"I sing of arms and of a man…": medial epicondylosis and the sexual division of labour in prehistoric Europe

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Highlights

- Thrower's elbow (medial epicondylosis) is a rare occupational syndrome today.
- The lateral to medial (*L*/*M*) epicondylar ratio is greater than 1 in living populations.
- The *L*/*M* ratio permits comparisons in past populations.
- European prehistoric males display a specific pattern of lesions for the right elbow.
- Right upper limb use in throwing motions is a long-term status-linked male proclivity.

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"I sing of arms and of a man…": medial epicondylosis and the sexual division of labour in prehistoric Europe☆

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ABSTRACT

Sexual division of labour in European prehistory is usually inferred by indirect means: ethnographic analogy, pictorial representation, or from grave inclusions. The study of skeletal activity-related morphology seems the most direct means by which to interrogate the question of sexual division of labour in past societies. In this paper we present the results of an analysis of enthesopathies (i.e. lesions of the tendon attachments) of the elbow in three time-successive population samples spanning the prehistoric, pre-industrial historic, and modern European eras. We employ an innovative analytical procedure, the lateral to medial epicondylar ratio (*L*/*M* ratio) to assess limb use. Results indicate a tendency for lateral epicondylosis in all samples, except for prehistoric males, who possess medial epicondylosis more frequently, and for the right side only. The increased prevalence of pathological changes of the right medial epicondyle suggests lateralized limb use that corresponds with "thrower's elbow". This indicates that males, but not females, preferentially employed movements involving throwing motions in these hunter-gatherer and early farming groups. Based on this evidence we postulate the existence of a persistent sexual division of labour in these prehistoric European populations involving one or several strenuous activities linked to unilateral limb use.

1. Introduction

In prehistory sexual division of labour or gendered activity, a part of gender relations that contributes to the roles that men and women play in society, is often inferred from analyses of grave goods, as a part of the social identity of the deceased (see, for Q2 example, Chapman, 1997; O'Shea and Zvelebil, 1984; Rega, 1997; Stig-Sorensen, 1997; Treherne, 1995), and artistic representations, both pictographs and figurines (Conkey, 1991; Duhard, 1993; Joyce 2004; Nelson, 1997). Interpretations depend on analogies drawn from cross-cultural studies that provide evidence for ostensibly universal sex differences in labour (Wood and Eagly, 2002). Within non-industrial societies, the majority of tasks are strongly gendered, but substantial diversity exists across societies with respect to which sex performs a particular task (Gilchrist, 2004; Moore, 1994; with regard to the effect of age and social change, respectively). In almost all groups hunting large game and warfare appear to be largely, albeit not exclusively, men's activities (Keeley 1986: 35; Knüsel and Smith, 2013; Murdock and Provost, 1973; Testart, 1986; Wood and Eagly, 2002). With regard to hunting, Testart (1986) points out that among modern hunter-gatherers, females can and do hunt, but almost never with weapons that penetrate the flesh. In a sample of 50 worldwide traditional societies from the Human Relations Area Files probability sample, men as opposed to women overwhelmingly engage in games and sports employing projectiles, such as spears, sticks, javelins, darts, and stones (Deaner and Smith, 2012). As a whole, men perform movements involving percussive force, as in the use of an adze or an axe (Testart, 1986); these require similar movements of the upper limb to those employed in throwing, the biomechanics and injurious effects of which has been studied in detail for some years (Bennett, 1941, 1947, 1959; Fleisig et al., 1996; Gainor et al., 1980; Jobe et al., 1983; McCue et al., 1985; Priest et al., 1974; Tullos and Bryan, 1985).

Throwing is among the most dynamic and demanding of physical activities, requiring complex sequential movements of the shoulder, arm, and forearm, as well as each segment of the body from the fingers to the toes in various combinations for the different forms of projectile use. The power of the throw is as much a product of the trunk, hips and lower limbs as it is of the upper

Q1 ☆ From the opening lines of Virgil's *Aeneid*.

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Table 1
Reported prevalence rates of epicondylosis in modern clinical groups performing various trades, professions, and activities. The higher lesion frequencies for lateral or medial epicondyles is indicated in bold.

