Using dental and activity indicators in order to explore possible sex differences in an adult rural medieval population from Thebes (Greece)

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ABSTRACT: Assessing the subsistence strategies of past populations; through their dietary and occupational patterns; could provide important information regarding social status and possible gender differences, especially in turbulent historical periods, as the one of the Crusader's occupation in Greece (1204–1460 AD). Therefore, the human sample from Aghia Triada in Thebes (13th–14th c. AD) serves as the ideal skeletal material. Diet was explored through two dental indicators; dental caries and tooth wear, while occupational stress was explored through three activity markers; osteoarthritis (OA), spinal facet remodeling and Schmorl's nodes. The aims of the present study are to assess the dietary and activity patterns of the stated population and explore possible sex differentiations. A total of 126 teeth and 350 vertebrae have been examined. The entire population presents a caries rate of 16.7%, and males present a much higher caries frequency than females (25.5% males vs. 9.9% females). Furthermore, females present significantly higher rates of osteophytes than males, whereas no significant sex differences were found regarding facet remodeling and Schmorl's nodes. Dental results confirm historical information of medieval Thebes having an agricultural economy and are also in agreement with isotopic data. In addition, our findings suggest very intense physical activity for both sexes, whereas the distribution of facet remodeling along the spine could indicate a possible gender division of labor. Our study proposes two positive correlations; between facet remodeling and osteophytes, and between Schmorl's nodes and facet remodelling; as activity indicators in past or/and modern populations. Finally, we strongly encourage the inclusion of spinal facet remodelling in studies focusing on occupational stress.

KEY WORDS: caries, tooth wear, osteoarthritis, facet remodeling, Schmorl's nodes

Introduction

Human populations in Europe faced various challenges during the medieval period, such as disease transmission due to increased interconnectedness, urbanism, climate change, and expanding socioeconomic differentiation (i.e. Storey 1992; Aberth 2005). The specific medieval environment had an impact on human health diet and activity. In particular, Greece faced significant challenges during the Crusader's Occupation, especially during the Catalan one (1311–1379) (See Chapter 1.1). Therefore, assessing the subsistence strategies of past populations; through their dietary and occupational patterns; could provide important information regarding the aforementioned turbulent period of time and reveal social or/and gender disparities. Consequently, the excellent preserved population of Aghia Triada in Thebes (13th–14th c. AD) is suited in order to fulfill the stated purpose.

As diet is an integral component of the cultural history of ancient populations, it can serve as an excellent indicator of social status. Dental caries is a strong indicator of diet, therefore a good indicator of social status that could also point out to potential dietary sex differences. Dental wear is directly associated with dietary habits, and for that reason its study has been included in this research. Activity patterns in the past were also related to social status. Sex-based division of labor in past populations has been documented in several studies (e.g., Merbs 1983; Sofaer-Derevenski 2000; Manzon and Gualdi-Russo 2016). A person's sex in the past was associated with their social status, although the factor of physical strength should not be ignored. Spinal osteoarthritis (OA), Schmorl's nodes, and spinal facet remodeling, are activity indicators, and therefore they can be regarded as strong indicators of social status.

The objectives of the present study are to a) assess the dietary and activity patterns of the stated populations and b) to identify possible sex differences in relation to diet and activity, using the aforementioned dietary and activity markers. We test the following hypotheses: 1) as the stated population was significantly dependent on agriculture high caries rate is expected, 2) that due to harsh living conditions, the population under study presents intense physical activity, 3) that females would probably show higher caries rates in relation to males, as diachronically women are expected to present higher caries frequencies due to biological and cultural reasons, and 4) that males due to their physical strength are expected to exhibit more intense labor activity.

Historical Background

Boeotia belonged since 1204 to the Duchy of Athens, with Athens being the capital in the early years and Thebes since 1210. The following years were turbulent with constant alterations to the conquerors, the Franks (1204–1311), the Catalans (1311–1379), the Navarrese Company (1379–c. 1388) and the Florentines (ca. 1388–1460). The structure of the Duchy was feudal in accordance with the West-listed practices, with a strong military organization all over the Boeotian countryside. In the agricultural and craft industry, the prominent position continued to be the silversmithing, whose precious products were sought after in the West. The operation of a mint in Thebes revealed its long-lasting value as a polit-

ical, economic and commercial centre of the era (Archaeological Museum of Thebes: The period of Western Rule).

