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Entheseal changes in the Hellenistic-Roman population of Boğazköy, Turkey
Evidence for gender division of labor?

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Abstract: *Entheseal changes (EC) are changes to areas where connective tissue (tendon or ligament) attaches to bone. Previous studies have suggested that heavy physical activity has an effect on EC development, among other factors such as age, body size, and (male) sex. In this study, EC in the upper limbs was examined in a Hellenistic-Roman rural population from Boğazköy, Turkey to assess gender differences in activity patterns. EC was positively correlated with age at death, and therefore, old adults were excluded when comparing the EC scores of males and females. Significant differences in EC between the sexes were tentatively considered as an indicator of gender-specific activities. Females exhibited significantly higher EC scores at the common extensor muscles' origin site (lateral epicondyle of the humerus), with a right-sided dominance. Common extensor muscles are related to movements of the wrist. It is assumed that the repetitive labor of weaving, spinning, and grinding may have caused these changes. Significantly higher EC scores in males than females were found only in the insertion site of the supraspinatus and infraspinatus muscles (greater tubercle of the humerus). EC scores in this shoulder-related enthesis also showed a right-sided dominance. It is assumed that some activities performed by males, such as woodcutting, shoveling, and building-related activities may have caused EC in this enthesis.*

Key words: upper limb; lateral epicondylitis; activity patterns

Introduction

The term "enthesis" refers to the junction between a tendon or ligament and a bone (Benjamin & Ralph 1998). Changes to entheses in the form of new bone formation or bone destruction are called "entheseal changes" (EC) (Jurmain et al. 2012). Previously, terms such as "musculoskeletal stress markers" (MSM) (Hawkey & Merbs 1995) and "enthesopathies" (Dutour 1986) were also used in the bioarchaeological literature for these changes. In particular, MSM gained wider acceptance, but Jurmain and Villotte (2010) stated that this term is biased because it emphasized only

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one of the etiological factors of EC. "Enthesopathy", on the other hand, implies a pathological condition. Therefore, it is now suggested that EC is used as a less biased and more neutral term (Jurmain & Villotte 2010). Activity-related changes in bones have received thorough attention from bioarchaeologists as they can be used to reconstruct past lifestyles. In this regard, it has become popular to study EC alongside degenerative joint disease and cross-sectional bone geometry (Jurmain et al. 2012). Studies examining the relationship between activity and EC have increased gradually since the 1980s and have improved in terms of both methodology and approach.

Understanding activity-related EC is based on bone remodeling as a response to mechanical loading. According to Hawkey and Merbs (1995), mechanical stress causes an increase in blood flow to the periosteum, which stimulates osteon remodeling resulting in bone hypertrophy at the enthesis. However, the change in process varies depending on the type of enthesis. There are two types of entheses according to their structure: fibrous and fibrocartilaginous. At fibrous entheses, the tendon or ligament attaches either directly to the bone or via the periosteum. At fibrocartilaginous entheses, different tissue zones are present: pure dense fibrous connective tissue, uncalcified fibrocartilage, calcified fibrocartilage, and bone (Benjamin et al. 2006). Hawkey and Merbs' (1995) definition explains the changes in fibrous entheses. Changes in fibrocartilaginous entheses, however, develop as a result of different processes in which the aforementioned tissues are integrated (Benjamin & Ralph 1998; Benjamin et al. 2006). Genetic factors and body mass have a greater effect on the robusticity of fibrous entheses, and therefore it is suggested that changes in fibrocartilaginous entheses reflect the effect of physical activity better than fibrous entheses (Jurmain et al. 2012; Villotte et al. 2010a).

