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Original Article

Morphological changes in the interosseous membrane of the forearm during forearm rotation

Tomoki Ono, PT, MSc[1, 2)*], Koji Iwamoto, PT, PhD[3)], Masahiko Monma, RT, PhD[1)], Makoto Takahashi, PT, MSc[1, 4)], Kazuhide Tomita, PT, PhD[1)]

[1)] *Graduate School of Health Science, Ibaraki Prefectural University of Health Sciences: 4669-2 Ami, Inashiki-gun, Ibaraki 300-0394, Japan*
[2)] *Mejiro Orthopedics and Internal Medicine Clinic, Japan*
[3)] *Department of Physical Therapy, Tokyo Professional University of Health Science, Japan*
[4)] *Department of Physical Therapy, School of Health Sciences, Japan University of Health Sciences, Japan*

Abstract. [Purpose] Changes in forearm interosseous membrane dynamics during forearm rotation relative to the shoulder joint position remain poorly understood. The purpose of this study was to clarify interosseous membrane dynamics during forearm rotation in shoulder abduction and external rotation positions. [Participants and Methods] We conducted open magnetic resonance imaging on 17 healthy forearms in the prone position. Three limb positions were set for measuring the forearm rotation angle: intermediate, maximum pronation, and maximum supination. Images were obtained with the shoulder joint abducted at 90°and externally rotated at 90°. The forearm interosseous membrane angle was measured at three points: the apex of the forearm interosseous membrane, the radius, and the ulna. The measurement of the interosseous angle was repeated thrice. [Results] Sufficient intra-rater reliability was confirmed for the forearm interosseous membrane angle measurement. The interosseous membrane of the forearm showed a mean dorsal convex shape during forearm pronation (141.7° ± 0.83°), and the mean palmar convex shape during forearm supination (−141.6° ± 0.64°). [Conclusion] This study provides useful information for future research by quantifying the dynamics of the interosseous membrane of the forearm, which is an important soft tissue for forearm rotation. The establishment of a quantitative evaluation method for forearm interosseous morphological changes will help further elucidate forearm rotation movements during sports activities.
Key words: Forearm interosseous membrane, Forearm rotation, Open magnetic resonance imaging (MRI)

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INTRODUCTION

Forearm rotation is the rotation of the radius around an axis that passes through the radial head and ulnar styloid process[1, 2)]. The joint movement is controlled by the soft tissue[3–6)] called forearm interosseous membrane (IOM) connecting the distal and proximal radiioulnar, brachioulnar, and brachioradial joints[7–9)]. The IOM of the forearm is a structure having ligamentous characteristics between the radius and the ulna[10)]. In addition, morphological changes occur during forearm rotation[11, 12)]. The interosseous membrane divides the forearm into anterior and posterior compartments, serves as the site for attachment of muscles of the forearm as well as to transfer forces from the radius to the ulna by connecting them without restricting pronation and supination. As the forearm moves from pronation to neutral position, the interosseous fibers change from relaxed to tense. When the forearm moves from the neutral position to supination, they change from a relaxed state to a tense state again. They once again become relaxed as the forearm enters supination[13)].

*Corresponding author. Tomoki Ono (E-mail: tomoki522@gmail.com)

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Forearm rotation is important in activities of daily living, such as grooming and eating[14, 15]. Most of these movements are performed with the forearm in a drooped or mildly flexed position of the shoulder joint, with the forearm pronation and supination. While several studies have been conducted on forearm rotation[15, 16], the focus of these studies has been on its impact on daily life. Forearm rotation is essential, even during overhead sporting motions, such as pitching[17, 18]. In the throwing motion, it has been suggested that the position of the forearm affects the external rotation of the glenohumeral joint[19], the forearm rotation moment and elbow joint moment[20]. In addition, cadaveric studies have indicated that the forearm rotation limb position may affect elbow joint valgus stability[21]. It is known that the amount of forearm rotational motion varies with the angle of flexion of the elbow joint. In elbow joint flexion, the supination motion is greater, and in elbow joint extension, the pronation motion is greater[22]. To the best of our knowledge, no study has been conducted on forearm rotation assuming sporting motions. This study aimed to provide a basic study for understanding overhead sports movements and to determine the dynamics of the interosseous membrane during forearm rotation at 90° of shoulder abduction and 90° of external rotation.

PARTICIPANTS AND METHODS

The experiment was conducted on healthy participants from December 2020 to August 2021.

