

Morphology and Morphometry of the Dorsal Interosseous Muscles of the Hand: Laterality and Sexual Dimorphism

Morfología y Morfometría de los Músculos Interóseos Dorsales de la Mano: Lateralidad y Dimorfismo Sexual

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MVUNDLA, M. M.; OLOJEDE, S. O.; LAWAL, S. K.; NAIDU, E. C.; AZU, O. O. Morphology and morphometry of the dorsal interosseous muscles of the hand: laterality and sexual dimorphism. *Int. J. Morphol.*, 42(3):773-778, 2024.

SUMMARY: The dorsal interosseous muscles (DIM) are intrinsic muscles of the hand located dorsally between metacarpal bones, which play a role in finger abduction. Anatomical variations of these muscles in terms of form and length have been well documented, but variations regarding sex and laterality are underexplored. The aim of this study was to investigate the morphology and morphometry of the DIM of the hand regarding sexual dimorphism and laterality. Twenty human cadavers belonging to the white individuals (n = 40 hands) with known sex and laterality were used for this study. DIMs were dissected and observed for morphology. Also, a digital calliper was used to measure the midpoint length of the DIM. The origin and insertion of all the DIM were normal with the left hand having no additional, supernumerary, and absent muscles in each compartment. The variations were only found on the right side and predominant in females: 2 out of 11 (18.18%) hands containing a space with a supernumerary muscle; 1 out of 11 (9.09%) hands having a space with a double muscle; and 1 out of 11 (9.09%) hands having a compartment with a unipennate muscle. In males, 1 out of 9 (11.11%) hands had a compartment with a supernumerary muscle. The mean midpoint length of each muscle in females and males in both hands from the first to the fourth muscle, respectively, was documented. In females on the left: 46.79 ± 3.56; 42.62 ± 3.57; 49.02 ± 4.21; 41.66 ± 2.15 and right: 47.30 ± 2.49; 39.27 ± 4.14; 45.69 ± 4.64; 38.12 ± 4.08. In males, it was on the left: 50.01 ± 3.95; 41.98 ± 3.79; 47.90 ± 4.83; 41.79 ± 4.25, and on the right: 46.65 ± 2.09; 39.01 ± 4.25; 47.47 ± 3.41; 38.31 ± 4.40. The mean midpoint length of the DIM was relatively higher on the left hand compared to the right hand in both females and males. In this study, variations regarding the supernumerary muscle, double interosseous space, and unipennate muscles were only observed on the right-hand side and predominantly in females, an insight that may guide in the treatment of fractures, stiffness of the hand, and compartment syndromes.

KE WORDS: Dorsal interosseous muscle; Morphology; Morphometry; Variations; Sex; Laterality.

INTRODUCTION

The interosseous muscles of the hand are found firmly attached between the metacarpal bones (Valenzuela & Varacallo, 2018). The DIM function as flexors of the metacarpophalangeal, and extensors of the interphalangeal joints playing a role in finger abduction (Nayak *et al.*, 2016). The DIM (bipennate) develops from two adjacent metacarpal bones on the medial and lateral sides with tendons inserted on the extensor hood and proximal phalange of each finger (Nayak *et al.*, 2016). The interossei muscles of the hand derive from the deep mesoderm layer with tendons fully forming and, functionally during the end of week twelve of embryological formation (Susman *et al.*, 1999). The first DIM arises on both

sides of the first and second metacarpals inserting on the second phalanx base laterally and its extensor hood (Valenzuela & Varacallo, 2018). The second DIM originates on the second metacarpal medially, and on the third metacarpal laterally by inserting laterally on the third phalanx base and its extensor hood (Valenzuela & Varacallo, 2018). The third DIM is derived medially on the third metacarpal and the fourth metacarpal is laterally inserted on the third phalanx base and its extensor hood (Valenzuela & Varacallo, 2018). The fourth DIM develops on the fourth metacarpal laterally and the fifth metacarpal medially inserting laterally at the fourth phalanx base and its extensor hood (Valenzuela & Varacallo, 2018).