The silversmiths, carpentry, tanneries and agricultural products made Thebes a great and wealthy city, particularly during the Frankish period (1204–1311 AD). Furthermore, the presence of the Jewish and the Armenian population in the city of Thebes was very intense. According to the 12th century Traveler, Benjamin of Tudela, 2,000 Jews lived in Thebes, a population that remained prominent during the following years. Most of them were Greek-speaking Spanish-Jew and Romans. Their main activity was the processing, weaving, dyeing and the trade of silk. In contrast, Greeks' main activities were related to agricultural production and to a lesser extent to the silk industry. Armenians' main activity was wax-processing and to a lesser degree silk processing, weaving and dyeing (Tsevas 2006).

During the Catalan domination (1311–1379 AD) though, the cities of Attica and Boeotia suffered great material and institutional disasters by the Catalans. The Catalans were organized in a closed social and religious group to preserve their racial integrity and survival. Specifically, in the city of Thebes, the Catalans were fortified inside the acropolis, with the other ethnicities residing outside of it. The trade to Barcelona and Mallorca was in acne, while Thebes was turned into a place of slave-trafficking. After 1348, the plague epidemic on the one hand and the constant raids of the Turks on the other, as well as the conflicts between the Franks, the Byzantines and the Ottomans, led almost to the abandonment of rural settlements and to the decline of rural life (Miller 1908: 211–235).

The Byzantine Diet

The Byzantine diet was based on grains, oil and wine, while legumes, fruits and vegetables were also frequently consumed (i.e. Dalby 1996; Motsias 1998). Wheat and barley were the grains most commonly preferred, albeit millet (C_4 grain) was also cultivated (Teall 1959). However, millet was mainly considered as the food of the poor and was particularly used in cases of failure of more preferred crops (Garnsey 1991:116; Gallant 1991:116). Apart from millet, another C_4 cultivar; sugarcane; was rarely consumed as considered more suitable for medicaments (Galoway 1977; Eideneier 1991). Sheep, goats, pigs, chickens and cattle were the main domesticated animals during the Byzantine period, with goats and sheep constituting the main animal sources. In rural populations, game was also plentiful (i.e. Motsias 1998; Dalby 2003; Koder 2005). Moreover, a significant intake of milk along with dairy products, such as cheese, has been documented (i.e. Kazhdan 1997; Motsias 1998, Dalby 2003).

In addition, marine sources played a part in Byzantine's diet as more than 110 fish and 30 other aquatic organisms are mentioned in literature (i.e. Dagron 1995; Maniatis 2000; Chrone-Vakalopoulos and Vakalopoulos 2008). Fish could be salted or even dried and preserved fish eggs and fish sauce (garum) were also consumed (Dalby 1996; Koder 2005). Furthermore, freshwater intake has also been reported (Chrone-Vakalopoulos and Vakalopoulos 2008), particularly in regions where lakes and rivers existed (like in Thebes). Marine and freshwater sources were probably important items in the Byzantine diet due to the potential role of fasting in the daily life. The

Greek-Orthodox church imposed certain restrictions regarding various food items (Koder 2015; Nicholas and Louvaris 2005; Parry 2005), such as meat. Fish was actually permitted and even during the strictest fasting periods marine sources, such as shellfish were allowed. However, it cannot be assumed that all people followed the said restrictions, particularly during the Frankish and Catalan period, as people of different ethnicity and religion coexisted in Greece and Thebes in particular.

As for sex dietary differences, even though in Medieval Greece the ancient customs of meat-eating events practically were vanished; the Symposium process and the sacrificial ceremonies that took place before the Christianization of Greece, involved a gender variability associated to the preferential access of males to meat and fish (Detienne 1989); the concept of men gathering in the form of tavern, and later the restaurant and the café, consuming meat-eating dishes remained (Garvie-Lok 2001). For instance, during the Ottoman period in Greece and in Constantinople, restaurants and cafes were places where only men were expected to socialize (Matthaiou 1997:130–136).

Dental caries and tooth wear

Dental caries epidemiology is one of the most important ways in which the diet of past populations can be assessed (Hillson 2001), and in addition the most common pathology found in ancient human remains (Lanfranco and Eggers 2010). Caries is defined as a disease process characterized by the focal demineralization of dental hard tissues by organic acids produced by bacterial fermentation of dietary carbohydrates (Larsen et al.