EC has been extensively studied for reconstructing past activity patterns (e.g., Kennedy 1983; Dutour 1986; Hawkey & Merbs 1995; Chapman 1997; Robb 1998; al-Oumaoui et al. 2004; Eshed et al. 2004; Molnar 2006; Villotte et al. 2010b). EC has been applied to various research questions in archaeological samples, such as gender division of labor (Hawkey & Merbs 1995; Robb 1998; Molnar 2006; Lieverse et al. 2009; Villotte et al. 2010b; Villotte & Knüsel 2014; Santana-Cabrera et al. 2015), social status differences and division of labor (Porčić & Stefanović 2009; Havelkova et al. 2011; Schrader 2015; Refai 2019), grave goods and identity (Molnar 2010), differences in subsistence activities (Dutour 1986; Hawkey & Merbs 1995; Eshed et al. 2004), and identifying specific activities (Dutour 1986; Peterson 1998; Villotte & Knüsel 2014). Some researchers used identified skeletal collections in which an individuals' occupations were known to reveal the relationship between EC and work-related tasks (Cunha & Umbelino 1995; Mariotti et al. 2004, 2007; Villotte 2006; Alves Cardoso & Henderson 2010; Villotte et al. 2010a; Milella et al. 2012; Henderson et al. 2012, 2013). In most of these studies, EC was found to be age-related rather than occupation-related, and as a result, the effectiveness of collating the relationship between EC and activity began to be questioned (Cunha & Umbelino 1995; Mariotti et al. 2004, 2007; Alves Cardoso & Henderson 2010; Milella et al. 2012). However, Villotte et al. (2010a) when examining changes in fibrocartilaginous entheses found a strong relationship between EC and heavy manual work. Niinimäki (2011) also found that heavy labor in early life resulted in higher EC scores. Some recent studies (on either fibrous or fibrocartilaginous entheses in archaeological samples) comparing groups that can be distinguished by occupation and social status have also found that EC is more prominent in individuals engaged in high levels of physical activity (Schrader 2015; Yonemoto 2016; Refai 2019). A study using multivariate analysis in an identified collection revealed differences in EC scores between occupation groups, such as occupations related to farming, physically demanding occupations, and also physically undemanding occupations (Milella et al. 2015). Also, Karakostis et al. (2017) used 3D measurements of hand entheses and multivariate analysis in an identified skeletal collection and found a relationship between occupation and EC in hands.

There are also some experimental studies on animals that have revealed a relationship between EC and activity. Zumwalt (2006) did not observe a significant change in the entheses of adult sheep trained on a treadmill for 90 days and therefore suggested that this activity was not involved in EC development. However, studies by Karakostis et al. (2019a, 2019b) using experimental data from turkeys and rats, and applying three-dimensional measurements combined with multivariate statistics revealed that variation in physical activity patterns has a direct influence on EC.

Most studies have reported that males have more prominent EC than females (for example, see Hawkey & Merbs 1995; Villotte et al. 2010b; Molnar 2006, 2010; Weiss 2007; Santana-Cabrera et al. 2015; Schrader 2015; Refai 2019). However, it has been found that differences between the sexes are negligible when body or muscle size is controlled (Weiss 2003; Niinimäki 2012). Weiss (2003) suggested that EC are associated with body size, and that those with larger bodies, hence predominantly males, have higher EC scores. Villotte et al. (2010a), however, suggested that this is an explanatory finding for fibrous entheses rather than fibrocartilaginous entheses. It is also argued that hormones may affect the sexual differences of EC (Mariotti et al. 2007; Niinimäki 2012). A clinical study using ultrasonographic scans performed on 960 entheses of 80 healthy individuals demonstrated that age, male sex, body mass index, and high physical activity were all independently correlated with EC (Bakirci et al. 2020).

Certain diseases such as diffuse idiopathic skeletal hyperostosis (DISH) and seronegative spondyloarthropathies (SpA), as well as traumatic injuries can also lead to the development of EC (Resnick & Niwayama 1983; Jurmain et al. 2012). Researchers have emphasized that attention should be paid to the presence of these pathological conditions (Henderson 2008; Villotte et al. 2010b). These particular diseases can easily be distinguished by characteristic changes in the vertebral column and sacroiliac joints (Rogers & Waldron 1995).

Some researchers have focused on the methodology to enable better evaluation of EC and its causes. Different methods have been developed for recording EC (e.g., Hawkey & Merbs 1995; Robb 1998; Mariotti et al. 2004; Villotte 2006; Henderson et al. 2016). There have also been attempts to use 3D surface scanners to measure EC (Henderson & Gallant 2007; Pany et al. 2009; Karakostis & Lorenzo 2016; Karakostis et al. 2017). Some studies recommend using multivariate analysis among multiple entheses rather than analyzing each enthesis separately (Karakostis & Lorenzo 2016; Karakostis et al. 2017).

As outlined above, several factors may play a role in the development of EC, and activity is suggested to definitely be one of them. In particular, studies examining the relationship between heavy physical activity and EC support this claim. Thus, it was decided to use EC in fibrocartilaginous entheses of the upper limbs to assess activity in a rural archaeological sample from central Anatolia. In rural communities individuals often perform repetitive, sometimes heavy tasks throughout their lives. Gender division of labor, as still observable in today's Anatolian villages, is a common feature in rural communities. The aim of this study is to reveal whether there were gender differences in activity patterns in the Hellenistic-Roman population of Boğazköy by examining EC.

