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The anatomy and prevalence of the juncturae tendinum in the hands. A systematic review and meta-analysis

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SUMMARY

The movement of the fingers of the hand is thought to be limited in extension due in part to the presence of the juncturae tendinum (JT) in the dorsal webspaces. Clinically, these structures may help surgeons in identifying the extensor slips of the extensor digitorum communis (edc) and constitute an additional resource for tendon repair. These connections are highly variable in relation to their frequency and shape. Based on von Schroeder's classification, an evidence synthesis of those structures was performed; nineteen cadaveric studies were located with a total of 2060 hands. Using meta-analytical methods, the pooled prevalence values were computed for each webspace and each type of JT; the JT type 1 (JT-1) and 3 (JT -3) were by far the most common in the 2nd and 4th webspaces, respectively. In the 3rd webspace, the JT type 2 (JT-2) had the highest prevalence value, followed by JT-3 and JT-1. The pooled means of JT size revealed that JT-3 was significantly longer and thicker than JT-1 and JT-2, while JT-1 was significantly wider than JT-2 and JT-3. Ancestry-based prevalence values showed that Middle Eastern populations had the lowest overall JT prevalence values, and Indian and Turkish ancestries had the highest values. Side-based prevalence values demonstrate significance only for the JT-3y type in the 4th webspace, where it was twice more frequent on the left side. While JT-3 was not infrequent between edc to the ring finger and extensor digiti minimi (16.5%), it occurred 13 times more when edc to the little finger was absent. This anatomical meta-analysis is likely to generate more accurate prevalence and mean size values of the juncturae tendinum in human hands.

Key words: Juncturae Tendinum – Hand – Extensor – Meta-analysis

INTRODUCTION

The tendons of the extensor digitorum communis (edc) muscle are linked distally on the dorsum of the hand by connections – the juncturae tendinum (JT), also called intertendinous connections. These connective tissue bands extend mainly between the tendons of the edc and to the extensor digiti minimi (edm).

Often described as highly variable in surgical anatomy reference textbooks (Doyle and Botte, 2003; Van Kampen and Amadio, 2012), the JT is thicker on the ulnar side of the hand when compared to that on the radial side (Doyle and Botte, 2003). Von Schroeder et al. (1990) proposed a classification of the JT based on their size (Fig. 1): Type 1 (JT-1) is a thin filamentous band with a transversal course, found mostly in the second webspace with a more proximal location than other types of JT; type 2 (JT-2) is thicker and better defined, and it is present mainly in the third webspace; and type 3 (JT-3) consists of a thick, tendon-like band that is more prevalent in the fourth webspace. Based on the interconnection shape, two subtypes of JT-3 have been identified by the same authors: the y-shaped JT (JT-3y) splits "into two equal halves that inserted into the two tendons of adjacent digits", one slip was defined as JT-3y,

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the other as a continuation of the base tendon. The base tendon was defined by the muscle belly from which it originated. The r-shaped JT (JT-3r) is a single oblique JT stemming from a base tendon. Pinar et al. (2009) demonstrated that the histological examination of JT types supported the macroscopic classification.

When the edc tendon to the fifth finger (edc-v) is missing, the majority of hands have a JT connecting the edc of the ring finger (edc-iv) to the edm, or to the aponeurosis of the little finger (Kaplan and Hunter, 1984; Zilber and Oberlin, 2004; Celik et al., 2008; Jeon et al., 2010). In those studies, the absence of edc-v was associated with a thick JT-3, and a JT was likely to be absent in the case of a relatively large edc-v. Rarely, a JT could be found between edc of the index, the extensor indicis (ei) proprius (von Schroeder et al., 1990; von Schroeder and Botte, 2001). We are aware of one case report describing a JT between edc and the extensor pollicis longus (epl); the patient lacked independent extension of the thumb and fingers in both hands (Steichen and Petersen, 1984). Another case reports described a connection between epl and ei (Cavdar and Sehirli, 1996), and between edc to the index and ei (el Badawi et al., 1995). Because of the less oblique direction of its JTs, the ring finger is clinically considered as the least independent in terms of mobility (von Schroeder and Botte, 1993; Agarwal and Tirthani, 2011). It is highly important to note that the JT from the edc-iv to the little finger may be mistakenly defined as the edc-v (Yammine, 2015). Some authors suggested that JT-3 may represent a developmental remnant of the edc-v tendon (Leslie, 1954; von Schroeder and Botte, 1993; Zilber and Oberlin, 2004).

