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Original Article

Examination of the correlation between the knee extension angles in the sitting and supine positions measured using ImageJ software: a prospective cross-sectional study

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Abstract. [Purpose] We aimed to examine the correlation between the knee extension angles in the sitting and supine positions measured using ImageJ software. [Participants and Methods] A total of 50 legs in 25 healthy participants (17 males and 8 females) were included in our study. The knee extension angle was measured in the sitting and supine positions with the participants actively and maximally extending their knee joint on one side. The participants were photographed from the side with their knees centered in the image. Thereafter, the photographs were imported into the ImageJ image processing software to calculate the knee extension angles. [Results] The mean values of the knee extension angles in the sitting and supine positions were 131.5 ± 11.2° and 132.1 ± 12.2°, respectively, with a correlation coefficient of 0.85. No systematic errors were observed, and the minimal detectable change was 12.9°. [Conclusion] The knee extension angle in the sitting position showed a strong correlation with that in the supine position, with no systematic errors observed. Therefore, measurement of the knee extension angle in the sitting position can be an alternative to its measurement in the supine position.
Key words: ImageJ, Knee extension angle, Sitting position

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INTRODUCTION

In disabled older adults, hamstring shortening is known to be more likely to occur in older adults with impaired basic movement skills[1)]. Shortening of the hamstrings causes knee flexion contractures, while lack of knee extension range during standing gait contributes to instability in those movements. Davis et al. examined the intra-examiner reproducibility of four hamstring length measurements (i.e., knee extension angle [KEA], sacral angle, straight leg raising, and sit and reach), and recommended measurement of the KEA[2)]. The KEA is generally measured using a goniometer in the supine position[3)]. Accurate measurement of joint range of motion (ROM) using an angle meter in the supine position requires two people: a fixator in an appropriate limb position that does not cause trick motion compensatory movements and a measurer who applies the goniometer[3)]. In addition, a certain amount of skill is required to fix the limb position, palpate the bone index, and apply the goniometer[4)]. Measurement errors may occur depending on how the individual applies resistance force[5)]. In general, facility residents who require assistance or nursing care tend to spend most of their time during the day sitting. In addition,

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many elderly people have round backs or complain of back pain, and these elderly people often have difficulty in getting into the supine position[6]. Furthermore, measurements in the supine position require a bed, and cannot be easily performed in facilities where patients usually sit. Moreover, if it is also difficult to easily get up from there, measurement in the supine position will be burdensome to the participant. Against this background, it is significant to establish a measurement method in the sitting position. To establish a simple and reliable joint angle measurement method that could be performed by a single examiner in the sitting position, Nakajima et al. investigated intra-examiner reproducibility of KEA measurements in the sitting position using Image J image processing software (US National Institute of Health, Bethesda, MD) and reported good reliability[7]. However, it was unclear if the KEA was correlated with that measured in the supine position, which is more common procedure. To our knowledge, no studies regarding this issue have been reported. If the angle is more consistent with the corresponding angle in the supine position, the measurement of the KEA in the sitting position could be an alternative technique.

Therefore, this study aimed to examine the correlation between the KEA in sitting and supine positions using Image J software.

PARTICIPANTS AND METHODS

A total of 50 legs of 25 healthy participants (17 males and 8 females; mean age, 31.5 ± 4.6 years; mean height, 167.5 ± 7.3 cm; mean weight, 61.3 ± 9.1 kg) were included in this study (Table 1). Participants capable of fully extending the knee joint in the sitting position were excluded from the study.

This study was conducted in accordance with the tenets of the Declaration of Helsinki and approved by the Ethics Committee of our hospital (approval number: R-3-12). Written informed consent was obtained from all participants prior to the commencement of the study.

Landmark signs were placed on the participant's fibular head and lateral malleolus when measuring the KEA. The sitting posture was defined as the edge-sitting posture with the trunk in the vertical position. To prevent the participant's posterior pelvic tilt, a 10° metal tilting plate was inserted from behind in front of the ischial tuberosity. The KEA was measured when the knee joint on one side was actively extended to the maximum (Fig. 1), with full orientation regarding appropriate methods and trick motion.