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Variations in the morphometry and morphology of the hand have been reported since the 18th century in literature (Nayak *et al.*, 2016). In one study the absence of these muscles has been reported in one or more spaces with some cadaveric specimens having extra heads or more than the expected number of muscles in each space (Bergman *et al.*, 1988). A study by Eladoumikdachi *et al.* (2002) found three heads of the dorsal interossei muscle, each with unique distal attachments. There are many variations in the morphology and morphometry of the DIM (Valenzuela & Varacallo, 2018). In a previous prospective study, approximately 25% of the DIM were unipennate concluding oversimplification of sites for the attachment of these muscles in some literature (Eladoumikdachi *et al.*, 2002). Bergman *et al.* (1988) noted cases of absence of the interosseous muscles in one or several spaces, multipennate muscles, and double muscles in a space. Nayak *et al.* (2016) in a prospective study of fifteen cadavers with no sex predilection, thirty hands were dissected, and it was discovered that only three hands had supernumerary muscles in the dorsal interossei of the hand.

Based on the available studies in the literature, variations in form and length of the DIMs have been documented but there is paucity of information related to the variations of DIMs in terms of sex and laterality. The reason for these underexplored variations maybe ascribes to the location of these muscles (adherent to bone) thus reduces available information in terms of their variability in form, length, laterality and sex. On this account, this study was conceptualized and designed to observe the morphological, measure and document the morphometric variations in DIM of the hand concerning sex and laterality.

MATERIAL AND METHOD

Materials. The equipment that was used for the dissection of the cadavers were dissecting scissors, scalpels, removable blades, dissection forceps, and dissection fluids. The cadavers were preserved with special chemicals i.e., embalming. Images of the specimens were taken, and a qualitative description of the male and female DIM variations was observed and documented.

Ethical approval. Ethical approval for this study was obtained from the Biomedical Research Ethics Committee of the University of KwaZulu-Natal with an ethical approval number (BREC), reference BREC: 00005966/2023.

Sample size. This study was conducted at the University of KwaZulu-Natal, College of Health Science, Discipline of Clinical Anatomy on Westville Campus, and Nelson Mandela School of Medicine from August to the 15th of October 2023. Twenty adult human cadavers (White) with known sex and

laterality within the age range of seventy to ninety years were used for this study.

Inclusion and exclusion criteria. Adult, full cadavers with known sex and laterality were included in this study. Cadavers showing no evidence of injury, trauma, disease, or deformity of the upper limb were included in this study. Cadaveric specimens showing evidence of injury, trauma, disease, and deformity were excluded from this study.

Dissection of the dorsal interosseous muscles. Dissection instruments (dissecting kits) were used to dissect the dorsum of the left and right hands using dissection instructions given in Grant's Dissectors Manual 16th edition by Detton (2020). As described in the manual: the skin was reflected to expose the dorsum of the hand. Tendons of the extensor digitorum muscle were cut by the extensor retinaculum and reflected by the phalanges to expose the metacarpal bones where the dorsal interosseous muscles attach. Fascia was removed and fat was cleaned carefully without damaging the fibers of the muscles.

Morphological analysis. The different dorsal interosseous muscles were analyzed and observed with the aid of a magnifying lens as these muscles are small. The origin, insertion, and fibers of each muscle in each space were observed and noted. Supernumerary muscles and extra heads were noted according to their attachments and pennation.

DIM analysis

Morphometric analysis. Digital callipers were used to measure the midpoint of the muscle belly length in each space; this was done three times in centimetres, and the average of the acquired lengths was taken. All measurements were recorded in millimetres to 2 decimal places. All Available variations were noted according to their morphology and morphometry.

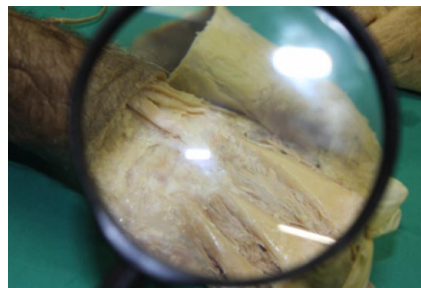


Fig. 1. Showing the DIM through a magnifying lens.

Statistical analyses. Statistical tests were conducted to compare the differences in measurements. This data was compared using a t-test for data distributed normally. The p-values were adjusted for the comparisons of multiple groups. Mean and standard deviation were reported for variables distributed normally. The significance level was set at $p < 0.05$.

