop. 2014 Sep 18;5(4):469-85. doi: 10.5312/wjo.v5.i4.469. PMID: 25232523; PMCID: PMC4133453.
4. de Zwart AH, van der Esch M, Pijnappels MA, Hoozemans MJ, van der Leeden M, Roorda LD, Dekker J, Lems WF, van Dieën JH. Falls associated with muscle strength in patients with knee osteoarthritis and self-reported knee instability. J Rheumatol. 2015 Jul;42(7):1218-23. doi: 10.3899/jrheum.140517. Epub 2015 May 1. PMID: 25934818.
5. Bauer M, Feeley BT, Wawrzyniak JR, Pinkowsky G, Gallo RA. Factors affecting return to play after anterior cruciate ligament reconstruction: a review of the current literature. Phys Sportsmed. 2014 Nov;42(4):71-9. doi: 10.3810/psm.2014.11.2093. PMID: 25419890.
6. Lehinkuhl LD, Smith LK, editors. Brunnstrom's Clinical Kinesiology. 4th ed. Philadelphia: F.A. Davis Company, 1983; 287-307.
7. Kim HJ, Lee HJ, Shin JY, Choi YS, Kyung HS. Measurement of knee rotation angles using a smartphone application: an experimental study of porcine knees. Knee Surg Relat Res. 2017 Dec 1;29(4):302-6. doi: 10.5792/ksrr.17.046. PMID: 29172391; PMCID: PMC5718789.
8. Jeon YS, Choi SW, Park JH, Yoon JS, Shin JS, Kim MK. Mid-term outcomes of anterior cruciate ligament reconstruction with far anteromedial portal technique. Knee Surg Relat Res. 2017 Mar 1;29(1):19-25. doi: 10.5792/ksrr.15.061. PMID: 28231644; PMCID: PMC5336366.

9. Lorbach O, Kieb M, Brogard P, Maas S, Pape D, Seil R. Static rotational and sagittal knee laxity measurements after reconstruction of the anterior cruciate ligament. Knee Surg Sports Traumatol Arthrosc. 2012 May;20(5):844-50. doi: 10.1007/s00167-011-1635-5. Epub 2011 Aug 3. PMID: 21811853.
10. Zaffagnini S, Martelli S, Falcioni B, Motta M, Marcacci M. Rotational laxity after anterior cruciate ligament injury by kinematic evaluation of clinical tests. J Med Eng Technol. 2000 Sep-Oct;24(5):230-6. doi: 10.1080/03091900050204287. PMID: 11204247.
11. Cimbiz A, Cavlak U, Murat S, Hallaceli H, Beydemir F. A new clinical design measuring the vertical axial rotation through tibial shaft resulting from passive knee and subtalar joints rotation in healthy subjects: a reliability study. J Med Sci. 2006;6(5):751-7. doi: 10.3923/jms.2006.751.757
12. Mossberg KA, Smith LK. Axial rotation of the knee in women. J Orthop Sports Phys Ther. 1983;4(4):236-40. doi: 10.2519/jospt.1983.4.4.236. PMID: 18806440.
13. Nagai T, Sell TC, Abt JP, Lephart SM. Reliability, precision, and gender differences in knee internal/external rotation proprioception measurements. Phys Ther Sport. 2012 Nov;13(4):233-7. doi: 10.1016/j.ptsp.2011.11.004. Epub 2012 Feb 8. PMID: 23068898.
14. Testa R, Chouteau J, Viste A, Cheze L, Fessy MH, Moyen B. Reproducibility of an optical measurement system for the clinical evaluation of active knee rotation in weight-bearing, healthy subjects. Orthop Traumatol Surg Res. 2012 Apr;98(2):159-66. doi: 10.1016/j.otsr.2011.08.017. Epub 2012 Feb 14. PMID: 22336486.
15. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med. 2016 Jun;15(2):155-63. doi: 10.1016/j.jcm.2016.02.012. Epub 2016 Mar 31. Erratum in: J Chiropr Med. 2017 Dec;16(4):346. PMID: 27330520; PMCID: PMC4913118.
16. Kovacs FM, Abraira V, Royuela A, Corcoll J, Alegre L, Tomás M, Mir MA, Cano A, Muriel A, Zamora J, Del Real MT, Gestoso M, Mufraggi N; Spanish Back Pain Research Network. Minimum detectable and minimal clinically important changes for pain in patients with nonspecific neck pain. BMC Musculoskelet Disord. 2008 Apr 10;9:43. doi: 10.1186/1471-2474-9-43. PMID: 18402665; PMCID: PMC2375888.
17. Irrgang JJ, Safran MR, Fu FH. The knee: ligamentous and meniscal injuries. In: Zachazewski JE, Magee DJ, Quillen WS, editors. Athletic Injuries and Rehabilitation. Philadelphia: W.B. Saunders Company, 1996;623-92.
18. Samukawa M, Magee D, Katayose M. The effect of tibial rotation on the presence of instability in the anterior cruciate ligament deficient knee. J Sport Rehabil. 2007 Feb;16(1):2-17. doi: 10.1123/jsr.16.1.2. PMID: 17699883.
19. Ahrens P. Analysis device for femorotibial rotation measurement: a cadaveric study [dissertation]. München: Technischen Universität München, Fakultät für Medizin; 2010.
20. Almquist PO, Ekdahl C, Isberg PE, Fridén T. Knee rotation in healthy individuals related to age and gender. J Orthop Res. 2013 Jan;31(1):23-8. doi: 10.1002/jor.22184. Epub 2012 Jul 9. PMID: 22778072.
21. Almquist PO, Arnbjörnsson A, Zätterström R, Ryd L, Ekdahl C, Fridén T. Evaluation of an external device measuring knee joint rotation: an *in vivo* study with simultaneous Roentgen stereometric analysis. J Orthop Res. 2002 May;20(3):427-32. doi: 10.1016/S0736-0266(01)00148-6. PMID: 12038614.
22. Draganich LF, Sathy MR, Reider B. The effect of thigh and goniometer restraints on the reproducibility of the Genucom knee analysis system. Am J Sports Med. 1994 Sep-Oct;22(5):627-31. doi: 10.1177/036354659402200510. PMID: 7810786.
23. Russell DF, Deakin AH, Fogg QA, Picard F. Repeatability and accuracy of a non-invasive method of measuring internal and external rotation of the tibia. Knee Surg Sports Traumatol Arthrosc. 2014 Aug;22(8):1771-7. doi: 10.1007/s00167-013-2812-5. Epub 2013 Dec 27. PMID: 24370989.
24. Muaidi QI. Does gender make a difference in knee rotation proprioception and range of motion in healthy subjects? J Back Musculoskelet Rehabil. 2017 Nov 6;30(6):1237-43. doi: 10.3233/BMR-169613. PMID: 28800303.
25. Sari M. Relationship between physical factors and tibial motion in healthy subjects: 2D and 3D analyses. Adv Ther. 2007 Jul-Aug;24(4):772-83. doi: 10.1007/BF02849970. PMID: 17901026.
26. Kisner C, Colby LA. Therapeutic Exercise: Foundations and Techniques. 6th ed. Philadelphia: F. A. Davis Company, 2012;764-8.