1991). Therefore, caries is directly associated with the consumption of carbohydrates, and for that reason, in archaeological contexts, caries can be used as a very useful tool in order to explore social differences between sexes. Dental caries is also associated with dental plaque bacteria (Keyes and Jordan 1963), as well as with starches (Lingstrom et al. 2000). Starches can have the potential to serve as substrates for bacterial acidogenesis in plaque and thus lead to cariogenesis (Lingstrom et al. 2000). Moreover, the gradual progressive nature of caries leads to a pattern of development that is strongly related to age (Manji et al. 1991; Thylstrup and Fejerskov 1994); thus, the factor of age must be taken into consideration when recording carious lesions in a past population.

In addition, caries has been widely studied in many populations all over the world, especially in populations of hunter-gatherers and agriculturalists and that is because this transition of subsistence strategy was accompanied by a higher frequency of oral pathologies and specifically of dental caries (Lukacs 1996; Larsen 1997; Hillson 1996, 2001). Furthermore, studies have examined caries rates in different types of societies. According to these studies, hunter-gatherers present caries frequencies between 0%–5.3%, populations with mixed diets 0.44%–10.3% and agriculturalists from 2.2%–26.9% (Turner 1978, 1979; Schollmeyer and Turner 2004). Determining the type of a society is very important, as it can be definitely associated with the identification of possible gender differences regarding diet.

Dental wear is the tooth-on-tooth wear that creates wear facets on both teeth involved (Hillson 2008). Occlusal wear is usually recorded by scoring

the pattern of dentine exposed as the wear progresses (Hillson 2008). Smith's (1984) scheme; also followed in this study; is the most frequently used one and this is a recognized standard (Buikstra and Ubelaker 1994). Tooth wear was correlated with diet as early as in 1965, in Anderson's study, when he concluded that dental wear and wear patterns could be clues to the reconstruction of a population's subsistence and diet.

Many other studies correlated tooth wear to the bioculture and diet of a population (Molnar 1971; Scott 1979; Smith 1984; Littleton and Frohlich 1993). Contrary to caries rates, the transition from hunter-gatherers to agriculturalists was accompanied with an important decline in tooth wear rates (e.g. Anderson 1965; Molnar 1971; Hinton 1981; Kennedy 1984; Pastor 1992; Lubell et al. 1994), as populations that underwent agricultural intensification started to consume softer food items, resulting in reduced wear rates. However, apart from the reduction of wear rates, the onset of agriculture also brought the differentiation of wear patterns. For instance, it has been documented that populations of hunter-gatherers presented evenly distributed flat wear, whereas agricultural communities a more angled wear (Eshed et al. 2006). Furthermore, a hypothesis of caries attrition competition has been formed, based on the assumption that a beneficial effect of tooth wear is to avoid development of caries (Maat and Van der Velde 1987). This effect is related to the slow and gradual degrees of wear that can be proved to be beneficial, as they can move away potentially carious surfaces from teeth, smoothing the fissures and the cavities of teeth. On the other hand though, severe tooth wear could cause an enlargement of neighboring tooth fis-

sures, resulting to particles of food being 'trapped' in them. This could lead to periodontal disease, and to the exposure of the enamel-cementum junction, leading to bacteria development that could cause dental caries.

Osteoarthritis (OA), spinal facet remodeling, and Schmorl's nodes

Osteoarthritis (OA) is clinically characterized by cyst formation, osteophytes and subchondral sclerosis with joint space loss, and in some cases eburnation as an end result (Resnick and Niwayama 1988). Furthermore, other than dental diseases, OA is one of the most common pathological conditions observed in human skeletal remains (Resnick and Niwayama 1988; Weiss and Jurmain 2007). Age, weight and mechanical loading have been considered some of the most important etiological factors of OA (eg. Waldron 1997; Sofaer-Derevenski 2000; Solano 2002; Weiss 2005; 2006). It is believed that severe OA scores on specific joints are the result of continued use of specific muscles and joints in daily and repetitive tasks (Weiss and Jurmain 2007). Therefore, OA has been considered an important activity indicator, especially in ancient populations. However, genetic, anatomical and body mass index influences must not be overlooked regarding OA epidemiology, even though heritability estimates concerning this condition have been obtained from contemporary urban populations, which in general do not experience extreme mechanical loading (Weiss and Jurmain 2007).