In this study, 17 right forearms of 17 healthy participants with no past history or history of finger, wrist, forearm, or elbow joint surgery were investigated. The participants were 12 men and five women, with an average age of 31.0 ± 5.6 years (Table 1). The inclusion criteria were that there were no complaints of pain during the experiment and all experimental data were available for analysis. The exclusion criteria were a contraindication to magnetic resonance imaging (MRI) examination before MRI examination and pain in the upper extremities during the examination. All processes in this experiment were conducted at laboratory.

All study participants underwent elbow joint range of motion (ROM) measurements prior to MRI examination. Subsequently, they practiced forearm rotation movement such that compensatory movements did not occur. The forearm pronation and supination angles were measured prior to the MRI experiments, with the participant taking the same posture as that for the MRI examination (Fig. 1). Then, open MRI imaging was conducted to image the elbow joint and forearm using MRI (AIRIS Vento 0.3 Tesla, Fuji Film, Tokyo, Japan, Fig. 2A) with a coil (Fig. 2B). The imaging was performed by one technologist under the guidance of an experienced radiologist. The measurements were performed with participants in the prone position with the shoulder joint elevated (Fig. 3A). The elbow joint position was set at 45° flexion, at which the ROMs for forearm pronation and supination were approximately the same. Three limb positions were set for the forearm rotation angle: maximum pronation (Fig. 3B), intermediate (Fig. 3A), and maximum supination (Fig. 3C). During imaging, the scapula and pelvis were fixed with a belt, and the participant was instructed on forearm rotation before the measurement, such that the axis of rotation could be fixed without shaking as the forearm rotated. This ensured sufficient forearm rotation. When changing the limb position of the forearm, the examiner entered the MRI room and confirmed that there was no problem with the axis of rotation movement and that no compensatory movements occurred in the wrist and elbow joint. The MRI imaging conditions are provided in Table 2. Horizontal, coronal, and sagittal tomographic images were obtained for each forearm positions. For positioning imaging, the cross-section was determined based on the centre of the forearm in the horizontal tomographic image. For sagittal and coronal tomographic imaging, the cross-section was determined based on the axis passing through the ulnar styloid process from the radial head, which was the forearm rotation axis. Captured images that met the following criteria were selected for analysis. For the horizontal tomographic images, each slice was observed from the distal forearm, and three slices from the distal slices where the shape of the interosseous membrane of the forearm could be traced were analysed. In the sagittal and coronal images, the tilt of the radial head articular surface relative to the humerus was analysed from the slices in which the radial head was most clearly visualised. Additionally, the distance between the humerus and the radial head was analysed from the three slices where the radial head was clearly visualised.

Table 1. Attributes of the study participants

Sex		Male: 12
		Female: 5
Age (years)		Ave: 31.0 ± 5.6
Height (cm)		Ave: 167.6 ± 12.9
Elbow range of motion	Flexion	Ave: 142.4 ± 11.9°
	Extension	Ave: 5.6 ± 2.4°
Forearm range of motion	Pronation	Ave: 100.9 ± 10.0°
	Supination	Ave: 47.9 ± 6.9°

Ave: average.

Fig. 1. Measurement position for forearm rotation range of motion. A stick is attached to the MP joint as a marker for measuring the range of motion of the forearm rotation (black ellipse).

The forearm interosseous membrane angle was measured at three points: the apex of the forearm interosseous membrane, radius, and ulna (Fig. 4). The slices of the horizontal tomographic image were confirmed from the distal position, and three slices from the most distal slice that could trace the morphology of the forearm interosseous membrane were analysed. After determining whether the slice to be analysed had a dorsal or palmar convex form, the apex of the forearm interosseous membrane was determined and the angle connecting this apex with the ulna and radius was measured (Fig. 4). The dorsal convexity angle was recorded as a positive angle and the volar convexity angle as a negative angle. One observer performed

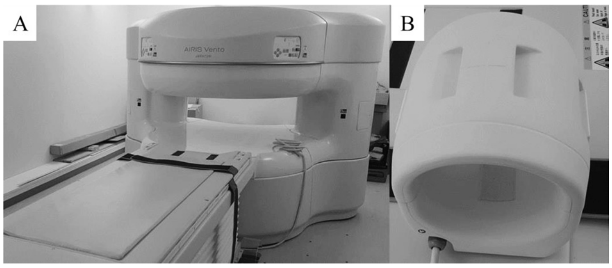

Fig. 2. Equipment used for magnetic resonance imaging (MRI). A, Open MRI scanner (AIRIS Vento 0.3 Tesla, Fuji Film, Tokyo, Japan). B, MR coil.