Population	*N*	Lateral epicondyle	Medial epicondyle	*L*/*M* ratio	Reference
General practice population	8500	0.7%	0.1%	6.0	Hamilton, 1986
Nursery school cooks (women only)	209	20.1%	11.5%	1.7	Ono et al., 1998
Social welfare employees (other than cook. women only)	366	7.7%	3.0%	2.6	Ono et al., 1998
Automobile manufacturing workers	1198	3.3%	2.2%	1.5	Gold et al., 2009
Assembly-line packers (women only)	152	2.6%	3.3%	0.8	Luopajarvi et al., 1979
Shop assistants (women only)	133	2.3%	0.0%	/	Luopajarvi et al., 1979
General population	4783	1.3%	0.4%	3.3	Shiri et al., 2006
General population (men)	2696	1.3%	0.6%	2.2	Walker-Bone et al., 2004
General population (women)	3342	1.1%	1.1%	1.0	Walker-Bone et al., 2004
Blue collar workers (shoe factory)	253	2.0%	0.0%	/	Roquelaure et al., 2002
Workers in repetitive/constrained jobs (men)	393	1.5%	2.3%	0.7	Nordander et al., 2009
Workers in repetitive/constrained jobs (women)	1106	3.3%	1.6%	2.1	Nordander et al., 2009
Workers in varied/mobile jobs (men)	522	1.5%	0.6%	2.5	Nordander et al., 2009
Workers in varied/mobile jobs (women)	656	1.7%	0.5%	3.4	Nordander et al., 2009
Workers in strenuous jobs	Not clear	0.6%	0.2%	3.0	Viikari-Juntura et al., 1991
Workers in non-strenuous jobs	Not clear	0.5%	0.3%	1.7	Viikari-Juntura et al., 1991
Sewing machine operators (women only)	82	4.9%	0.0%	/	Anderson and Gaardboe, 1993
Auxiliary nurses and home helpers (women only)	25	0.0%	0.0%	/	Anderson and Gaardboe, 1993
Public gas- and waterworks employees, high exposure (right side)	46	10.9%	2.2%	5.0	Ritz, 1995
Public gas- and waterworks employees, high exposure (left side)	46	6.5%	6.5%	1.0	Ritz, 1995
Public gas- and waterworks employees, moderate exposure (right side)	52	7.7%	5.8%	1.3	Ritz, 1995
Public gas- and waterworks employees, moderate exposure (left side)	52	13.5%	1.9%	7.0	Ritz, 1995
Public gas- and waterworks employees, no exposure (right side)	82	7.3%	2.4%	3.0	Ritz, 1995
Public gas- and waterworks employees, no exposure (left side)	82	7.3%	2.4%	3.0	Ritz, 1995
Cases of work-related peri-articular injuries (France, 1998)	8972	16.1%	1.9%	8.6	Gary and Costa-Salute, 2001
workers exposed to repetitive movements	1759	12.3%	4.0%	3.1	Bourgeois et al., 2000
workers not exposed to repetitive movements	343	7.9%	3.5%	2.3	Bourgeois et al., 2000
Baseball pitchers (9–12 years old)	298	11.1%	21.8%	0.5	Lyman et al., 2001

extremities (Toyoshima et al., 1974; Pappas et al., 1985), but the shoulder and elbow joints and their associated soft tissue structures are those most often injured (Ciccotti et al., 2004; Jobe and Cicciotti, 1984).