RESULTS

Morphological analysis. The results of the findings revealed that the origin and insertion of all the DIMs were normal with the left hand having no additional, supernumerary, and absent muscles in each compartment

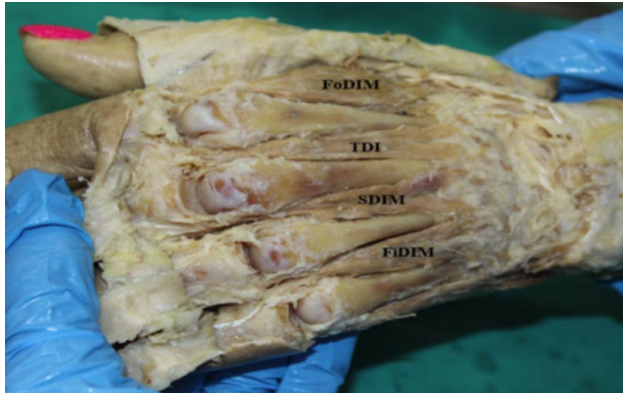


Fig. 2. Showing normal morphology of the DIM on the left hand in a female: a first dorsal interosseous muscle (FiDIM), a second dorsal interosseous muscle (SDIM), a third dorsal interosseous muscle (TDI) and a fourth dorsal interosseous muscle (FoDIM).

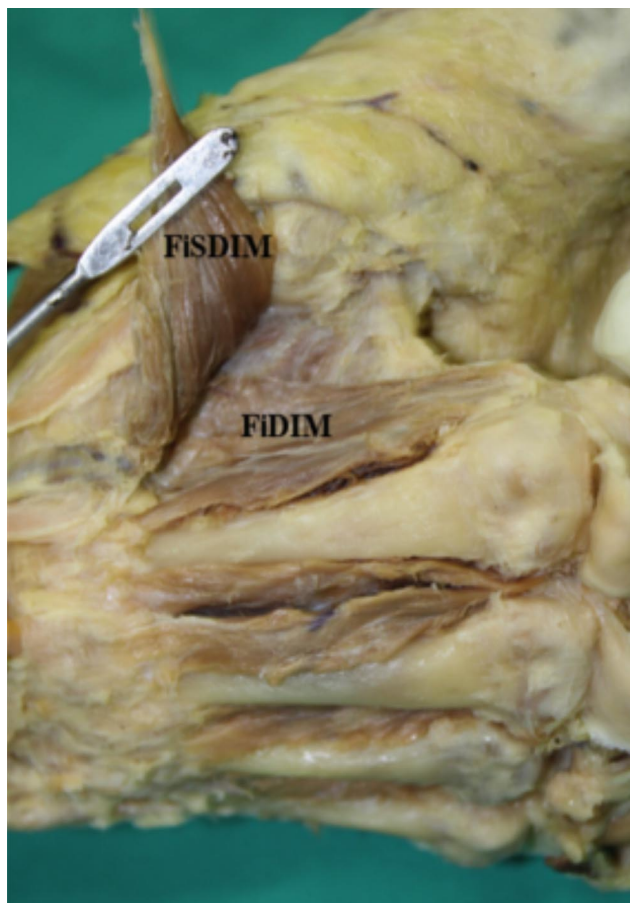


Fig. 3. Showing a right hand with a first supernumerary dorsal interosseous muscle (FiSDIM) in a female.

(Fig. 2). On the right hand, 2 out of 20 (10 %) hands had a first dorsal supernumerary muscle (Fig. 3); 1 out of 20 (5 %) hands had two unipennate heads on the second dorsal interosseous space (Fig. 4); 1 out of 20 (5 %) hands had a third dorsal interosseous supernumerary muscle (Fig. 5). The variations were only found on the right side and predominant in females: 2 out of 11 (18.18%) hands containing a space with a supernumerary muscle (Figs. 3 and 5); 1 out of 11 (9.09%) hands having a space with a double muscle; and 1 out of 11 (9.09%) hands having a compartment with a unipennate muscle (Fig. 5). In males, 1 out of 9 (11.11%) hands had a compartment with a supernumerary muscle.