Material and methods

The study sample comes from the archaeological site of Boğazköy located near the modern city of Çorum in north-central Anatolia (the peninsula that today constitutes the Asian part of Turkey) (**Figure 1**). The site is better known as Hattuša, the capital city of the Hittite Empire established in the second millennium BC. Archaeological excavations commenced in 1932 by the German Archaeological Institute (DAI) and are today continued by an international team under the directorship of Dr. Andreas Schachner (German Archaeological Institute, Istanbul).

The city of Hattuša was destroyed around 1200 BCE with the collapse of the Hittite Empire but the site continued to be sporadically settled thereafter for centuries. There is evidence for a small Iron Age settlement (12^{th} to 5^{th} centuries BCE) in certain areas at the site (Schachner 2011:311-327). Following the abandonment of the settlement after the Iron Age, the Galatians, a Celtic tribe of Southeast European origin, migrated to Boğazköy in the 3^{rd} century BCE. A new Galatian-Hellenistic settlement was established at Boğazköy, which survived through the Roman Imperial and Byzantine periods until the end of 11^{th} century CE (Schachner 2011:327-335).

Figure 1. Map of Turkey showing the location of Boğazköy.

To distinguish the post-Hittite settlements established here, the site is called Boğazköy with reference to the nearby (modern) village. The Hellenistic-Roman settlement at Boğazköy had a mainly rural characteristic, but expanded in size and importance beyond that of a small village in the Roman Imperial period. The Roman period ruins include a monumental building with a pool of water, a fortification wall, a military camp, and a necropolis (Schachner 2015; 2016; 2018). The skeletal remains were recovered from the Hellenistic-Roman cemetery located in the lower town. The coin and ceramic findings, as well as radiocarbon dates, demonstrate that the necropolis was in use from the 3rd century BCE until the second half of the 4th century CE (Kühne 1969; Kühn 2014; Schachner 2016, 2018). Simple inhumations are the most common burial type in the cemetery, and about half of these simple inhumations were covered by roof tiles. There are also burials with the individual(s) placed in stone cists, and also in large storage jars (*pithoi*).

The number of excavated individuals dated to the Hellenistic-Roman period was 121, but only adults (20+ years old) were included in this study. In total 69 adults were examined, with 34 males, 28 females, and 7 individuals of undetermined sex. Adults

Table 1. Sex and age-at-death distribution of examined individuals.

	Young adults	**Middle adults**	**Old adults**	**Total**
Males	13	13	8	34
Females	18	8	2	28
Indeterminate	4	3		7
Total	35	24	10	69

were grouped into three age categories according to Buikstra & Ubelaker (1994): young adults (20-34 years), middle adults (35-49 years) and old adults (50+ years). As shown in **Table 1**, there is an equal distribution of young and middle adult males, while there is a bias in the number of young adult females. Since the number of old adult females is very small, it is preferable to exclude old adults when making male-female comparisons in this study. The number of males and females are equal when old adults are excluded.

The sex and age-at-death estimation of the skeletal remains, as well as the observation of EC was made by the author. Sex determination was based on pelvic and cranial morphology (Phenice 1969; Acsádi & Nemeskéri 1970; Buikstra & Ubelaker 1994). The determination of age at death was based on morphological alterations of the pubic symphysis (Brooks & Suchey 1990), auricular surface (Lovejoy et al. 1985), changes of the sternal rib end (Işcan et al. 1984, 1985), and dental attrition (Brothwell 1981).

In this study, EC in fibrocartilaginous entheses were selected for examination based on the assertion that they better reflect the activity-related stresses (Villotte et al. 2010a). Seven fibrocartilaginous entheses of the upper limbs were examined for EC (see **Table 2**).

Contour and surface changes were noted as EC. Contour changes can be described as protrusions or enthesophytes at the edge of the enthesis (**Figure 2**). Surface changes appear as osseous lesions (**Figure 3**) and foramina and cysts (**Figure 4**). The three-stage scale proposed by Villotte (2006) was used for recording EC: A) healthy enthesis (absence of protrusions at the edge and/or surface changes such as osseous lesions, foramina, and cysts); B) slight EC (slight protrusions at the edge and/or changes such as osseous lesions, foramina, and cysts seen on less than half of the surface); C) major EC (prominent protrusions at the edge and/or marked changes such as osseous lesions, foramina and cysts covering more than half of the surface). Stages B and C are grouped together as presence (as opposed to absence) for the purposes of statistical analysis. Right and left sides were recorded separately as there may be bilateral asymmetry due

Table 2. Examined entheses, their attachment sites, and their associated joints.