The torques generated by dynamic movements (i.e. those in excess of the range of normal joint motions) produce injuries in the shoulder and elbow joints of the dominant limb (McCue et al., 1985; Tullos and Bryan, 1985). The overhead throwing motion places valgus stress on the elbow that is transmitted via the flexor-pronator muscles to the medial epicondyle of the humerus, producing "valgus extension overload syndrome", a form of repetitive stress syndrome that is the most common cause of elbow injuries in the throwing athlete (Cain et al., 2003). Medial epicondylosis,[1] also called "thrower's elbow" is a condition affecting the site of attachment of the medial collateral ligament and origin of the common flexor tendon at the medial epicondyle (Baccarani and Simonini, 1968; Bramhall et al., 1994; Ciccotti et al., 2004; Jobe and Ciccotti, 1994; Miller, 1960; Ouellette et al., 2008). It is a rare condition seen mainly in sports involving overhead throwing but also in occupational activities creating similar forces (as in hammering in carpentry) (Ciccotti et al., 2004; Jobe and Ciccotti, 1994). Lateral epicondylosis or "tennis elbow" is more common than medial epicondylosis and described in connection with numerous sports and occupational activities (Jobe and Ciccotti, 1994; Shiri and Viikari-Juntura, 2011). When medial and lateral epicondylosis are studied together in living populations the frequency of lateral epicondylosis divided by the frequency of medial epicondylosis (the *L*/*M* ratio) is almost always greater than 1 (Table 1). Of those groups studied, baseball pitchers are the only group where the occurrence of medial epicondylosis is clearly greater than lateral epicondylosis (Table 1). Unilateral enthesopathy of the medial epicondyle has been recognized previously as a good skeletal marker of throwing and used to discuss the sexual division of labour in prehistoric groups (Dutour, 1986; Villotte et al., 2010a) but for small samples, and the *L*/*M* ratio has never been studied in detail. The goal of this article is to present the frequencies of lateral and medial epicondylosis in several prehistoric and historic samples and use the *L*/*M* ratio in order to discuss the sexual division of labour in activities associated with the throwing motion. Because these repeated movements affect the skeleton in a patterned way, their relative distribution in male and female skeletons provides an unrivalled opportunity to assess sexual division of labour directly from the remains of those who performed tasks.

2. Material and methods

The frequencies of lateral and medial epicondyle enthesopathies in several prehistoric and historic groups have been calculated, and the *L*/*M* ratio has been determined for three large samples of prehistoric, pre-industrial historic, and modern documented populations (Table 2). Two different analyses were performed: one involving the total number of observed right and left condyles, and a second of humeri with both condyles preserved and recorded. A single observer (S.V.) performed all enthesis examinations employing the same methodological criteria (Villotte, 2006; Villotte et al., 2010b). These samples include adult specimens only. Age at death and sex are known for the identified skeletal collections (the modern documented populations) (see Villotte, 2009 for a description of these collections). Estimation of age-at-death and sex of the prehistoric and pre-industrial historic individuals was based on recently published methods with demonstrably good reliability (references in Villotte et al., 2010a).

[1] Contrary to "epicondylitis", the more neutral term "epicondylosis" does not suggest inflammation and is thus more appropriate (even if less used). As in most of the cases of medial or lateral epicondyle enthesopathies there is no histopathological evidence of either acute or chronic inflammation (Khan et al., 1999).

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Table 2
Frequencies of lateral and medial epicondylosis for each sub-sample. The higher lesion frequencies for lateral or medial epicondyles is indicated in bold.