For measurement in the supine position, the hip and knee joints of the measuring limb were placed in 90° flexion, and the measuring limb was placed on a 30–40-cm platform to match the length of the participant's femur. The contralateral hip and knee joints were in 0° extension. A 5-kg weight was placed on the thigh of the contralateral limb to prevent compensatory hip flexion. Then, the KEA was measured when the knee was actively extended to the maximum (Fig. 1). The other person held the lower leg of the measuring limb in the auto-extended position and immobilized the femur of the measuring limb to prevent compensation for the flexed or extended position. All participants used the same pillow.

The measurer positioned the smartphone internal camera (iPhone 12, Apple Inc., Cupertino, CA, USA; photo mode, resolution: 2,532 × 1,170) horizontally on the table from right beside the participant and captured images centered on the knee. The photographs were imported into Image J software. The measurement line was aligned with the landmark (the lateral malleolus to the fibular head), and the KEA was calculated as the angle between the horizontal line (sitting position) or vertical line (supine position) and the landmark. The reason for not using the femoral greater trochanter as the landmark is that the bony index is large, which could lead to errors during palpation. The position of the femoral greater trochanter may also be altered by the thickness of the buttock and posterior thigh. Therefore, horizontal or vertical lines were used. The KEA was defined as the angle formed by the measurement lines in this measurement, not the joint ROM indicated by The Japanese Association of Rehabilitation Medicine[8].

After confirming the normality of the data distribution of the KEA in supine and sitting positions with the Shapiro–Wilk test, the association between the KEAs in both positions was examined using Pearson's product-rate correlation coefficient. Bland–Altman analysis was performed to check for systematic errors. For all statistical analyses, the significance level was set at a 5% risk rate. A modified R Commander 4.1.2 (McMaster University, Hamilton, ON, Canada) was used for statistical analyses.

Table 1. Participant's characteristic

	All (n=25)	Male (n=17)	Female (n=8)
Age (years)	31.5 ± 4.6	33.1 ± 4.0	28.0 ± 3.9
Height (cm)	167.5 ± 7.3	171.7 ± 5.6	159.8 ± 3.6
Body weight (kg)	61.3 ± 9.1	65.9 ± 5.7	51.3 ± 6.6
Body mass index (kg/cm^2)	21.7 ± 2.4	22.5 ± 2.3	20.0 ± 2.0

Mean ± standard deviation.

RESULTS

The mean KEAs in sitting and supine positions were 131.5 ± 11.2° and 132.1 ± 12.2°, respectively. Scatter plots of the KEAs in the seated and supine positions are presented in Fig. 2. The correlation coefficient was r=0.85 ($p<0.01$). Bland–Altman plots were created based on the measurements obtained from the two evaluation methods (Fig. 3). Fixed and proportional biases were not observed. The standard error of the mean was 0.89°, and the minimal detectable change (MDC) was 12.3° (Table 2).

DISCUSSION

Herein, we investigated the agreement between the KEA in sitting and supine positions using Image J software. The KEA in sitting and supine positions were 131.5 ± 11.2° and 132.1 ± 12.2°, respectively. The correlation coefficient between the KEAs in the two positions was r=0.85, suggesting a strong correlation.

Active KEA measurement is recommended for measuring hamstring muscle length[2, 9]. The hamstrings consist of three muscles: semitendinosus, semimembranosus, and biceps femoris, all of which originate at the ischial tuberosity[10]. The pelvis tends to tilt more posteriorly in the sitting position compared with in the supine or standing position due to a decrease in lumbar vertebral anteversion[9]. Generally, when the pelvis is tilted posteriorly, hamstrings attached to the sciatic tuberosity