Entheses	Attachment sites	Joints
M. subscapularis insertion	Lesser tubercle of humerus	Shoulder
M. supraspinatus & M. infraspinatus insertion	Greater tubercle of humerus	
M. brachioradialis origin	Lateral supracondylar ridge of humerus	Elbow
M. biceps brachii insertion	Radial tuberosity	
M. triceps brachii insertion	Ulna olecranon	
Common extensor origin	Lateral epicondyle of humerus	Wrist
Common flexor origin	Medial epicondyle of humerus	

Figure 2. Enthesophytes at the common extensor and common flexor origins.

Figure 3. Osseous lesions at the M. subscapularis insertion.

Figure 4. Foramina at the M. supraspinatus and M. infraspinatus insertion.

to handedness. The **Tables 3** and **4** of sex and age-at-death were made based on the right-sided EC scores, but in the absence of a right-sided bone the scores of the left side were used. However, EC scores of both left and right sides were also presented for males and females (**Tables 5** and **6**).

Skeletons with vertebral and sacroiliac joint fusions (indicators of possible SpA or DISH), and healed fractures of the upper limb and shoulder girdle bones that may have affected the development of EC were not included in this study.

The data was analyzed using the 16th version of the SPSS Data Analysis Program. A Spearman's Rho test was applied to correlate EC with sex and age at death with $p<0.05$ being considered to be statistically significant. The Spearman correlation coefficient (r_s) values close to ±1 indicate a "strong" effect, and values close to 0 indicate a "weak" effect. Body mass was not correlated with EC in this study.

Mean EC scores of right and left sides were compared using the non-parametric Wilcoxon signed rank test. Bilateral asymmetry was calculated for each enthesis using the formula following Eshed et al. (2004): (mean left/mean right) $\times$ 100. According to this formula, a value of 100 indicates symmetry, values below 100 indicate right-sided dominance of EC, and values above 100 indicate left-sided dominance of EC. Values close to 100 indicate a weak asymmetry, and values with increasing deviation from 100 indicate a strong asymmetry.

Results

For the sample population, EC scores demonstrated an increasing trend with advancing age (**Table 3**), which is consistent with previous studies. When both sexes are pooled, the correlation between EC scores and age at death was significant for most of the entheses, although the number of old adult individuals examined is relatively small. Only the EC score of the brachioradialis muscles' origin did not increase with advancing age since it was very high in young adults for both males and females. Significant age correlations with EC were also found for males in the biceps brachii insertion (r_s=0.383, p=0.049) and the common extensor origin (r_s=0.510, p=0.022). For females, EC scores of the common flexor origin was significantly correlated with age (r_s=0.607, p=0.048).

Correlation between sex and EC scores was analysed with the age-at-death groups separated, but no significant difference was found as the sample sizes were too small. When young and middle adults were pooled, the difference between the sexes was significant for the common extensor origin, where females showed higher EC scores (r_s=0.396, p=0.037) (**Table 4**, **Figure 5**). For the supraspinatus and infraspinatus insertion, females had no EC at all (r_s=0.509, p=0.044). However, it should be taken into consideration that the number of observed supraspinatus and infraspinatus in-

Table 3. Mean scores of EC in age-at-death groups (males and females pooled, * – significant differences).

	Young adults		Middle adults		Old adults		Spearman's Rho	
Muscles	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	r_s	**p**
Subscapularis	9	0.22	8	0.62	2	0.50	0.344	0.149
Suprasp. & infrasp.	9	0.11	9	0.33	3	1.00	0.546	0.011*
Brachioradialis	21	0.67	16	0.69	6	0.67	0.011	0.944
Biceps br.	20	0.25	16	0.62	7	0.86	0.471	0.001*
Triceps br.	15	0.33	16	0.56	6	0.33	0.092	0.590
Common extensor	17	0.47	13	1.00	5	0.80	0.393	0.020*
Common flexor	16	0.13	10	0.60	6	0.67	0.504	0.003*

Table 4. Mean scores of EC by sex (young and middle adults pooled, * – significant differences).

	Males		Females		Spearman's Rho	
Muscles	**N**	**Mean**	**N**	**Mean**	r_s	**p**
Subscapularis	8	0.50	7	0.43	0.071	0.800
Supr. & infrasp.	9	0.44	7	0.00	0.509	0.044*
Brachioradialis	15	0.73	17	0.71	0.030	0.869
Biceps br.	20	0.55	13	0.23	0.316	0.074
Triceps br.	17	0.53	12	0.33	0.194	0.313
Common ext.	15	0.53	13	1.00	0.396	0.037*
Common flex.	12	0.33	11	0.36	0.032	0.886