The function of JT is still not entirely understood: it may assist with spacing of edc tendon slips, or contribute to force redistribution (Michon, 1971); it may add for the coordination and stabilization of the extension of the metacarpophalangeal joints (mcpj) (von Schroeder and Botte, 1993). The JT prevent independent extension of the digits and are clinically important because they may bridge and therefore mask tendon lacerations (Botte, 2003). Subluxation of JT may cause snapping over metacarpal heads, and a complete transection of a JT may lead to subluxation of the extensor tendon over a flexed mcpj (von Schroeder and Botte, 1997; Farrar and Kundra, 2012). A JT may be trapped between the metacarpal neck and the base of the proximal phalanx, and can cause an irreducible palmar mcpj dislocation (Patel and Bassini, 2000). Importantly, the juncturae may help identifying the extensor tendons, and have been used for tendon or dorsal aponeurosis repair (Carr and Burge, 1992; Jebson and Blair, 1992; Zilber and Oberlin, 2004; Tanaka et al., 2006).

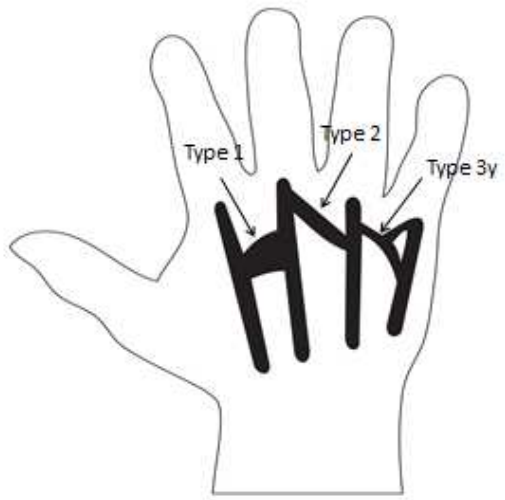

Fig. 1. Types of Juncturae Tendinum (based on von Schroeder's classification). Type 1: thin, Type 2: thick, Type 3: tendon-like.

The aim of this study is to perform an evidence synthesis on the prevalence, types and relationships of the juncturae tendinum in the human hand.

METHODS

The Checklist for Anatomical Reviews and Meta-Analysis (CARMA) guidelines were followed while conducting this systematic review and meta-analysis (Yammine, 2014a).

Search strategy and identification of studies

A systematic literature search was conducted through a number of electronic databases such as Medline, Embase, Scielo and Google Scholar from inception to June 2014.In details, we first updated the search strategy used in a previous meta-analysis while locating articles related to the prevalence of the edc tendon and its variants (Yammine, 2015). Then we conducted a second search using the Boolean combination of broad terms such as (juncturae OR "intertendinous connections") AND (hand OR finger* OR digit*) to locate the maximum number of relevant articles. We also searched the websites of the following journals: *Acta Anatomica, Anatomical Sciences International, Annals of Anatomy, Clinical Anatomy, European Journal of Anatomy, Folia Morphologica, International Journal of Anatomical variations, International Journal of Morphology, Italian Journal of Morphology and Embryology, Journal of Anatomy, Journal of Hand Surgery [Br and Am], Journal Bone and Joint Surgery [Br and Am]*, *Okajimas Folia Anatomica (Japan), Romanian Journal of Morphology and Embryology, Surgical and Radiological Anatomy, The Anatomical Record (A and B).* All included articles were citation-tracked using Google Scholar to ensure that all relevant articles were identified. Duplicates were deleted.