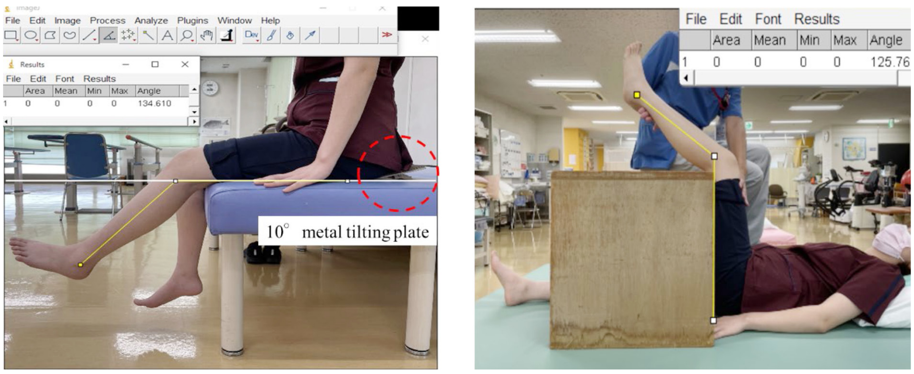

Fig. 1. Knee extension angle (KEA) measurement using ImageJ.
Left: sitting position. Right: supine position
Left: To prevent the participant's posterior pelvic tilt, a 10° metal tilting plate was inserted from behind in front of the ischial tuberosity. The sitting position is bilateral hip flexion.
Right: For measurement in the supine position, the hip and knee joints of the measuring limb were placed in 90° flexion, and the measuring limb was placed on a 30–40 cm platform to match the length of the participant's femur. The contralateral hip and knee joints were in 0° extension. A 5 kg weight was placed on the thigh of the contralateral limb to prevent compensatory hip flexion.

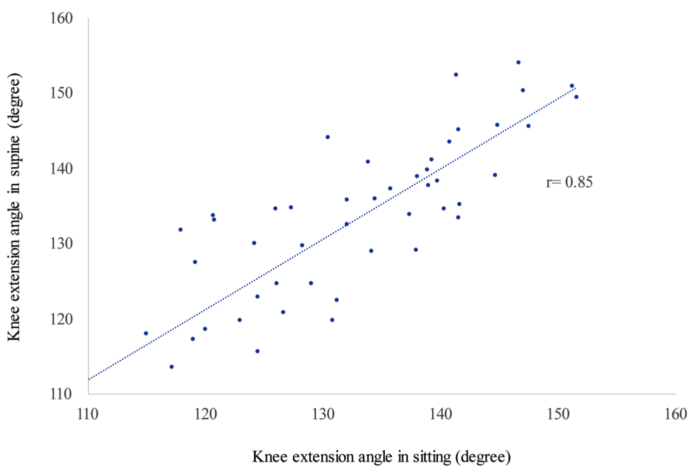

Fig. 2. Knee extension angle (KEA) scatter plots for supine and sitting positions.

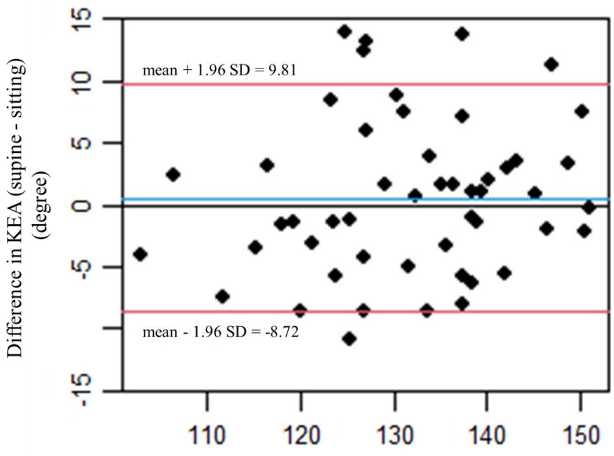

Fig. 3. Bland–Altman Plot (Estimation of the limits of agreement).
KEA: knee extension angle.

Table 2. Systematic errors and minimal detectable change in measurement results

	Fixed bias	Proportional bias		
	Mean bias (95% CI)	Slope of the regression line	SEM	MDC
KEA in sitting and supine position	0.6 (−1.2 to 2.3)	0.091	0.89	12.3

KEA: knee extension angle; CI: confidence interval; SEM: standard error of the mean; MDC: minimal detectable change.

relax their muscle length and, thus, the KEA measured in the sitting position is larger[10]. However, in the present study, the angles obtained in the sitting position were similar to those obtained in the supine position; this was attributed to the insertion of a 10° metal tilting plate in the sciatic region at the end of the vertical trunk position to prevent posterior pelvic tilt and providing sufficient orientation and prior practice regarding trick motion. Therefore, regarding the KEA, measurements obtained in the sitting position can be an alternative to those obtained in the supine when appropriate methods for preventing posterior pelvic tilt are used.