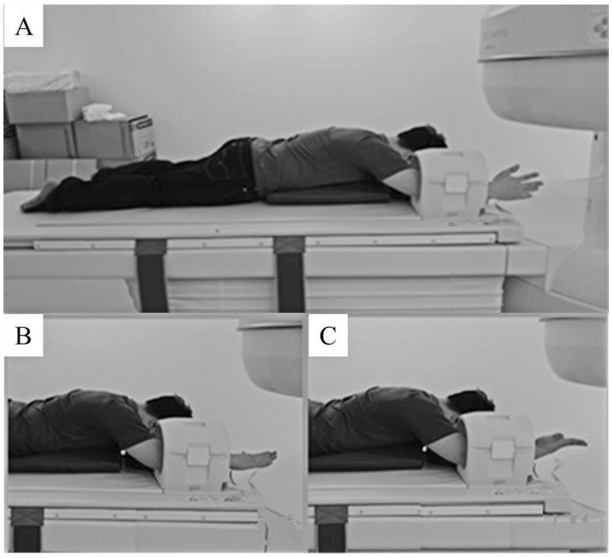

Fig. 3. Positions for the measurement of the forearm. The measurements were performed with participants in the prone position. Three limb positions were set for the forearm rotation angle: maximum pronation (Fig. 3B), intermediate (Fig. 3A), and maximum supination (Fig. 3C).
A: Intermediate position, B: Maximum pronation position, C: Maximum supination position.

Table 2. Open magnetic resonance imaging conditions

The repetition time: TR	780.5 ms
The echo time: TE	12 ms
Flip angle	30°
Field of view	350 cm
Matrix	224 × 128
Thickness	3.0 mm
Interval	3.5 mm
Number of signal averaging: NSA	1
Scanning time	5 min 05 sec

the MRI analysis in triplicate to examine intraobserver reliability. IBM SPSS Statistics version 26 (Armonk, NY, USA) was used for statistical analysis, with a significance level of 5%. Means and standard deviations were calculated for each of the study participants' characteristics. For the forearm interosseous angle measurements, repeated measurements were taken three times on each of the three MRI images. One observer performed this triplicate MRI image analysis. The intraclass correlation coefficients (ICC (1,3)), mean value, and standard error were calculated for the forearm interosseous membrane angles measured. All experimental research conducted in this study was approved by the Ethics Committee of our institution (approval number: 966; approval date: October 2020). The purpose and content of the study were explained in writing to the participants, and their written informed consent was obtained.

RESULTS

All of the 17 study participants met the study inclusion criteria. All participants did not have any contraindications to MRI measurements and did not complain of upper extremity pain or other symptoms during the experiment. Table 1 shows the joint ROM of the elbow joint and forearm measured prior to the MRI, along with the sex, age, and height of all participants. No cases exhibited significant limitations in ROM. Figure 5 shows the change in the angle of the forearm interosseous membrane obtained from forearm horizontal tomography. The dorsal convex shape was taken as a positive value, and the palmar convex shape as a negative value. The forearm interosseous angle was measured three times repeatedly from the same MRI image, The ICC (1, 3) coefficient was 0.99. Regarding the morphology of the forearm interosseous membrane, the forearm interosseous membrane had a palmar convex shape in the mid-forearm position and forearm supination position, and the angle was calculated as a negative value. As a result, the shape of the forearm was almost flat at −159.6° at the mid-forearm position. The supinated position of the forearm was convex (−141.6°). Regarding forearm pronation, the forearm interosseous membrane had a dorsal convex shape, and the angle was calculated as a positive value. During forearm pronation, the interosseous membrane angle was 141.7°.