Criteria for study selection

Literature concerning the prevalence and the types of JT is infrequent, so all published or unpublished cadaveric or clinical studies reporting prevalence rates were included in the review. The primary outcomes are: a) the true prevalence of JT, and/or b) the types of JT, in at least one dorsal webspace with regard to edc tendons. The true JT prevalence rate is defined as the number of hands affected compared to the number of hands available for study.

Secondary outcomes are the prevalence values with regard to ancestry, gender, laterality and side, the interactions between those variables, and the anatomical relationships with eip and edm tendons. To ensure unbiased selection of included studies, abstracts from conferences were not included.

No restriction was imposed on date, language or age. Titles and abstracts were initially screened, and full-text articles were obtained when at least one primary outcome was thought to be reported.

Data extraction and analysis

Data extracted included sample size, sample details, type of investigation (clinical or cadaveric), and the results. Analysis was performed using StatsDirect v2.7.8 (Altrincham, United Kingdom). Proportion meta-analysis (MA) was used to calculate the pooled prevalence estimate (PPE), and odds ratio (OR) meta-analysis was used to establish potential associations with other variables such as ancestry, gender, laterality or side. The "two independent proportion test" was used to look for significant proportion differences between studies reporting JT frequencies in different ancestry populations. Descriptive analysis was conducted when the data were not amenable to meta-analysis. We examined heterogeneity amongst studies using I^2 statistics; whenever $I^2 > 50\%$, the random-effect estimate was reported.

RESULTS

Search results

The two search strategies yielded a total of 715 hits. Fifty-two duplicates were removed. After initial screening, 110 articles were potentially relevant; 21 narrative reviews and 74 clinical or cadaveric case reports were excluded. From the fifteen studies which met our inclusion criteria, another four were included after reference checking. In total, we located 19 cadaveric studies reporting at least one of the pre-defined primary outcomes (Table 1). Only the "adult" data reported in the study of Palatty et al. (2013) was computed. No clinical studies were found. Prevalence values of JT types in each intermetacarpal space (ims) are shown in Tables 2, 3 and 4.

Table 1. Characteristics of the included studies.

Studies	Population	Age	Sample size: cadavers	Male	Female	Sample size: hands	Right	Left
Abdel-Hamid et al., 2013	Egyptian	Adults	-	-	-	95	44	51
Agarwal and Tirthani, 2011	Indian	Adults	60	-	-	120	60	60
Celik et al., 2008	Turkish	Adults	24 + 6 upper limbs	30	0	54	30	24
Dass et al., 2011	South Indian	Adults	-	-	-	100	47	53
El-Badawi et al., 1995	Saudi	Adults	-	-	-	181	-	-
Godwin and Ellis, 1992	British	Adults	25	-	-	50	25	25
Gonzales et al., 1995	American	Adults	-	-	-	50	-	-
Gonzales et al. 1996	American	Adults	-	-	-	72	-	-
Govsa et al., 2011	Turkish	Adults	19	19	0	38	19	19
Hirai et al., 2001	Japanese	Adults	-	-	-	548	276	272
Jeon et al., 2010	Korean	Adults	50	18	32	50	-	-
Kitano et al., 1996	Japanese	Adults	17 cad + 12 patients	-	-	40	-	-
Mori, 1964	Japanese	Adults	-	-	-	205	-	-
Palatty et al., 2013	Indian	Adults Fetuses	15 10	- -	- -	30 20	15 10	15 10
Pinar et al., 2009	Turkish	Adults	24 cad. +6 specimens	54	0	54	30	24
Tanaka et al., 2007	Japanese	Adults	39	15	24	41	24	17
von Schroeder and Botte, 1990	American	Adults	20			40	20	20
von Schroeder and Botte, 1995	American	Adults	-	-	-	43	22	21
Wehbe, 1992	American	Adults	120	62	58	240	120	120
Zilber and Oberlin, 2004	French	Mean = 79 y	27 (only 23 paired)	13	14	50	24	26

Table 2. Prevalence and types of junctura tendinum in 2nd IMS.