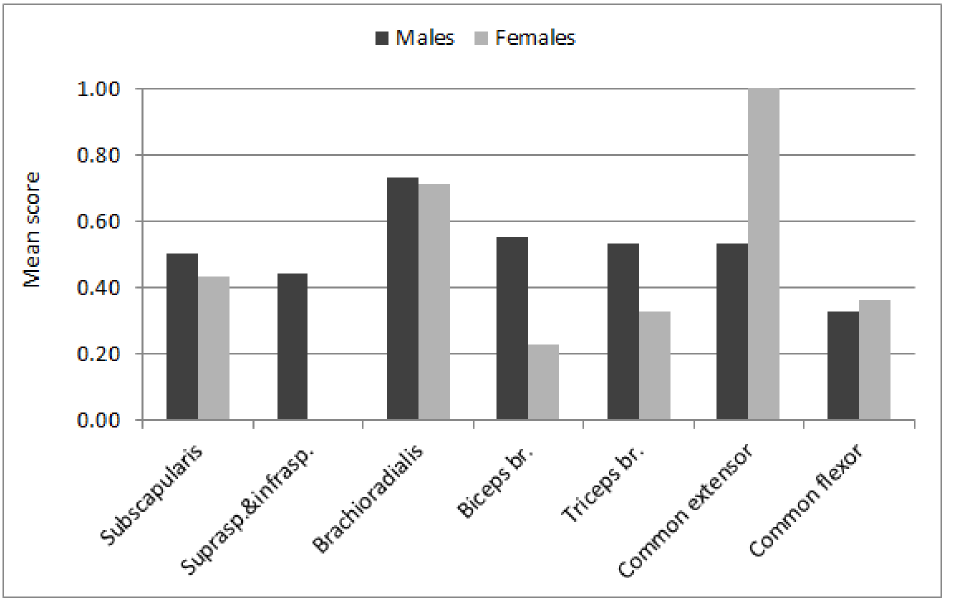

Figure 5. Mean scores of EC by sex (young and middle adults pooled).

sertions was relatively low. Although not significant, males also exhibited higher EC scores at the biceps and triceps brachii muscles' insertion sites. There were only minor differences between the sexes in the EC scores of the subscapularis, brachioradialis, and common flexor muscles (**Table 4**).

In males, EC at the subscapularis, supraspinatus and infraspinatus, and brachioradialis insertions, and the common extensor origin exhibit a right-sided dominance (**Table 5**). In females, EC at the biceps and triceps brachii insertions, and the common extensor and common flexor origins have a right-sided dominance (**Table 6**).

Table 5. EC scores for left and right sides and bilateral asymmetry index in males (young and middle adults pooled); a value of 100 indicates symmetry (S), values below 100 indicate right-sided dominance (R), and values above 100 indicate left-sided dominance (L).

	Left		Right		Wilcoxon test			Asymmetry	
Muscles	N	Mean	N	Mean	N	Z	p	Index	Side
Subscapularis	8	0.38	5	0.40	5	-1.000	0.317	95	R
Suprasp. & infrasp.	7	0.14	7	0.43	5	-1.000	0.317	33	R
Brachioradialis	15	0.67	13	0.69	13	0.000	1.000	97	R
Biceps br.	18	0.56	16	0.56	14	0.000	1.000	100	S
Triceps br.	14	0.43	15	0.33	12	0.447	0.655	130	L
Common extensor	11	0.36	10	0.60	6	-1.000	0.317	60	R
Common flexor	11	0.36	9	0.33	8	0.000	1.000	109	L

While there was a right-sided dominance at the insertions of the shoulder, elbow, and wrist related muscles in males, there was no right-sided dominance at the insertions of the shoulder muscles in females. In females, there was right-sided dominance only in the entheses of the elbow and wrist related muscles. For males, EC scores of supraspinatus and infraspinatus (rotator cuff muscles), and EC scores of the triceps brachii and common flexor muscles in females show stronger right-sided dominance than the other muscles. However, no significant differences were found between the EC scores of right and left sides in either males or females according to a Wilcoxon signed rank test, probably because of the small sample sizes (**Tables 5** and **6**).