Samples	Collections	Periods	Females								Males							
			Right epicondyles				Left epicondyles				Right epicondyles				Left epicondyles			
			N total and %			L/M ratio	N total and %			L/M ratio	N total and %			L/M ratio	N total and %			L/M ratio
			Lateral		Medial		Lateral		Medial		Lateral		Medial		Lateral		Medial	
Modern Documented Sample (223 females and 430 males)	Spitalfields (England)	18–20th c. AD	67	**68.7%**	64	39.1%	1.8	60	**70.0%**	55	34.5%	2.0	53	**39.6%**	46	19.6%	2.0	49	**36.7%**	50	12.0%	3.1
	Coimbra (Portugal)		131	**35.1%**	118	16.1%	2.2	124	**21.8%**	111	14.4%	1.5	119	**20.2%**	121	6.6%	3.1	133	**11.3%**	112	7.1%	1.6
	Sassari (Italy)		/					/					110	**20.9%**	110	8.2%	2.5	120	**10.8%**	114	7.0%	1.5
	Bologna (Italy)		/					/					64	**39.1%**	56	8.9%	4.4	65	**29.2%**	56	12.5%	2.3
	Total Modern Documented Sample		*198*	***46.5%***	*182*	*24.2%*	1.9	*184*	***37.5%***	*166*	*21.1%*	1.8	*346*	***26.9%***	*333*	*9.3%*	2.9	*367*	***17.7%***	*332*	*8.7%*	2.0
Pre-industrial Historic Sample (211 females and 89 males)	Post-medieval (France)	16–18th c. AD	106	**59.4%**	92	33.7%	1.8	96	**53.1%**	85	21.2%	2.5	11	**72.7%**	16	43.8%	1.7	16	**56.3%**	14	28.6%	2.0
	Medieval (England)	10–11th c. AD	39	**64.1%**	40	45.0%	1.4	34	**58.8%**	41	31.7%	1.9	32	**68.8%**	36	33.3%	2.1	34	**47.1%**	39	20.5%	2.3
	Antiquity (France)	2nd–3rd c. AD	4	**50.0%**	6	0.0%	/	7	**28.6%**	8	12.5%	2.3	20	**25.0%**	17	11.8%	2.1	16	**18.8%**	18	16.7%	1.1
	Total Pre-industrial Historic Sample		*149*	***60.4%***	*138*	*35.5%*	1.7	*137*	***53.3%***	*134*	*23.9%*	2.2	*63*	***55.6%***	*69*	*30.4%*	1.8	*66*	***42.4%***	*71*	*21.1%*	2.0
Prehistoric Sample (169 females and 139males)	Middle Neolithic (Switzerland)	3.2–2700 BC	21	**42.9%**	18	22.2%	1.9	20	**25.0%**	21	23.8%	1.1	15	26.7%	15	**53.3%**	0.5	9	**22.2%**	11	18.2%	1.2
	Middle Neolithic (France)	4.5–4000 BC	12	**41.7%**	16	12.5%	3.3	14	**35.7%**	15	13.3%	2.7	11	18.2%	11	**27.3%**	0.7	9	**22.2%**	10	0.0%	/
	Early Neolithic (Germany)	5000 BC	25	**20.0%**	28	10.7%	1.9	24	8.3%	22	**9.1%**	0.9	35	28.6%	36	**36.1%**	0.8	29	**24.1%**	31	6.5%	3.7
	Late Mesolithic (Portugal)	6.4–5300 BC	27	**29.6%**	42	11.9%	2.5	22	**22.7%**	21	9.5%	2.4	19	0.0%	24	**12.5%**	0.0	15	6.7%	15	6.7%	1.0
	Early/Middle Mesolithic (Europe)	10–7000 BC	14	**21.4%**	11	9.1%	2.4	12	8.3%	11	**9.1%**	0.9	11	27.3%	9	**33.3%**	0.8	10	**20.0%**	10	0.0%	/
	Upper Palaeolithic (Europe)	30–10,000 BC	10	**10.0%**	10	0.0%	/	9	**11.1%**	10	0.0%	/	15	6.7%	16	**25.0%**	0.3	17	**11.8%**	17	0.0%	/
	Total Prehistoric Sample		*109*	***28.4%***	*125*	*12.0%*	2.4	*101*	***18.8%***	*100*	*12.0%*	1.6	*106*	*18.9%*	*111*	***30.6%***	0.6	*89*	***18.0%***	*94*	*5.3%*	3.4

3. Results

Fig. 1 displays the frequencies of medial and lateral epicondyle enthesopathies in the modern documented (i.e. identified) sample. Frequencies of enthesopathies increase with age, but for each age category and for both sides the *L*/*M* ratio falls into the range of variation seen for living samples (Table 1). For most of the age categories considered, enthesopathies of the lateral epicondyle are two or three times more common than they are for the medial epicondyle, as for living samples. Moreover, there is no apparent correlation between age-at-death and the ratio. For all comparisons except one, enthesopathies are more frequent for the lateral epicondyle. The ratio below 1 for the first age group for the left side, as well as the very high ratio for the 30–39 age-class, can be explained by the very low frequency of cases seen for the medial epicondyle (one in both cases).

Frequencies for the right and left sides for each collection are presented in Table 2. As there is no control for age, frequencies cannot be compared between groups, but this can be done within each sub-sample. In all modern documented and pre-industrial historic collections, enthesopathies are more common at the lateral epicondyle for both sides and both sexes. For the prehistoric groups, the situation is dramatically different. For females, medial epicondylosis is more frequent in two cases (from 12 comparisons): for the site of Stuttgart-Mühlhausen (Early Neolithic) and for the sample dating from the Early/Middle Mesolithic, a minor difference (less than 1%) is observed for the left side. For males and for each of the groups considered, the ratio clearly favours the medial epicondyle of the right side. When groups are pooled (Fig. 2) the *L*/*M* ratio is always positive and varies from 1.8 to 3.4, except in the right side of the male prehistoric group (0.6), indicating that, although the lateral epicondyle is affected, it is more often accompanied by medial epicondylar enthesopathies in these males than for their same sex counterparts from more recent times and for females. When only humeri with both medial and lateral epicondyles scored are taken into account and when only one enthesopathy is recorded, there is a significant tendency for the lesion to occur at the lateral epicondyle for all groups and both sides, except for prehistoric males for the right side (Table 3).