Studies	NB hands	2nd IMS					
		Absence of JT	JT 1	JT 2	JT 3r	JT 3y	Total JT
Abdel-Hamid et al., 2013	95	61 (64.2%)	19 (20%)	15 (15.8%)	0	0	34 (35.8%)
Agarwal and Tirthani, 2011	120	98 (81.7%)	-	-	-	-	22 (18.3%)
Celik et al., 2008	54	21 (38.8%)	31 (57.4%)	2 (3.7%)	0	0	33 (61.1%)
Dass et al., 2011	100	13 (13%)	83 (83%)	4 (4%)	0	0	87 (87%)
El-Badawi et al., 1995	181	115 (63.6%)	-	-	-	-	66 (36.4%)
Godwin and Ellis, 1992	50	10 (20%)	-	-	-	-	40 (80%)
Gonzales et al., 1996	72	72 (100%)	-	-	-	-	0
Hirai et al., 2001	548	170 (31%)	378 (69%)	0	0	0	378 (69%)
Kitano et al., 1996	40	19 (47.5%)	21 (52.5%)	0	0	0	21 (52.5%)
Mori, 1964	205	20 (9.7%)	-	-	-	-	185 (90.3%)
Palatty et al., 2013	30	6 (20%)	22 (73.3%)	2 (6.7%)	0	0	24 (80%)
Pinar et al., 2009	54	21 (38.9%)	31 (57.4%)	2 (3.7%)	0	0	33 (61.1%)
von Schroeder and Botte, 1990	40	5 (12.5%)	35 (87.5%)	0	0	0	35 (87.5%)
von Schroeder and Botte, 1995	43	6 (14%)	37 (86%)	0	0	0	37 (86%)
Wehbe, 1992	240	34 (14.2%)	182 (76%)	24 (10%)	0	0	206 (85.8%)
Zilber and Oberlin, 2004	50	9 (18%)	41 (82%)	0	0	0	41 (82%)

Table 3. Prevalence and types of junctura tendinum in 3rd IMS.

Studies	**Nb hands**	**3rd IMS**					
		Absence of JT	**JT 1**	**JT 2**	**JT 3r**	**JT 3y**	**Total JT**
Abdel-Hamid et al., 2013	95	29 (30.5%)	4 (4.2%)	18 (18.9%)	24 (25.3%)	20 (21.1%)	66 (69.5%)
Agarwal and Tirthan, 2011	120	4 (3.3%)	-	-	-	-	116 (96.7%)
Celik et al., 2008	54	2 (3.7%)	9 (16.7%)	32 (59.3%)	3 (5.5%)	8 (14.8%)	52 (96.3%)
Dass et al., 2011	100	0	9 (9%)	67 (67%)	8 (8%)	16 (16%)	100 (100%)
El-Badawi et al., 1995	181	46 (25.4%)	-	-	-	-	135 (74.6%)
Godwin and Ellis, 1992	50	0	-	-	-	-	50 (100%)
Hirai et al., 2001	548	16 (3%)	0	160 (29%)	372 (68%)	0	532 (97%)
Mori, 1964	205	20 (9.7%)	-	-	-	-	185 (90.3%)
Palatty et al., 2013	30	0	6 (20%)	15 (50%)	6 (20%)	3 (10%)	30 (100%)
Pinar et al., 2009	54	2 (3.7%)	9 (16.7%)	32 (59.3%)	3 (5.5%)	8 (14.8%)	52 (96.3%)
von Schroeder and Botte, 1990	40	0	11 (27.5%)	16 (40%)	12 (30%)	1 (2.5%)	40 (100%)
von Schroeder and Botte, 1995	43	0	-	-	-	-	43 (100%)
Wehbe, 1992	240	0	48 (20%)	113 (47%)	79 (33%)		240 (100%)
Zilber and Oberlin, 2004	50	2 (4%)	-	-	-	-	48 (96%)

Table 4. Prevalence and types of junctura tendinum in 4th IMS.