Schmorl's nodes have been extensively studied by and named after George Schmorl (Schmorl 1926; Schmorl and Junghanns 1959). This term has been mainly adopted to apply to the end re-

sult of the prolapsed disc, or the lesion that eventually is formed on the surface of the affected vertebral body (Faccia and Williams 2008). Schmorl's nodes result from: a) congenital defects of the spine; b) age (senescent processes); and c) traumatic events (Resnick and Niwayama 1978). However, according to Schmorl and Junghanns (1971), these lesions are usually a result of daily physical activity. A number of studies have used Schmorl's nodes as indicators of demanding physical activity (i.e. Angel et al. 1987; Baker 1997; Coughlan and Holst 2000; Knusel 2000; Manzon and Gualdi-Russo 2016). In addition, these lesions have been used in order to assess differences in activity patterns between the sexes (Rathbun 1987; Parrington and Roberts 1990).

Wolff's law of transformation states that "the form of the bone being given, the bone elements place or displace themselves in the direction of the functional pressure and increase or decrease their mass to reflect the amount of func-tional pressure" (Kennedy 1989:134). Bone remodeling is a skeletal response to applied stresses, in order to maintain integrity in support and movement (Rubin et al. 1990). Hence, is somewhat surprising, that plastic change (bone remodeling, and specifically spinal zygapophyseal facet remodeling) has been subject to less intensive study than OA. According to Sofaer-Derevenski (2000), the biomechanical forces leading to facet remodeling could make it one of the most reliable indicators of activity, and specifically of load bearing. Therefore, studying the distribution of facet remodeling along the spine could provide specific information as to how the loads might have been carried (ex. on the head or on the back, etc.) in a population.

Materials and Methods

Thebes is an important city of Boeotia and is located 96.86 km north of Athens. (Fig. 1). Thebes is placed within fertile

Fig. 1. The geographical location of Thebes

plains and has access both to freshwater and marine sources. The excavation point was Aghia Triada, a four acres plot located west of the Kadmeia Acropolis of the city. The excavations took place from 1986 until 1990 by the 1st Ephorate of Byzantine Antiquities. The specific spot, named after the contemporary church of Aghia Triada, was specifically chosen from the archaeologists due to its geographic location. Aghia Triada was considered to be the ideal location in order for archaeologists to study the monetary movement of the region (Galani-Krikou 1997). In addition, the archaeologist/excavator in charge, (Ms. Koilakou), pointed out that Aghia Triada was most likely the spot where the silk workshops were placed. The fact that Aghia Triada is located nearby "Dirkis' stream" (Fig. 1), along with the tanks and other relevant findings revealed within the said area, convinced the researcher that the silk workshops were placed there, as dyeing the silk fibers in particular, requires a great amount of water (Galani-Krikou 1997).

The skeletal collection of Aghia Triada in Thebes consists almost entirely of individual burials (Fig. 2), and it is dated between the 13th–14th centuries A.D. The preservation of the bones was, thankfully, very good. Sixteen (16) individuals were actually studied, 7 males and 9 females, and a total of 126 teeth and 350 vertebrae.

Sex determination of the skeletons was conducted using the morphological criteria of the skull and pelvis (Bass 1987; Buikstra and Ubelaker 1994). Age estimation was based mainly on pubic symphysis morphology, the auricular surface and the sternal end of the ribs (Byers 2005). 9 individuals belong to the younger age category (20–35 years old), 6 to the middle aged one (35–50 years old) and only 1 adult belongs to the 51+ group.

Dental caries and dental wear

Teeth were recorded according to the FDI tooth numbering system. Dental caries was assessed by macroscopic examination and a dental probe. Dental caries was recorded according to the 'Standardized System for Recording Dental Caries in Prehistoric Skeletons' by Metress and Conway (1975). According to this system teeth were recorded as present or absent (antemortem tooth loss and postmortem tooth loss were also recorded), all tooth surfaces were observed and the degree of carious lesions was rated on a scale from 1 (minimal) to 4 (crown destruction).

Dental wear was recorded according to Smith's (1984) protocol which was

Fig. 2. Exhumation photograph from Aghia Triada in Thebes.

based on hunter-gatherers and agriculturalists. This specific protocol includes eight (8) degrees of wear. The degrees ranging from 1 to 2 represent slight wear (no wear or very slight exposure of dentine), degrees from 3 to 5 represent moderate wear (moderate exposure of dentine), and degrees from 6 to 8 represent severe wear (nearly total exposure of dentine).