4. Discussion

Although entheseal changes are age-related (e.g. Villotte, 2009; Villotte et al., 2010b), for the *L*/*M* ratio there is no associated age correlation (Fig. 1). We did not attempt to control for age-at-death in the present study due the number of individuals for which it had not been possible to assess it, or for which the assessment provided a very broad age range. Thus, frequencies of medial or lateral epicondylosis cannot be compared across samples, but the *L*/*M* ratio can. Moreover, the present study clearly shows that this ratio is almost always greater than 1 in the archaeological and clinical samples. The *L*/*M* ratio for the right side in the prehistoric male sample, below the range of variation seen for historic samples presented here, as well as in clinical samples (Table 1), highlights a specific pattern for the right arm. This very low *L*/*M* ratio is seen today only in young baseball pitchers (Lyman et al., 2001). This provides strong evidence for the mechanical origin of these lesions, as the pattern would have been seen for both sides if they had resulted from hormonal or other intrinsic factors. Medial epicondyle enthesopathy frequently co-occurs with lateral epicondyle enthesopathy when it is unrelated to the throwing motion (Gold et al., 2009; Walker-Bone et al., 2004). When only humeri with both medial and lateral epicondyles scored are taken into account, and when only one enthesopathy (medial or lateral) is recorded, the right medial epicondyle tends to be more often injured in

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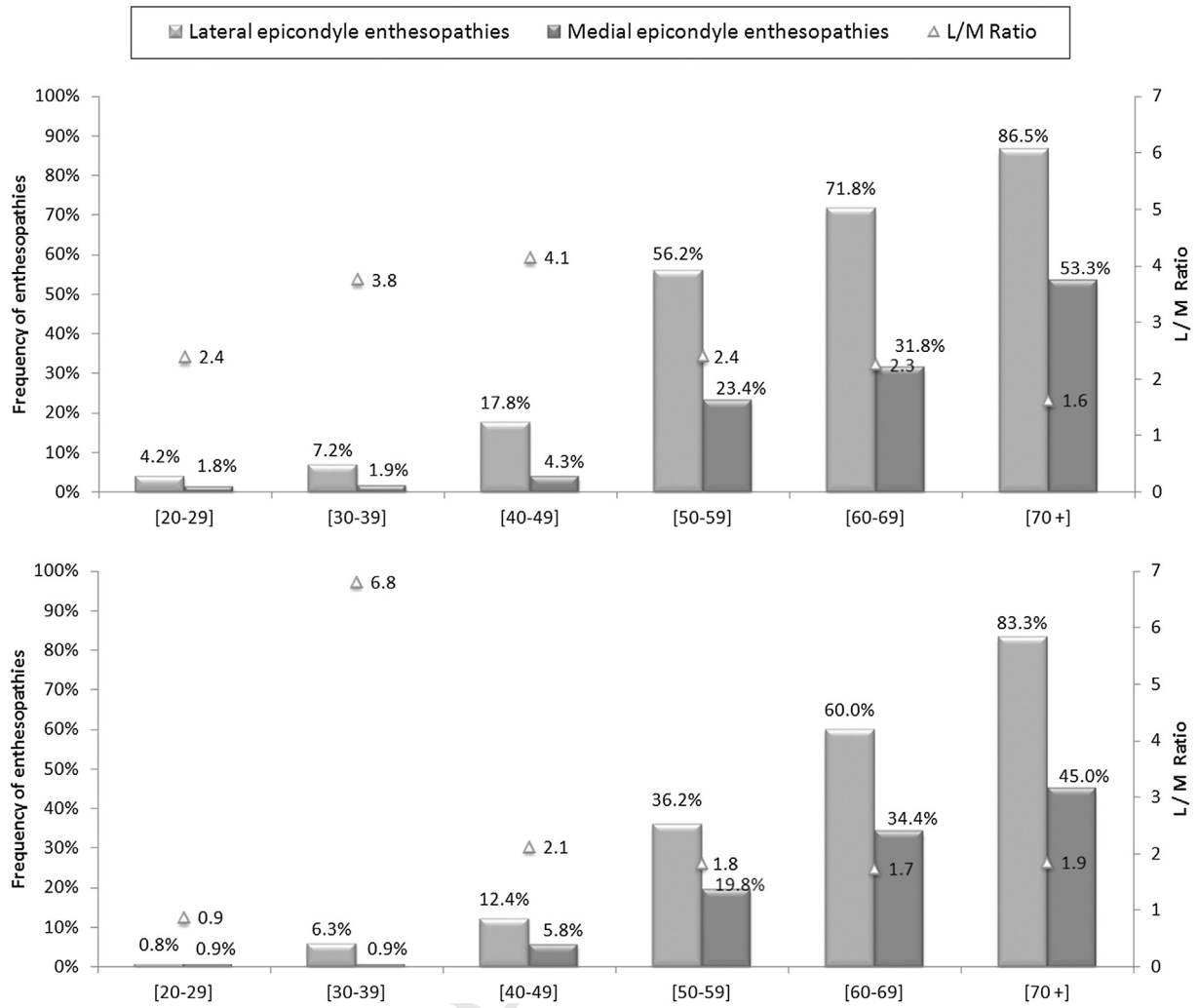