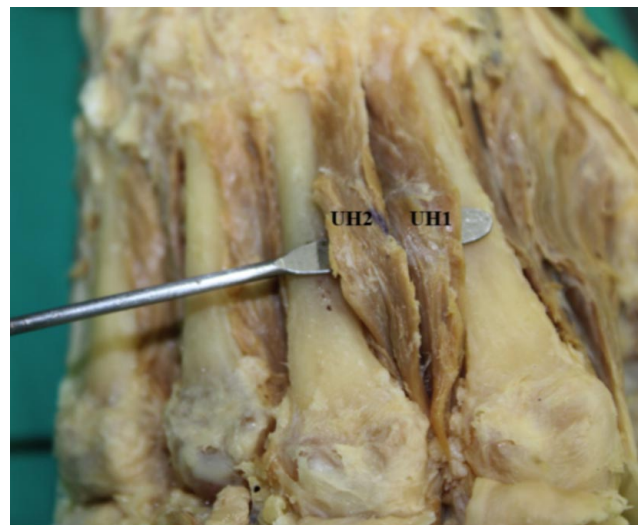


Fig. 4. Showing a right hand with two unipennate heads (UH) in a second dorsal interosseous muscle compartment in a female.

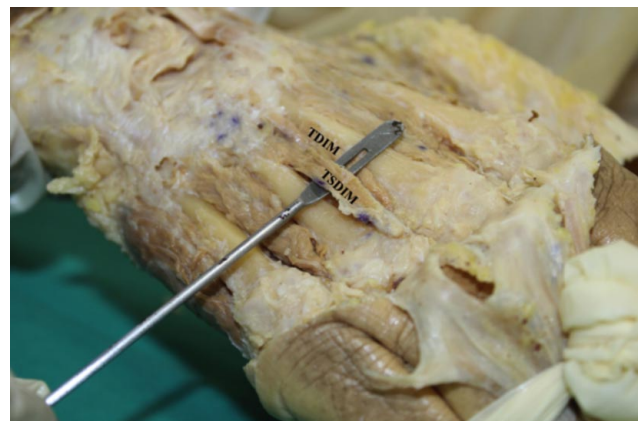


Fig. 5. Showing a right hand with a third supernumerary dorsal interosseous muscle in a male.

The midpoint length of each DIM was measured from the point of origin to the point of insertion in millimeters and recorded. The mean midpoint length of each DIM from the

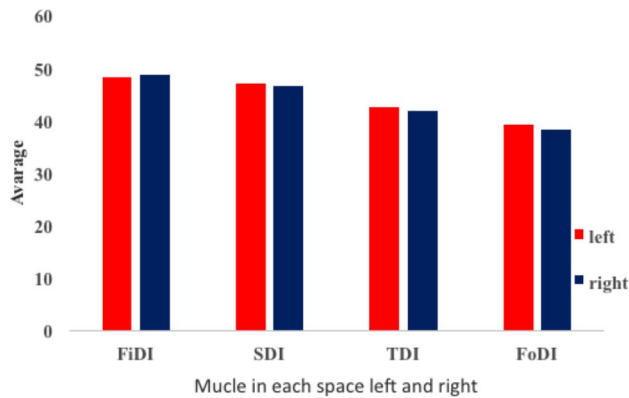


Fig. 6. The midpoint length of the DMI in each space with regard to laterality.

first to the fourth muscle respectively was taken (Table I) with the left hand: 48.24 ± 4 mm; 47 ± 3.59 mm; 42.33 ± 4.39 mm; 39.15 ± 3.17 mm and right hand: 48.52 ± 2.33 mm; 46.49 ± 3.61 mm; 41.72 ± 4.03 mm; 38.20 ± 4.11 mm. The mean midpoint length of each muscle in females and males from the first to the fourth muscle respectively was documented. In females on the left hand: 46.79 ± 3.56; 42.62 ± 3.57; 49.02 ± 4.21; 41.66 ± 2.15 and right hand: 47.30 ± 2.49; 39.27 ± 4.14; 45.69 ± 4.64; 38.12 ± 4.08 (Fig. 6). In males, it was on the left hand: 50.01 ± 3.95; 41.98 ± 3.79; 47.90 ± 4.83; 41.79 ± 4.25, and on the right hand: 46.65 ± 2.09; 39.01 ± 4.25; 47.47 ± 3.41; 38.31 ± 4.40 (Fig. 7). The mean midpoint length of the DIM was relatively higher on the left hand compared to the right hand in both females and males.

Table I. This table describes the relationship between the mean midpoint length of each DIM between females and males in the left and right hands.