Facility residents often spend most of their time in a sitting position. Moreover, frail and diseased elderly residents often cannot easily assume a supine position. Although there are some studies[3, 4] that have examined the reproducibility of KEA measurements performed by two persons, it is not always possible to employ two people to measure the KEA in clinical settings. Nakajima et al. examined the intra-rater reproducibility of KEA measurements in the sitting position using Image J software in one examinee and reported good reproducibility with an intra-class correlation coefficient (1, 1) of 0.89; the MDC was 10.3°[7]. Olivencia et al. conducted a study on KEA reliability in 71 healthy participants in the supine position. In their work, an examiner used a goniometer and the participant was immobilized with a belt or side bar. Interestingly, they reported that the MDC was 12°[11]. The MDC of the measurement method used in our study was 12.3°, which was consistent with measurements in sitting and supine positions using Image J software. The KEA had a large ROM and a similar error range comparable with that of previous studies[11].

Measurement with Image J software has the disadvantage that the angle cannot be determined on the spot because it requires a procedure to import the captured image into a personal computer. However, the reason we did not use a goniometer this time is that the possibility of information bias cannot be ruled out[12]. If the angle was known on the spot, the possibility that the angle would be arbitrarily adjusted due to the information bias of the measurer cannot be denied. In this method, information bias is considered unlikely to occur because the measurement is made by capturing the data into a personal computer. In addition, goniometers measure in 5° or 1° increments. Image J can also measure decimal points. Therefore, this method can measure angles in more detail than goniometers.

In conclusion, KEA measurement in the sitting position using Image J software is a simple, reliable, and valid method, which yields KEA consistent with those measured in the supine position. This method can be performed by a single examiner, has good reproducibility, and has a similar level of error that is comparable with previous studies.

One limitation of this study is that the number of measurements in this study was one validation. For more reliable results, it is desirable to measure multiple times and use the average value. Although the measurements were made on healthy participants in this study, we did not make such measurements on elderly participants with diseases or participants with deformed spinal columns. In the future, those issues need to be examined as well.

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Conflict of interest

None of the authors has any conflict of interest to declare.

REFERENCES

1) Fukuya Y: The relation between motion of daily living and joint range of motion in the adult with central nervous disturbance. Phys Ther Jpn, 1994, 21: 90–93.
2) Davis DS, Quinn RO, Whiteman CT, et al.: Concurrent validity of four clinical tests used to measure hamstring flexibility. J Strength Cond Res, 2008, 22: 583–588. [Medline] [CrossRef]
3) Kuriyama H, Nakayama T, Miyazaki T, et al.: Influence of fluctuation of range of motion on measurement reproducibility. Kochi Rehabil Inst Kiyo, 2018, 20: 35–37.
4) Shigeshima K, Sakanoue N: Concurrent validity reproducibility of motion measurements with inclinometers. Kochi Rehabil Inst Kiyo, 2006, 7: 39–46.
5) Ono T, Aoyama H, Komazawa H, et al.: Comparison of two methods of goniometry. Yamagata J Health Sci, 2000, 3: 55–57.
6) Halbertsma JP, Göeken LN, Hof AL, et al.: Extensibility and stiffness of the hamstrings in patients with nonspecific low back pain. Arch Phys Med Rehabil, 2001, 82: 232–238. [Medline] [CrossRef]
7) Nakajima F, Nakayama T, Yamasaki H, et al.: Intrarater reliability of active range of motion measurement with Image J. Kochi Rehabil Prof Univ Kiyo, 2023, 4: 23–26.
8) The Japanese Association of Rehabilitation Medicine: Joint range of motion indication and measurement methods (Revised April 2022). https://www.jarm.or.jp/member/kadou03.html
9) Endo K, Suzuki H, Nishimura H, et al.: Sagittal spinal alignment in the standing, sitting and supine position. J Orthop Sci, 2012, 47: 235–239.
10) Nakamura R: Fundamental Kinesiorogy, 6th ed. Tokyo: Ishiyaku Publishers, 2003, pp 240–242.
11) Olivencia O, Godinez GM, Dages J, et al.: The reliability and minimal detectable change of the ely and active knee extension tests. Int J Sports Phys Ther, 2020, 15: 776–782. [Medline] [CrossRef]
12) Seino H, Kobayashi Y, Imuta M, et al.: Effectiveness of static stretching in which the implementation time is set based on the subjective feeling of stretching: a randomized crossover study. PT J, 2022, 5: 587–593.