Studies	Nb hands	4th IMS						
		Absence of JT	JT 1	JT 2	JT 3r	JT 3y	Total JT	JT EDC-IV/ EDM
Abdel-Hamid et al., 2013	95	28 (29.5%)	1 (1.1%)	1 (1.1%)	7 (6.3%)	59 (62.1%)	67 (70.5%)	-
Agarwal and Tirthani, 2011	120	15 (12.5%)	-	-	-	-	105 (87.5%)	-
Celik et al., 2008	54	0	1 (1.8%)	4 (7.3%)	20 (37%)	30 (53.7%)	54 (100%)	-
Dass et al., 2011	100	0	1 (1%)	15 (15%)	73 (73%)	11 (11%)	100 (100%)	-
El-Badawi et al., 1995	181	151 (87.3%)	-	-	-	-	23 (12.7%)	43 (28.7%)
Godwin and Ellis, 1992	50	50 (100%)	-	-	-	-	0	1 (2%)
Gonzales et al., 1995	50	20 (40%)	-	-	-	-	30 (60%)	10 (20%)
Govsa et al., 2011	38	0	-	-	16 (42.1%)	22 (57.9%)	38 (100%)	-
Hirai et al., 2001	548	240 (43.8%)	0	0	45 (8.2%)	263 (48%)	308 (56.2%)	37 (6.7%)
Jeon et al., 2010	50	4 (8%)	0	4 (8%)	20 (40%)	22 (44%)	46 (92%)	20 (50%)
Mori, 1964	205	5 (2.5%)	-	-	-	-	200 (97.5%)	-
Palatty et al., 2013	30	0	2 (6.7%)	6 (20%)	12 (40%)	10 (33.3%)	30 (100%)	-
Pinar et al., 2009	54	0	1 (1.8%)	4 (7.3%)	20 (37%)	29 (53.7%)	54 (100%)	-
Tanaka et al., 2007	41	-	-	-	-	-	-	10 (24.4%)
von Schroeder and Botte, 1990	40	0	0	9 (22.5%)	23 (57.5%)	8 (20%)	40 (100%)	-
von Schroeder and Botte, 1995	43	0	-	-	-	-	43 (100%)	-
Wehbe, 1992	240	0	7 (3%)	43 (18%)	190 (79%)		240 (100%)	
Zilber and Oberlin, 2004	50	0	0	0	50 (100%)		50 (100%)	

Relationship between JT and edc

Prevalence of JT and their types in the 2nd ims

Sixteen studies (Table 2) totalizing 1922 hands reported the prevalence of JT with a PPE of 63% (95% CI = 0.479 to 0.769, I^2 = 97.7%). Only eleven studies (von Schroeder and Botte, 1990; Wehbe, 1992; von Schroeder and Botte, 1995; Kitano et al., 1996; Hirai et al., 2001; Zilber and Oberlin, 2004; Celik et al., 2008; Pinar et al., 2009; Dass et al., 2011; Abdel-Hamid et al. 2013; Palatty et al., 2013) reported the type of JT in the 2nd ims with a total of 929 JTs and PPEs of 95% (95% CI = 0.882 to 0.988, I^2 = 91%), 5% (95% CI = 0.012 to 0.117, I^2 = 91%) for JT-1 and JT-2, respectively. No JT-3r or JT-3y was found in the 2nd IMS.