Fig. 1. Modern documented sample (four collections of individuals of known sex and age at death). Frequencies of enthesopathies and *L*/*M* ratios (triangles) for each age group, Top: right side, down: left side.

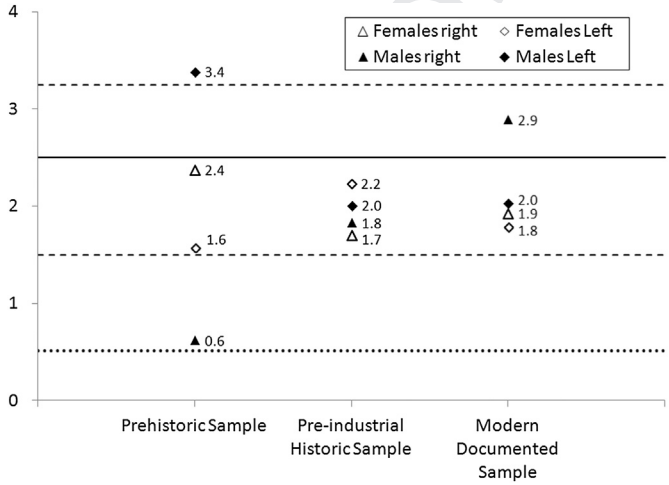

Fig. 2. *L*/*M* ratios for the prehistoric, pre-industrial historic, and modern documented samples. Full line and dashed lines: 25, 50th, and 75th percentiles calculated from *L*/*M* ratios from clinical studies (Table 1), excepted the group of pitchers (for which the ratio is presented by a dotted line).

prehistoric males (Table 3). Considering the high specificity of medial epicondyle injuries today, we suggest that the unilateral pattern of medial epicondylosis indicates that most of these lesions were likely due to the throwing motion. Cross-culturally, humans employ a single hand for tasks demanding skilled use of implements. This is most often the right hand (Coren and Porac, 1977; Calvin, 1983; Faurie and Raymond, 2004; Steele, 2002), and our study reveals that this was the same in the past. Today, ballistic skills, as opposed those requiring fine motor control, disproportionately employ the right hand (Annett, 1970). Within each prehistoric sample, the frequency of medial versus lateral epicondylar enthesopathies is higher in males. The consistency across these groups of hunter-gatherers and farmers provides strong support for a universal biocultural phenomenon linked to throwing, rather than being an artefact of sampling bias.

Hunting was essential during the Upper Palaeolithic and Mesolithic, but also appears to have played a considerable role in European Neolithic groups, providing dietary supplements and as a prestige-enhancing means of social distinction (Hachem, 2001, 2011; Jeunesse, 2010; Uerpmann, 2001). The use of complex projectile weapons, like the bow and arrow, spear-thrower, and dart, which do not seem to especially stress the medial epicondyle (see Villotte et al., 2010 and references therein), is attested in Europe for the latter part of the Upper Palaeolithic, Mesolithic and Neolithic

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Table 3
Humeri with both lateral and medial epicondyles scored. The *p*-value (McNemar's test) indicates a significant tendency for increased numbers of cases of lateral epicondylosis in all samples, except for prehistoric males, where individuals with medial epicondylosis alone are more prevalent than those with the lateral form, and on the right side only.