Osteoarthritis, Schmorl's nodes and Facet remodeling

Osteoarthritis was studied along the spine, according to the criteria formed by Rogers et al., (1987). Those criteria are as follows: eburnation, osteophytes, pitting and alteration of the joint contour (AJC). Eburnation leads directly to OA diagnosis, otherwise two of the remaining criteria must be observed in order to diagnose OA. Moreover, a more detailed recording of eburnation, osteophytes and pitting was conducted (Buikstra and Ubelaker 1994). For each of the above stated three criteria, 3 degrees were recorded. Degree 1: EB/OP/P occupy 1/3 or less of the total surface; Degree 2: EB/OP/P occupy between 1/3 and 2/3 of the total surface; and Degree 3: EB/OP/P occupy between 2/3 and 3/3 of the total surface. Alteration of the joint contour was recorded only as absent or present. Schmorl's nodes were also recorded as present or absent.

    Facet remodeling along the spine was recorded according to a four-stage system, formed by Sofaer-Derevenski (2000). According to this system, observations were made on the superior and inferior articular facets and changes such as the morphology of the margins were assessed giving the scores 0 to 3 for severity.

Statistical Analysis

All frequencies of dental caries and wear were calculated according to present teeth. Furthermore, frequencies of OA, facet remodelling and Schmorl's nodes, were calculated according to present vertebrae. The data did not follow a normal distribution, thus the Mann-Whitney's U test (non-parametric test) was implemented in order to compare males and females and adults in the two basic age categories (20–35 years old, 35–50 years old) ($p < 0.05$). Spearman's rank correlation coefficient ($p < 0.05$, or $p < 0.01$) and a principal component analysis plot were used in order to test how strongly the variables were associated with each other. All the analyses were carried out using SPSS (Statistical Package for the Social Sciences) version 21.

Results

Dental caries and wear

From the 126 present teeth examined, 55 belong to males and 71 to females. The total caries frequency of the population is 16.7% (21/126 teeth). Males present higher caries frequency than females (25.5% males, 9.9% females), and the difference between them is statistically significant (Mann Whitney U, $Z = -2.320$, $p = 0.022$). More specifically, younger males show caries rate at 16.1% (5/31 teeth) vs. younger females at 7.8% (4/51 teeth) ($\chi^2 = 1.355$, df=1, $p = 0.244$). Middle aged males show carious lesions in 7 out of 18 teeth (38.9%), while middle aged females exhibit carious lesions only in 3 out of 20 teeth (15%) ($\chi^2 = 2.788$, df=1, $p = 0.095$).

    In addition, males present higher caries rates in the occlusal and the mesial surfaces, whereas females exhibit high-

Table 1. Frequency of dental caries and caries locations, between the sexes

| | Total caries frequency | Teeth surfaces | | | | | χ^2 (p-value) | Mann-Whitney (p-value) |
		Occlusal	Buccal	Lingual	Mesial	Distal		
Males	25.5%* (14/55)**	16.4% (9/55)	1.8% (1/55)	0%	7.3% (4/55)	0%	0.001	0.022 (Total caries difference)
Females	9.9% (7/71)	4.2% (3/71)	5.6% (4/71)	0%	0%	0%	0.164	

* caries frequency, ** carious teeth/present teeth.

er percentage in the buccal surface (Table 1). Furthermore, males also present higher rates in caries degrees 1, 2 and 4. The total difference between the two sexes is again statistically significant (Table 2). Caries frequencies were also calculated between sexes, for each of the four types of teeth. None of the two sexes presents any percentage in the canines. In all of the remaining three types, males present higher rates than females. Males

show 47.6% in molars, whereas females show 28.6%. In premolars, females present 4.3% caries rate, and males 16.6%; lastly, in the incisors males present caries frequency at 11.1% (Fig. 3).

The frequencies of dental wear between males and females are presented in Table 3. Each one of the two sexes presents a statistically significant relation with dental wear, whereas no significant difference is found between the two sexes (Mann Whitney U, $Z = -1.333$ $p = 0.183$). Furthermore, percentages of severe wear (degrees 6 to 8) are only found in males, albeit the difference between males and females regarding severe wear is not statistically significant (Table 3).

Table 2. Frequency of caries degrees between the sexes

Caries degree	Males	Females
1	16.4*, (9/55)**	5.6 (4/71)
2	5.5 (3/55)	2.8 (2/71)
3	0	1.4 (1/71)
4	3.6 (2/55)	0
χ^2 (*p*-value)	0.001	0.421
Mann-Whitney (*p*-value)	0.022 (total degree difference)	

* caries frequency, ** carious teeth/present teeth.