Prevalence of JT and its types in the 3rd ims

Fourteen studies (Table 3) reported the prevalence of JT in the 3rd ims with a total of 1810 hands and a PPE of 92.7% (95% CI = 0.822 to 0.987, I^2 = 97.8%). Eight studies reported the types of JT (von Schroeder and Botte, 1990; Wehbe, 1992; Hirai et al., 2001;Celik et al., 2008; Pinar et al., 2009; Dass et al., 2011; Abdel-Hamid et al. 2013; Palatty et al., 2013)with a total of 951 JTs and PPEs of 16.8% (95% CI = 0.035 to 0.370, I^2 = 97.5%), 47.6% (95% CI = 0.363 to 0.591, I^2 = 91.5%), and 37.3% (95% CI = 0.213 to 0.549,I^2 = 96.5%) for JT-1, JT-2 and JT-3, respectively. Besides that of Wehbe (1992), the remaining seven studies reported the type of 475 JT-3 with PPEs of 62% (95% CI = 0.239 to 0.920, I^2 = 97.3%) and 38% (95% CI = 0.069 to 0.760, I^2 = 97.3%), for JT-3r and JT-3y, respectively.

Prevalence of JT and their types in the 4th ims

Seventeen studies (Table 4) reported the prevalence of JT in the 4th ims with a total of 1948 hands and a PPE of 87.4% (95% CI = 0.708 to 0.976, I^2 = 98.8%). Ten studies reported the types of JT (von Schroeder and Botte, 1990; Wehbe, 1992; Hirai et al., 2001; Zilber and Oberlin, 2004; Celik et al., 2008; Pinar et al., 2009; Jeon et al., 2010; Dass et al., 2011; Abdel-Hamid et al. 2013; Palatty et al., 2013) with a total of 989 JTs and PPEs of 1.5% (95% CI = 0.005 to 0.029, I^2 = 52%), 8.3% (95% CI = 0.027 to 0.165, I^2 = 93.2%) and 90.7% (95% CI = 0.814 to 0.970,I^2 = 94.1%) for JT-1, JT-2 and JT-3,

Table 5. Summary of main frequency findings.

JT type		Overall JT	JT-1	JT-2	JT-3	JT-3r*	JT-3y*
	2nd	63%	95%	5%	0	0	0
Webspace	3rd	92.7%	16.8%	47.6%	37.3%	62%	38%
	4th	87.4%	1.5%	8.3%	90.7%	45.3%	54.6%

*: values of JT-3r and JT-3y are based on JT-3 prevalence values and not on the overall values.

Table 6. Ancestry-based prevalence of JT.

Populations	Middle Eastern	Turkish	Indian	Japanese	American/ European
2nd webspace	**36.3%** (95% CI = 0.307 to 0.420, I^2 = 0%)	**61%** (95% CI = 0.516 to 0.698, I^2 = 0%)	**62.4%** (95% CI = 0.134 to 0.984, I^2 = 985%)	**72.7%** (95% CI = 0.516 to 0.895, I^2 = 96.2%)	**68.2%** (95% CI = 0.318 to 0.949, I^2 = 98.4%)
3rd webspace	**72.7%** (95% CI = 0.673 to 0.777, I^2 = 0%)	**95.5%** (95% CI = 0.908 to 0.985, I^2 = 0%)	**98.6%** (95% CI = 0.953 to 0.999, I^2 = 0%)	**94%** (95% CI = 0.856 to 0.989, I^2 = 92.2%)	**92.2%** (95% CI = 0.537 to 0.967, I^2 = 98.7%)
4th webspace	**39.5%** (95% CI = 0.004 to 0.925, I^2 = 99%)	**100%**	**97%** (95% CI = 0.848 to 0.997, I^2 = 91.6%)	**85%** (95% CI = 0.472 to 0.999, I^2 = 99%)	**79%** (95% CI = 0.279 to 0.995, I^2 = 99%)

respectively. Besides those of Wehbe (1992) and Zilber and Oberlin (2004), the remaining 8 studies having a total of 652 JT-3 showed PPEs of 45.3% (95% CI = 0.229 to 0.687, I^2 = 96.9%) and 54.6% (95% CI = 0.312 to 0.770, I^2 = 96.9%), for JT-3r and JT-3y, respectively.