Discussion

It is generally accepted that EC increases with age, as evidenced by various studies in both identified skeleton collections and archaeological samples (Henderson et al. 2017). This is likely due to long-term exposure of the enthesis to mechanical stress and/or decreased osteoblast activity in old age (Robb 1998; Weiss 2007; Milella et al. 2012; Niinimäki 2012). Males also have more pronounced EC due to larger body/muscle sizes and hormonal factors (Weiss 2003; Mariotti et al. 2007; Niinimäki 2012). Therefore, it is essential to control age-at-death and sex factors when evaluating observed EC scores. In the present study sample, a general increase with age-at-death was observed in EC scores, which is compatible with previous studies (Cunha & Umbelino 1995; Robb, 1998; Weiss, 2003, 2007; al-Oumaoui et al. 2004; Mariotti et al. 2004, 2007; Molnar 2006; Alves Cardoso & Henderson 2010; Villotte et al. 2010a; Havelkova et al. 2011; Niinimäki 2011; Milella et al. 2012). Males exhibited higher EC scores at some muscle insertion sites, but the difference between the sexes in favor of males was only significant for the supraspinatus and infraspinatus insertion, where, conversely, females had no EC at all. Females exhibited significantly higher EC scores at the common extensor muscles' origin site. Providing evidence for

Table 6. EC scores for left and right sides and bilateral asymmetry index in females (young and middle adults pooled); a value of 100 indicates symmetry (S), values below 100 indicate right-sided dominance (R), and values above 100 indicate left-sided dominance (L).

	Left		Right		Wilcoxon test			Asymmetry	
Muscles	**N**	**Mean**	**N**	**Mean**	**N**	**Z**	**p**	**Index**	**Side**
Subscapularis	6	0.50	7	0.43	6	0.000	1.000	116	L
Suprasp. & infrasp.	5	0.00	7	0.00	5	0.000	1.000	–	–
Brachioradialis	13	0.77	13	0.69	9	-1.000	0.317	112	L
Biceps br.	11	0.18	10	0.30	8	0.000	1.000	60	R
Triceps br.	10	0.10	8	0.38	6	-1.000	0.317	26	R
Common extensor	10	0.70	10	1.00	7	-1.732	0.083	70	R
Common flexor	7	0.14	7	0.57	3	0.000	1.000	25	R

a mechanical origin, EC at the common extensor origin was more pronounced on the right side in both males and females.

Significantly higher EC scores at the common extensor muscles' origin in females may be related to a condition known as lateral epicondylitis (inflammation of the epicondyle). Lateral epicondylitis (tennis elbow in common vernacular) occurs at the common extensor origin, while medial epicondylitis (golfer's elbow) occurs at the common flexor origin. Common extensor muscles are related to extension movements of the wrist. Repetitive and rotary movements of the wrist or repetitive application of a forceful grip can result in lateral epicondylitis (Borowski & Lintner 2018). There have only been a few studies focusing on markers of lateral or medial epicondylitis in archaeological samples (Spigelman et al. 2012; Villottte & Knüsel 2014). In those studies, enthesopathies (called EC in this study) at the epicondyles were accepted as indicators of epicondylitis. Villottte and Knüsel (2014) observed an increased prevalence of changes to the right medial epicondyle in males from prehistoric Europe and suggested that this is a sign of "thrower's elbow"—related to the repetitive action of throwing an object, such as a javelin or stone. Spigelman et al. (2012) examined lateral and medial epicondylitis as an indication of activity-related changes in the skeletons of a Byzantine period Black Sea coast sample from Turkey. They found that lateral epicondylitis was slightly more common in females, which was not the case for medial epicondylitis. They suggested that this was probably related to the old age of the females in the sample, but also considered the role of weaving and grinding activities.

Right-sided dominance of EC was also observed in this study at the attachment sites of the biceps and triceps brachii, and in the common extensor and common flexor muscles of the females. These muscles are related to flexion and extension movements at the elbow and wrist joints. On the other hand, EC at the supraspinatus and infraspinatus muscles' insertion site was exclusively observed in males and also had a strong dominance on the right-side. These muscles are rotator cuff muscles that have multiple functions such as glenohumeral abduction and external rotation of the arm and stabilization of the humerus head during arm movements (Escamilla et al. 2009). Based on these findings, EC in the sample population as a result of particular activities seems a logical explanation and possibility. Some activities performed by females (including wrist extension and rotation, elbow flexion and extension movements) would have caused extra stress on the wrist and elbow-related muscles and some activities specific to males (including abduction and external rotation of the arm) may have caused stress in the muscles of the shoulder.

In farming communities gender division of labor is often quite pronounced, with males and females performing different tasks from an early age and throughout the life course. Milella et al. (2015) identified and compared different occupations, and the physical and social specificity of agricultural activities. Although there is not much data about daily life at Boğazköy in the Hellenistic-Roman period, we can suggest that their lives and lifestyle shared many similarities with those of modern rural Anatolian villages, including the modern village of Boğazköy. Many farming communities, especially those relying on human or animal labor rather than mechanized techniques, share many basic similarities. Activities such as arable agriculture, the processing and preparation of grain and other foodstuffs, gardening, care of animals, milking, butchery, cutting and transporting wood, carrying water, weaving, spinning, laundry, and building construction constitute the main daily activities of village life. Some of these activities are gender-specific (both at Boğazköy, and further afield on a wider geographical scale), and may have an impact on the development of the previously discussed ECs that show variations between the sexes.