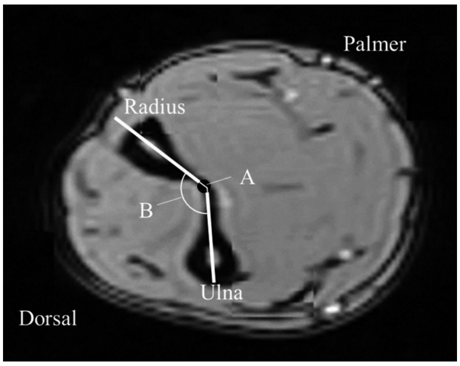

Fig. 4. Forearm horizontal tomogram for analysis of the forearm interosseous membrane angle.
(1) determine whether the interosseous membrane of the forearm was dorsal or palmar convex, (2) select apex A (black point) of the interosseous membrane of the forearm, (3) measure the angle between the radius, ulna and apex A of the interosseous membrane of the forearm (B), and repeat this process three times, with the average value being the interosseous angle of the forearm. The interosseous angle of the forearm with a flat interosseous membrane is 180°.

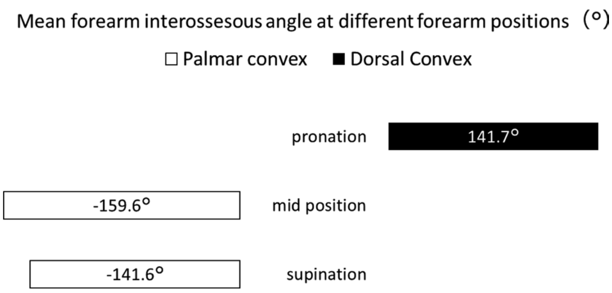

Fig. 5. Forearm interosseous membrane angle according to differences in the forearm position

DISCUSSION

Studies have clarified that during forearm rotation, the interosseous membrane of the forearm undergoes a morphological change that is convex on the dorsal side in the pronation position and convex on the palmar side in the supination position[11, 12]. The results of this study were similar to those of published studies. In this study, the analysis was performed at 90° shoulder joint abduction and 90° external rotation, assuming a pitching motion, and a similar trend was observed in the morphological changes of the interosseous membrane. The morphology of the interosseous membrane of the forearm, which was previously assumed to be roughly flat in the intermediate forearm position, was presumed to show a similar trend. In addition, we attempted to quantify the morphological changes in the interosseous membrane of the forearm, which had previously been captured by visual changes only, using the angles to the radius and ulna. Our measurement methods were reliable as indicated by a high ICC value. The interosseous membrane of the forearm significantly affects joint stability[22, 23]. However, the cause of this phenomenon has not yet been elucidated. We believe that the results of this study provide quantitative indices that will be useful in clarifying the functional anatomy of the forearm interosseous membrane.

This study had several limitations. First, the sample size was small and the age distribution of the sample was skewed. Although the sample size was similar to that in previous studies, it will be necessary to conduct further research into whether these results are applicable to all age groups and to understand the dynamics in children and the elderly. Next, although the experiment was conducted in limb positions assuming a sporting motion, the analysis was performed in a stationary limb position, and it is unclear whether the same results can be obtained during sporting motions. Furthermore, the results showed a smaller range of motion for the forearm rotation angle in the supination compared to the pronation, possibly due to the use of an elevated upper limb as the imaging limb position for the MRI, and the observation was not made for an equivalent range of motion. This difference is presumably due to the fact that the central position was defined by the position of the forearm relative to space, but not the central position relative to the humerus.

In most of the previous studies that analyzed morphological changes in the forearm interosseous membrane, the shoulder joint was performed in the drooping position. In this study, the analysis was performed with the shoulder joint in abduction and external rotation. The morphological changes in the forearm interosseous membrane were similar to those in previous studies. Morphological changes in the forearm interosseous membrane appeared not affected by changes in shoulder joint position. The morphological changes reported to date are valuable to understand motions even during sport activities, even during sporting motions. We believe that our results provide important information for future studies aiming to clarify the factors that affect these morphological changes, facilitating improved understanding of the effects of forearm rotation on sporting motions.

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Conflict of interest

None.