		Right				Left			
		N	Lateral epicondylosis only	Medial epicondylosis only	*P*	*N*	Lateral epicondylosis only	Medial epicondylosis only	*P*
Modern documented sample	Females	169	36	2	<0.001	149	29	3	<0.001
	Males	293	53	8	<0.001	304	39	9	<0.001
Pre-industrial historic sample	Females	115	32	4	<0.001	106	32	0	<0.001
	Males	56	20	2	<0.001	58	12	0	0.002
Prehistoric sample	Females	89	20	6	0.011	74	10	0	0.004
	Males	92	4	15	0.022	78	11	3	0.003

(Cattelain, 2006; Cattelain and Bellier, 2002; Clark, 1963; Rozoy, 1999; Shea, 2006). However, this does not exclude the use of more simple technology simultaneously: barbed points, javelins, killing sticks and boomerangs are known for the same period (Bahn, 1987; Burov, 1998; Cattelain and Bellier, 2002; Valde-Nowak et al., 1987). Even thrown stones are highly effective in hunting and warfare (Isaac, 1987). As documented in ethnographic literature (see Churchill, 1993 for a review), hand-thrown projectiles likely formed a frequent complement to the use of more complex weaponry in the prehistoric groups studied here. Thus, it appears that most cases of medial epicondylosis observed for these individuals are related to the use of overhead throwing during games, warfare, and hunting. Overhead throwing with force and accuracy is a skill uniquely developed in our species that played an important role in human evolution (Calvin, 1983; Darlington, 1975; Darwin, 1871; Isaac, 1987; Knüsel, 1992). Effective throwing behaviour (probably of stones initially) may date as far back as 4 million years ago (Calvin, 1983; Darlington, 1975; Isaac, 1987). Today, males perform significantly better than females in spatial ability tests, as in gauging movements across the visual field (Jardine and Martin, 1983; Voyer et al., 1995), as well as in both throwing velocity and accuracy exercises (Jardine and Martin, 1983; Tillaar and Ettema, 2004; Whittaker and Kamp, 2006). Significant correlations have been found between throwing accuracy and spatial ability, and these sex differences may reflect the evolutionary adaptations required of male hunters and later as armed warriors (Jardine and Martin, 1983; Kolakowski and Malina, 1974). Because this proclivity appears to form a fundamental part of masculine identity, prolonged training and socialization to achieve proficiency may be implicated in the occurrence of observed medial epicondyle enthesopathies.

Other activities may be associated with some of the medial epicondylosis seen in prehistoric males. The sling, an ancient implement used by herders to tend flocks, farmers to protect crops from scavengers – and as a weapon especially well known in the classical ancient world (Paunov and Dimitrov, 2000; Dohrenwend, 2002) – suggests one such activity, with evidence for what may be sling stones from prehistoric sites worldwide (Finney, 2006; Rosenberg, 2009; Vega and Craig, 2009), including the European Neolithic (Paunov and Dimitrov, 2000). Interestingly, as for other throwing activities men have a greater range in sling use (Vega and Craig, 2009). The intensive use of axes and adzes, objects which are well known from the Neolithic and throughout the Mesolithic (e.g. Valdeyron, 2011), may also have produced valgus stress in the medial compartment of the humerus similar to that seen in overhead throwing. Unilateral wood-working is a masculine activity in non-industrial societies (the average percentage of male participation calculated from 185 societies is 98.8%; Murdock and Provost, 1973), and it is noteworthy that thick-bladed adzes are found almost exclusively in male burials from the Early Neolithic Linearbandkeramik (Bakels, 1987), perhaps as a means of signalling masculine identity.

5. Conclusion

Sexual division in the use of throwing weapons is one of the most striking universal occurrences noted in cross-cultural studies (Murdock and Provost, 1973; Testart, 1986; Wood and Eagly, 2002). Our results indicate that sex differences indicative of this proclivity date back at least 30,000 years. Moreover, this sexual division of labour appears to have been a persistent feature of human groups through millennia and across societies with radically different subsistence economies and living a diverse range of environments. An ability to throw with accuracy and at increasing distance may represent one of the fundamental structuring factors in past human societies, with both biological and social implications.

Uncited references

Churchill and Rhodes, 2009; Dunsworth et al., 2003; Knüsel, 2000; Rhodes and Churchill, 2009. Q3

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