Murdock and Provost (1973) attempted to classify gender division of labor based on data derived from observing various cultures. In their classification spinning, the preparation of vegetal foods, and loom weaving were categorized as female dominated tasks, whereas work with wood/timber, animal butchering, land clearance, and house building were categorized as male dominated tasks. A cultural anthropological study conducted by Incirlioglu (1991) of two central Anatolian villages close to Kayseri (located approximately 200km southeast of Boğazköy) provide us with valuable information about the gender division of labor in the wider region of central Anatolia. In these villages, the tasks of women and men were often dependent on the season. In the summer, both men and women do agricultural work, such as crop harvesting, and there are no strictly gender specific tasks. Instead gender differentiation of agricultural work is determined by the tools used. Men use tractors and scythes; whereas women use sickles, and hoes and adzes for weeding. In the winter, girls and women weave carpets to provide income, and men clear away snow from the roads and roofs. In both summer and winter, women also do domestic work and tend to the household animals (cattle or water buffalo). Domestic work performed by females includes the preparation of food, baking bread, cooking, washing the dishes, laundry, sweeping the floor, and fetching water from either the public fountain or the household pump. Tending animals includes milking, feeding, watering, and grooming the animals, cleaning the barn, and collecting the droppings.

Repetitive wrist movements involved with some of the activities such as weaving, spinning, and grain/seed grinding can provide significant stressors to the common extensor muscles. EC at the insertion of the supraspinatus and infraspinatus muscles observed only in males is likely related to activities performed exclusively by men such as heavy lifting and carrying, woodcutting, shoveling, and other farming activities (e.g., hoeing). Havelkova et al. (2011) investigated EC related to division of labor in two communities from the Czech Republic dated to the Early Middle Ages; one from

Mikulcice Castle, and the other from the castle's rural hinterland. In both communities, females exhibited the same types of EC that were likely related to movement of the wrist. Males from the hinterland—the farmers—exhibited more EC in shoulder-related entheses. The researchers explained that their findings probably demonstrated the effect of possible female-specific activities such as weaving, spinning, grain grinding, and preparation of food, and possible male-specific activities related to the shoulder joint such as farming and building. Santana-Cabrera et al. (2015) found that in an archaeological sample from the pre-Hispanic period of Gran Canaria Island, males had more pronounced EC in the shoulder joint-associated entheses. Conversely, the EC results of females in their study were indicative of activities related to elbow and hand movements. The researchers suggested that female EC may be related to activities such as the extraction and processing of cereals, particularly grinding. Eshed et al. (2004) also found that the females in Natufian and Neolithic samples from the Levant had more pronounced EC in the muscle attachments close to the elbow and below the forearm, which are responsible for hand movements. The researchers suggest that there was a possible gender division of labor, with females performing activities, which used the forearm muscles such as basketry, spinning, weaving, and grain preparation (pounding and grinding). Molleson (1989) and Pitre et al. (2017) argued that EC in the attachment of the deltoid muscle on the humerus and the attachment of the biceps muscle on the radius are associated with the grinding activity of females in the ancient Near East.

The relationship of spinning and weaving activities with females is evidenced in written documents as well as in the archaeological record through media, such as grave goods of tools related to these activities or reliefs on funerary steles representing women at spinning (Vigo et al. 2014). Spindles and spindle whorls have been found as part of grave good assemblages across Anatolia from the Bronze Age to the Roman period (Vigo et al. 2014; Trinkl 1994, 1995). It has been suggested that spindles and spindle whorls may be related to textile manufacturing and therefore indicators of that activity, as well as possibly having a symbolic value (Vigo et al. 2014; Trinkl 1995). Women seem to have produced textiles for commercial purposes and/or the basic needs of the household from the Bronze Age to modern times in Anatolia (Barber 1991; Quataert 1993). The role of women in textile production was addressed in various written documents from the ancient Near East (Barber 1991). A woman preoccupied with spinning and weaving can also be found as a motif in Roman literature (Larsson Lovén 1998). Both spinning and weaving could be done in the household by women as part of their daily activities. According to Barber (1994), a specialist in textiles and textile manufacturing, the reason why spinning and weaving are considered to be female tasks is due to the work being continuously repetitive. This means that they can be performed in the household without being negatively impacted by

Figure 6. The bone spindle found in the grave of a female at Boğazköy (BO 68/124, Kühne 1969).

interruptions, they can be stopped and then re-started at intervals determined by the worker; for example, taking a break so that childcare needs can be met. Barber (1994) also states that food preparation is another activity with these kinds of work-worker relationship features.