	Sex	Group Statistics			
		N	Mean	Std. Deviation	Std. Error Mean
FiDI (L)	F	11	46.7909	3.56387	1.07455
	M	9	50.0133	3.95241	1.31747
SDI (L)	F	11	47.2991	3.56433	1.07469
	M	9	46.6456	3.79417	1.26472
TDI (L)	F	11	42.6164	4.20679	1.26839
	M	9	41.9833	4.83592	1.61197
FoDI (L)	F	11	39.2745	2.14930	.64804
	M	9	39.0078	4.24774	1.41591
FiDI (R)	F	11	49.0200	2.48998	.75076
	M	9	47.9000	2.09181	.69727
SDI (R)	F	11	45.6882	4.13608	1.24708
	M	9	47.4667	2.76078	.92026
TDI (R)	F	11	41.6591	4.63904	1.39872
	M	9	41.7933	3.40538	1.13513
FoDI (R)	F	11	38.1191	4.07516	1.22871
	M	9	38.3078	4.39798	1.46599

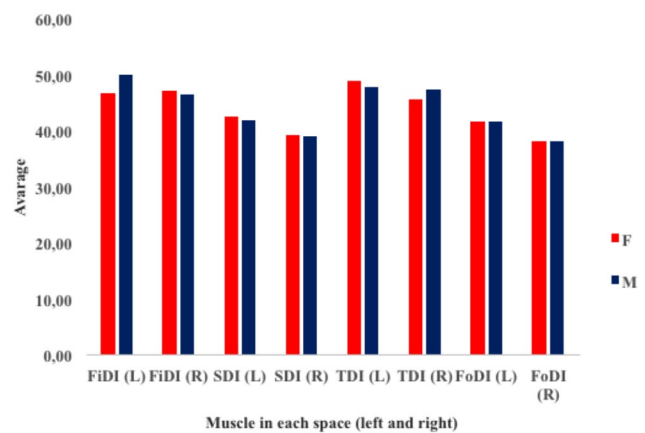


Fig. 7. The midpoint length of the DIM in each space between female and male with regards to laterality.

DISCUSSION

Knowledge of the variations in DIM is essential in clinical diagnosis and guides the treatment of fractures, the stiffness of the hand, and compartment syndromes (Nayak *et al.*, 2016). Extra heads of the DIM can be used for musculocutaneous flaps by hand surgeons in the correction of uncommon minor defects (Tang *et al.*, 2009). The interosseous muscles of the hand contain a high fiber compared to the muscle length which makes them unstable to change from the surrounding bony framework (Nayak *et al.*, 2016). These muscles show reduced power for every millimeter of decreased metacarpal length (Meunier *et al.*, 2004). An inflammatory swelling results in an increase in compartmental pressure due to the interosseous muscles being in tight compartments (Schreuders *et al.*, 2006). Intrinsic tightness leads to a reduced blood supply subsequently by fibrosis and muscle shortening (Schreuders *et al.*, 2006). All these important roles of DMI substantiate the need for investigating the possible variations in terms of laterality and sex that may exist within the population of interest in this study.

Morphology and morphometry variations of the DMI have been reported since the eighteenth century in literature (Nayak *et al.*, 2016). In one study the absence of the DMI has been reported in one or numerous spaces with some specimens being multipennate, and more than the expected number of muscles in each space (Bergman *et al.*, 1988). Eladounikdachi *et al.* (2002) discovered the dorsal interosseous muscle contains three heads with each head having

a unique distal attachment. Nayak *et al.* (2016) found the dorsal interosseous muscle containing three heads in the third digit. Natis *et al.* (2011), found a right-hand supernumerary muscle in a seventy-six-year-old Caucasian cadaver superficially located to the usual fourth dorsal interosseous muscle and proximal attached to the fourth metacarpal base (dorsally), traversing oblique and, distal to the fifth metacarpal head.