A summary of the meta-analytical results is shown in Table 5.

Size of JT

The study of Jeon et al. (2010) only reported the range of the length of JT-3; 5 to 25 mm. Three studies reported the size of JT-1, JT-2 and JT-3 (von Schroeder and Botte, 1990; Celik et al., 2008; Pinar et al., 2009). With a total of 126 hands, the pooled mean size values of the length, width and thickness for all JT types are shown in Table 5. Significance was found in all 3 size measures ($P < 0.05$); JT-3 was significantly longer and thicker than JT-1 and to a lesser degree than JT-2, and JT-1 was significantly wider than JT-2 and JT-3.

Interaction with ancestry

Two studies reported the prevalence of JT in Middle Eastern populations (El-Badawi et al. 1995; Abdel-Hamid et al. 2013) with a total of 276 hands. Three studies reported the prevalence of JT in Indian populations (Agarwal and Tirthani 2011; Dass et al. 2011; Palatty et al., 2013) with a total of 250 hands. Six studies reported the prevalence of JT in American/ European populations (Godwin and Ellis 1992; Wehbe, 1992; von Schroeder and Botte 1990; von Schroeder and Botte 1995; Gonzales et al. 1996; Zilber and Oberlin 2004) with a total of 495 hands. For the 2nd and 3rd webspaces, two studies reported the prevalence of JT in Turkish populations (Celik et al 2008; Pinar et al., 2009) with total of 108 hands, while for the 4th webspace there were three studies which reported the prevalence of JT in Turkish populations (Celik et al 2008; Pinar et al., 2009; Govsa et al., 2011) with a total of 146 hands. With regard to the Japanese population, three studies reported the prevalence of JT (Mori 1964; Kitano et al 1996; Hirai et al. 2001) with a total of 793 hands for the 2nd webspace, two studies reported the prevalence of JT (Mori 1964; Hirai et al. 2001) with a total of 753 hands for the 3rd webspace, and three studies reported the prevalence of JT in Japanese/Korean populations (Mori 1964; Hirai et al. 2001; Jeon et al., 2010) with a total of 803 hands for the 4th webspace. Ancestry-based prevalence values are shown in Table 6. For the 2nd webspace, significant differences in overall JT frequencies ($P < 0.001$) were found between different studied populations such as Middle Eastern < Turkish = Indian < Japanese = American/European. For the 3rd webspace, significant differences were such that; [American/European < Middle Eastern ($P < 0.001$)] < [Japanese < Indian = Turkish ($P = 0.01$)]. For the 4th webspace, significant differences ($P < 0.001$) were as follows; Middle Eastern < Japanese < American/ European< Indian < Turkish (Table 6).

Interaction with side

Pinar et al., (2009) reported the bilateral frequency of JT based on JT type and webspace; 75% for JT-1 in the 2ndwebspace, 92.3% for JT-2 and 33.3% for Jt-3r in the 3rdwebspace, 55.5% and 80% for JT-3r and JT-3y, respectively, in the 4thwebspace. Wehbe (1992) reported bilateral occurrence based on JT type only; JT bilaterality of any type was found in 24% of the cadavers, for JT-1 64% of the cases, for JT-2 in 52%, and

for JT-3 in 66% of the cadavers. Von Schroeder and Botte (1995) found no right-left tendencies but did not report side frequencies. Seven studies (von Schroeder and Botte, 1990; Celik et al., 2008;Pinar et al., 2009; Jeon et al., 2010; Dass et al., 2011; Abdel-Hamid et al. 2013; Palatty et al., 2013) reported side frequencies in their studies with a total of 980 JT; significance was found only for JT-3y in the 4th webspace where it is present twice more on the left side (OR = 2, 95% CI = 1.318 to 3.139, I^2 = 0%, P = 0.001).