A bone spindle (**Figure 6**) was found in the grave of a young female at Boğazköy (Kühne 1969) who exhibited changes in her lateral and medial epicondyles, and also greater intensity of the brachioradialis muscle associated with the elbow joint. It is possible that this spindle is symbolic of the activity of spinning and weaving or perhaps an indicator of the female gender in general. This finding shows that EC in the lateral epicondyle may be related to spinning and weaving and that the placing of an object in the grave, may not only have a symbolic meaning but may directly point to the daily life of the individual.

Weaving is a highly repetitive task as demonstrated by studies on modern female carpet weavers in Iran (Motamedzade & Moghimbeigi 2012). During weaving, the wrist and finger flexors and extensors are used continuously, with pinching movements and forceful grasping actions. A weaver ties up to 30 knots per minute. After three rows of knots a weaving comb, which can be heavy, is used to compress them. Spinning is also a repetitive task, although it is lighter than weaving. The wrist and fingers of the right hand are used to twist the hand spindle and to wind the yarn. Women start to perform these activities at a very young age. Incirlioglu (1991) observed that girls started carpet weaving at about 10 years of age in the villages of central Anatolia. Milella et al. (2012) suggested a possible precocious involvement of females in strenuous activities according to the results of EC in their study sample. This may be the case in our sample too, as the females exhibited very high EC scores in the common extensor origin, even at a young age.

Grinding is also one of the daily tasks of Anatolian women, who have traditionally been responsible for food preparation in household contexts. In Anatolian villages, saddle querns or rotary hand querns have been used in domestic contexts from antiquity until the present day (Tombul 2005). The rotary hand quern began to be used in the Mediterranean region during the Roman period (Runnels 1990; Ebeling 2019), while saddle querns have a much longer use history. To use both of them, repetitive forceful arm and hand movements are required. While using a saddle quern, the arms must forcefully push a rounded stone backward and forwards to grind the grain or seed. A rotary hand quern consists of two circular stones that fit together: an upper, mobile stone and a lower, stationary stone. For grinding, the top stone is rotated with the help of a vertical bar placed in a socket on it (Ebeling 2019). Using rotary hand querns requires flexion and extension of the elbow and a strong grip of the wrist. Pounding is also associated as being a woman's task, where wheat bran is removed in stone mortars with wooden hammers during the production of *bulgur*, an old traditional wheat product in Anatolia (Pasternak & Kroll 2017). This activity, which involves extension and flexion of the elbow, as well as a strong grip, is similar to using a racket. As a result, it is clear that such activities, which have been carried out by females from a young age as part of daily household activities, have the potential to create significant stress-loads on the wrist and elbow-related muscles.

Conclusions

Following the results and conclusions of previous studies it is clear that the relationship between EC and activity is not straightforward. As Jurmain et al. (2012) discuss, an "activity-only" approach is no longer acceptable for the etiology of EC. However, it is also not possible to completely reject the role of activity in the development of EC (Villotte et al. 2010a; Niinimäki 2011; Milella et al. 2015; Schrader 2015; Yonemoto 2016; Karakostis et al. 2017, 2019a, 2019b; Refai 2019; Bakirci et al. 2020). The use of different methods, statistical tools, and samples with dissimilar lifestyles or social structures appears to have produced conflicting results. Therefore, more studies on populations with different sociocultural structures will help to better understand the relationship between EC and activity. Traditional rural communities where individuals' daily tasks start at a young age and remain consistent and constant throughout life may be more appropriate to study activity-related changes than urban communities where occupations can be temporary, and changing.

Although we do not know much about daily life at Boğazköy in the Hellenistic-Roman period, we can suggest that some common features of (present day) traditional rural communities existed there as well, including a gender division of labor. Therefore, EC in the upper limbs was examined in this study sample to assess gender differences in activity patterns. The significant differences found in EC between the sexes are tentatively considered as an indicator of gender-specific activities. Females were found to exhibit significantly higher EC scores at the common extensor muscles' origin site. It is assumed that repetitive and rotary movements of the wrist involved with activities such as weaving, spinning, and grinding may have caused these changes. EC in the insertion of the supraspinatus and infraspinatus muscles was observed exclusively in males. These muscles are of the rotator cuff muscles involved in abduction and external rotation of the arm. Some activities performed by males, such as woodcutting, shoveling, and building-related activities may have caused extra stress in the muscles of the shoulder resulting in the observed EC.

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