REFERENCES

1) Matsuki KO, Matsuki K, Mu S, et al.: In vivo 3D kinematics of normal forearms: analysis of dynamic forearm rotation. Clin Biomech (Bristol, Avon), 2010, 25: 979–983. [Medline] [CrossRef]
2) Weiss AP, Hastings H 2nd: The anatomy of the proximal radioulnar joint. J Shoulder Elbow Surg, 1992, 1: 193–199. [Medline] [CrossRef]
3) Matthews LS, Kaufer H, Garver DF, et al.: The effect on supination-pronation of angular malalignment of fractures of both bones of the forearm. J Bone Joint Surg Am, 1982, 64: 14–17. [Medline] [CrossRef]
4) Patrick J: A study of supination and pronation, with especial reference to the treatment of forearm fractures. J Bone Joint Surg Am, 1946, 28: 737–748. [Medline]
5) Tarr RR, Garfinkel AI, Sarmiento A: The effects of angular and rotational deformities of both bones of the forearm. An in vitro study. J Bone Joint Surg Am, 1984, 66: 65–70. [Medline] [CrossRef]
6) Trousdale RT, Linscheid RL: Operative treatment of malunited fractures of the forearm. J Bone Joint Surg Am, 1995, 77: 894–902. [Medline] [CrossRef]
7) Manson TT, Pfaeffle HJ, Herdon JH, et al.: Forearm rotation alters interosseous ligament strain distribution. J Hand Surg Am, 2000, 25: 1058–1063. [Medline] [CrossRef]
8) Rein S, Esplugas M, Garcia-Elias M, et al.: Immunofluorescence analysis of sensory nerve endings in the interosseous membrane of the forearm. J Anat, 2020, 236: 906–915. [Medline] [CrossRef]
9) Rein S, Kremer T, Houschyar KS, et al.: Structural topography of the interosseous membrane of the human forearm. Ann Anat, 2020, 231: 151547. [Medline] [CrossRef]
10) Yi XH, Pan J, Guo XS: Anatomical and biomechanical study on the interosseous membrane of the cadaveric forearm. Chin J Traumatol, 2011, 14: 147–150. [Medline]

11) Nakamura T, Yabe Y, Horiuchi Y: Functional anatomy of the interosseous membrane of the forearm—dynamic changes during rotation. Hand Surg, 1999, 4: 67–73. [Medline] [CrossRef]
12) Watanabe H, Berger RA, Berglund LJ, et al.: Contribution of the interosseous membrane to distal radioulnar joint constraint. J Hand Surg Am, 2005, 30: 1164–1171. [Medline] [CrossRef]
13) Panigrahi R, Madharia D, Samant S: Hyalinization of interosseous membrane of forearm: a case report. J Clin Orthop Trauma, 2019, 10: S207–S210. [Medline] [CrossRef]
14) Kapandji A: Biomechanics of pronation and supination of the forearm. Hand Clin, 2001, 17: 111–122, vii. [Medline] [CrossRef]
15) Morrey BF, Askew LJ, Chao EY: A biomechanical study of normal functional elbow motion. J Bone Joint Surg Am, 1981, 63: 872–877. [Medline] [CrossRef]
16) Haverstock JP, King GJ, Athwal GS, et al.: Elbow motion patterns during daily activity. J Shoulder Elbow Surg, 2020, 29: 2007–2014. [Medline] [CrossRef]
17) Nissen CW, Westwell M, Ounpuu S, et al.: Adolescent baseball pitching technique: a detailed three-dimensional biomechanical analysis. Med Sci Sports Exerc, 2007, 39: 1347–1357. [Medline] [CrossRef]
18) Nissen CW, Westwell M, Ounpuu S, et al.: A biomechanical comparison of the fastball and curveball in adolescent baseball pitchers. Am J Sports Med, 2009, 37: 1492–1498. [Medline] [CrossRef]
19) Kibler WB, Sciascia A, Pike JS, et al.: Effect of forearm position on glenohumeral external rotation measurements in baseball players. Sports Health, 2022, 14: 577–584. [Medline] [CrossRef]
20) Solomito MJ, Garibay EJ, Nissen CW: A biomechanical analysis of the association between forearm mechanics and the elbow varus moment in collegiate baseball pitchers. Am J Sports Med, 2018, 46: 52–57. [Medline] [CrossRef]
21) Seiber K, Gupta R, McGarry MH, et al.: The role of the elbow musculature, forearm rotation, and elbow flexion in elbow stability: an in vitro study. J Shoulder Elbow Surg, 2009, 18: 260–268. [Medline] [CrossRef]
22) Malone PS, Cooley J, Morris J, et al.: The biomechanical and functional relationships of the proximal radioulnar joint, distal radioulnar joint, and interosseous ligament. J Hand Surg Eur Vol, 2015, 40: 485–493. [Medline] [CrossRef]
23) Kitamura T, Moritomo H, Arimitsu S, et al.: The biomechanical effect of the distal interosseous membrane on distal radioulnar joint stability: a preliminary anatomic study. J Hand Surg Am, 2011, 36: 1626–1630. [Medline] [CrossRef]