Prevalence of JT between edc-iv and edm

Six studies (Godwin and Ellis, 1992; El-Badawi et al. 1995; Gonzales et al., 1999; Hirai et al. 2001; Tanaka et al., 2007; Jeon et al., 2010) reported the presence of a JT-3 between **edc-iv and edm** tendons, with a total of 920 hands and a PPE of 17.7% (95% CI = 0.079 to 0.302,I^2 = 93.1%).

Prevalence of JT in relation to the absence of edc-V

Four studies (von Schroeder and Botte, 1990; Gonzales et al., 1995; Jeon et al., 2010; Govsa et al., 2011) reported JT frequencies in the 4th webspace with relation to the presence or absence of edc-V tendon and with a total of 154 JT and an OR of 2.6 (95% CI = 1.683 to 4.061, P < 0.0001, I^2 = 90%), meaning that JT prevalence was 2.6 times significantly higher when the edc-V was absent. Besides that of Gonzales et al. (1995), the remaining 3 studies reported the prevalence of JT types with a total of 124 JTs and a pooled OR of 12.5 (95% CI = 2.374 to 66.102, P = 0.002, I^2 = 0%) for JT-2 where it is significantly more prevalent when edc-V was present. For JT-3, the pooled OR was 13 (95% CI = 2.410 to 70.421, P = 0.002, I^2 = 0%), significantly higher when edc-V was absent.

DISCUSSION

The juncturae tendinum was most common in the 3rd webspace, followed by the 4th and then the 2nd. The types JT-1 and JT-3 were by far the most common in the 2nd and 4thwebspaces, respectively. In the 3rd webspace, JT-2 had the highest prevalence value, followed by JT-3 and JT-1.

Only the side-based prevalence values of JT-3y in the 4thwebspace had a significant difference where such type was more prevalent on the left side. No available data was found to look for gender-based frequencies. Significant differences were found between ancestry-based frequencies; the Middle Eastern populations had the lowest overall JT prevalence values, and particularly in the 2nd and 4th webspaces; Indian and Turkish ancestries had the highest values in the 3rd and 4th webspaces; and American/European samples had the highest occurrence in the 2nd webspace.

While a JT-3 was not infrequent between edc-iv and edm (16.5%), it occurred 13 times more when edc-v was absent.

Despite an extensive search strategy, no confirmation could be provided that this review located all relevant articles. However, the pooled sample sizes of 1922, 1810, and 1948 hands could be fairly considered as representatives to draw prevalence estimates of JT-1, JT-2 and JT-3, respectively.

The reported classification of the type of JT is observer-dependent, so the accuracy of the frequencies found in each study might not be as accurate as one could expect. However, the direction and size of a JT are significantly different between types, and could counterbalance such bias. Nevertheless, as stated by Zilber and Oberlin (2004), Celik et al. (2008) and Yammine (2014b, 2015), it is sometimes very difficult to differentiate between a slip from EDC-V, an ulnar slip of an extensor digiti minimi and quinti, and a JT-3. Such difficulty might have affected in some way the frequencies found in the 4th webspace.

Lastly, our results on ancestry-based frequencies did not cover African populations, because of no available published data. However, we were able to compute and compare prevalence values between North American/European, Japanese, Indians, Turkish and Middle Eastern populations.

In conclusion, this evidence-based anatomical review and meta-analysis yielded pooled results on the prevalence, type and relationship of the JT in each of the three ulnar webspaces of the dorsum of the hand. Most frequently, JT-1 and JT-3 were found in the 2nd and 4th webspaces, respectively, while JT-2 was most prevalent in the 2nd webspace. Along with the prevalence values of the subtypes JT-3r and JT-3y, the results of this review would be very helpful in identifying JT types and their connections to the extensor slips, and would assist surgeons when choosing JT as an additional structural resource for tendon repair.

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