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PONOVLJIVOST I POUZDANOST MJERENJA OPUŠTANJA KOLJENSKOG ZGLOBA U ROTACIJI DVOSTRUKOM GONIOMETRIJOM

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Rezultati dosadašnjih studija opsega pokreta u rotaciji koljenskog zgloba su proturječni. Dosad nije utvrđeno koja je najbolja metoda mjerenja rotacije koljena. Namjera ove studije bila je ispitati ponovljivost i pouzdanost mjerenja opuštanja koljenskog zgloba u rotaciji pomoću dva magnetska goniometra. U ispitivanju je sudjelovalo 30 zdravih osoba (15 muškaraca i 15 žena) u dobi od 20 do 32 godine. Dvostrukom goniometrijom mjerena je unutarnja i vanjska rotacija lijevog i desnog koljenskog zgloba u sjedećem položaju uz fleksiju koljena od 90°. Nije bilo statistički značajne razlike između prvog i drugog mjerenja. Intraklasni koeficijent korelacije (ICC) za ponovljivost kretao se od 0,812 do 0,858, a za pouzdanost od 0,655 do 0,837. Koeficijent varijacije za pojedinog ispitanika bio je manji od 10%, standardna greška mjerenja iznosila je od 1,4° do 2,0°, a najmanja promjena koju je bilo moguće otkriti iznosila je od 2,5° do 3,8°. Izmjerene vrijednosti unutarnje i vanjske rotacije nisu se u potpunosti slagale s onima drugih autora. Vrijednosti ICC ukazuju na dobru do vrlo dobru ponovljivost i pouzdanost mjerenja opuštanja koljena u rotaciji dvostrukom goniometrijom. Prije uvođenja u kliničku praksu bit će potrebna daljnja tehnička poboljšanja.

Ključne riječi: *Opuštanje u rotaciji; Koljenski zglob; Dvostruka goniometrija; Opseg pokreta*