In this study, the observed normal origin and insertion of all DIMs on the left hand without additional supernumerary and absent muscles in each compartment are consistent with a previous study in a seventy-six-year-old Caucasian cadaver in a study by Nayak *et al.* (2016) and Natsis *et al.* (2011), where a fourth supernumerary DIM was observed on the right hand. The first supernumerary DIM was documented, and two unipennate heads on the second DIM were also observed compared with a study by Eladounikdachi *et al.* (2002), where a DIM containing three heads in each space was documented. A third supernumerary DIM on the right hand was also found in this study correlating with the findings of Nayak *et al.* (2016), and colleagues on a South Indian population where three out of thirty (10%) dissected hands contained a third supernumerary DIM. This study differs from the current study as sex and laterality were not considered as part of the study by Nayak *et al.* (2016), and colleagues. In terms of laterality and sexual dimorphism, variations regarding the supernumerary muscle, double interosseous space, and unipennate muscles were only observed on the right-hand side and predominantly in females. This is the first study to document these findings which serves as the strength of this investigation.

Limitations. This study has a few limitations; sample size (20 cadavers) is a limiting factor as it affects the validity of the results. Only cadavers of white race within a limited age range of seventy to hundred years were considered for this study. Innervation and blood supply of the DIM were not considered in this study as possible causes of variations.

CONCLUSION

The morphology of the dorsal interosseous muscles differs in terms of sex and laterality with variations prevalent in females on the right. Furthermore, the presence of additional heads and supernumerary muscles in the interossei muscles of the hand presents no symptoms but can result in chronic compartment syndrome caused by a rise in intercompartmental pressure in a particular compartment. These characteristics should be considered by hand surgeons because DIM of the hand can be utilized for musculocutaneous flaps by hand surgeons in the correction of uncommon minor defects of the hand.

ACKNOWLEDGMENTS. The authors acknowledge the College of Health Science, University of KwaZulu-Natal, as well as the technical support received from the members of staff of the Discipline of Clinical Anatomy, University of KwaZulu-Natal.

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RESUMEN: Los músculos interóseos dorsales (DIM) son músculos intrínsecos de la mano ubicados dorsalmente entre los huesos metacarpianos, que desempeñan un papel en la abducción de los dedos. Las variaciones anatómicas de estos músculos en términos de forma y longitud están bien documentadas, pero las variaciones con respecto al sexo y la lateralidad están poco exploradas. El objetivo de este estudio fue investigar la morfología y morfometría de los DIM de la mano con respecto al dimorfismo sexual y la lateralidad. Para este estudio se utilizaron veinte cadáveres humanos pertenecientes a individuos blancos (n = 40 manos) con sexo y lateralidad conocidos. Los DIM se diseccionaron y observaron para determinar su morfología. Además, se utilizó un calibrador digital para medir la longitud del punto medio del DIM. El origen y la inserción de todos los DIM fueron normales y la mano izquierda no tenía músculos adicionales, supernumerarios y ausentes en cada compartimento. Las variaciones se encontraron sólo en el lado derecho y predominaron en el sexo femenino: 2 de 11 (18,18%) manos contenían un espacio con un músculo supernumerario; 1 de cada 11 (9,09%) manos presentando un espacio con doble músculo; y 1 de cada 11 (9,09%) manos presentaba un compartimento con músculo unipennate. En los hombres, 1 de cada 9 (11,11%) manos tenía un compartimento con un músculo supernumerario. Se documentó la longitud media del punto medio de cada músculo en mujeres y hombres en ambas manos desde el primer al cuarto músculo, respectivamente. En mujeres de izquierda: $46,79 \pm 3,56$; $42,62 \pm 3,57$; $49,02 \pm 4,21$; $41,66 \pm 2,15$ y derecha: $47,30 \pm 2,49$; $39,27 \pm 4,14$; $45,69 \pm 4,64$; $38,12 \pm 4,08$. En los varones fue hacia la izquierda: $50,01 \pm 3,95$; $41,98 \pm 3,79$; $47,90 \pm 4,83$; $41,79 \pm 4,25$, y a la derecha: $46,65 \pm 2,09$; $39,01 \pm 4,25$; $47,47 \pm 3,41$; $38,31 \pm 4,40$. La longitud media del punto medio del DIM fue relativamente mayor en la mano izquierda en comparación con la derecha tanto en mujeres como en hombres. En este estudio, las variaciones con respecto al músculo supernumerario, el doble espacio interóseo y los músculos unipennados sólo se observaron en el lado derecho y predominantemente en el sexo femenino, un conocimiento que puede guiar en el tratamiento de fracturas, rigidez de la mano y síndromes compartimentales.

PALABRAS CLAVE: Músculo interóseo dorsal; Morfología; Morfometría; Variaciones; Sexo; Lateralidad.

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