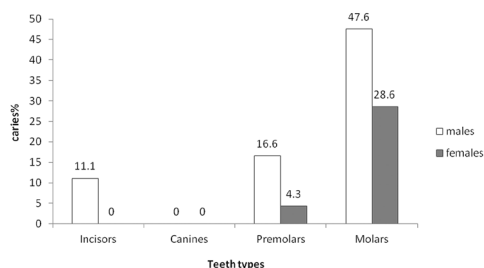
Fig. 3. Caries frequency between the sexes, in the four types of teeth

Table 3. Frequency of dental wear between the sexes

Dental wear's stages	Males	Females
1	9.1* (5/55)**	8.56 (6/71)
2	36.4 (20/55)	47.9 (34/71)
3	25.5 (14/55)	38 (27/71)
4	5.5 (3/55)	4.2 (3/71)
5	10.9 (6/55)	1.4 (1/72)
6	1.8 (1/55)	0
7	1.8 (1/55)	0
8	5.5 (3/55)	0
χ^2 (*p*-value)	0.00	0.00
Mann-Whitney (*p*-value)	0.183	

* dental wear frequency, ** teeth with wear/present teeth.

OA, Facet remodeling and Schmorl's nodes

The total frequency of OA for the entire population is just 0.9%. Males and females present almost equal frequencies of OA (males 0.6% and females 1.1%). In contrast, the percentages of osteophytes are must higher than those of OA. As mentioned above (See Chapter 2.2), osteophytes are just one of the 4 diagnostic criteria of OA, not leading alone to OA diagnosis. Males present a frequency of 10.9%, whereas females 22.3%, and the difference between them is statistically significant (Mann Whitney U, $Z=-2.871$, $p=0.004$) (Table 4). Furthermore, the highest frequencies of osteophytes are observed in the older adults (28%, 7/25) and the younger ones (20.6%, 36/175). The middle adults present a percentage of 10% (15/150). The difference between the middle adults and the younger ones is statistically significant (Mann Whitney U, $Z=-2.608$ $p=0.009$), as well as the difference between the older adults and the middle ones (Mann Whitney U, $Z=-2.506$, $p=0.012$).

Moreover, the two sexes present almost equal percentages of facet remodeling, (males 13.1% and females 12%), without any statistically significant difference between them (Table 4). Furthermore, males present a higher rate of Schmorl's nodes in relation to females, even though this differentiation is not

Table 4. Frequencies in activity spinal indicators, between the sexes

Activity indicators	Males	Females	Mann-Whitney (*p*-value)
Osteoarthritis	0.6* (1/175)**	1.1 (2/175)	0.563
Osteophytes	10.9 (19/175)	22.3 (39/175)	0.004
Eburnation	0.6 (1/175)	0.00	0.317
Pitting	1.7 (3/175)	1.7 (3/175)	1.00
Facet remodeling	13.1 (23/175)	12 (21/175)	0.747
Schmorl's nodes	4 (7/175)	1.1 (2/175)	0.092

* Frequency, ** number of affected vertebrae/total number of vertebrae.
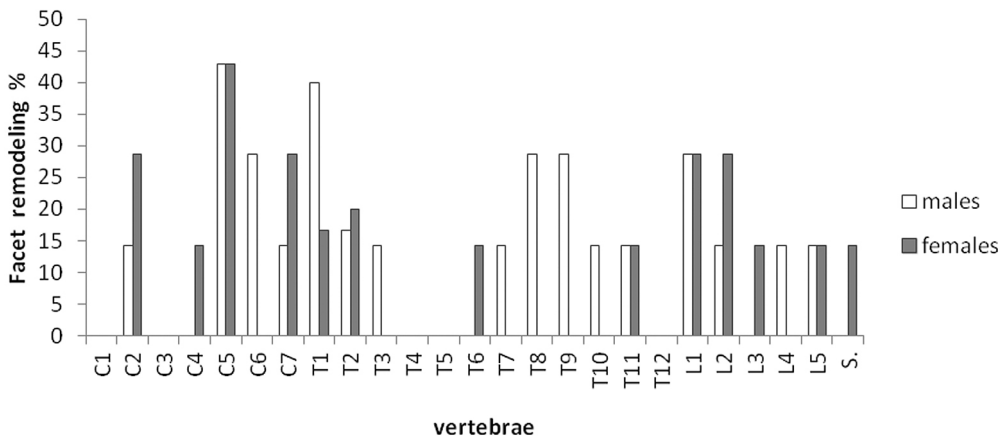

Fig. 4. Frequency of the distribution of facet remodeling along the spine between the sexes (C= cervical, T= thoracic, L= lumbar, S= sacrum)

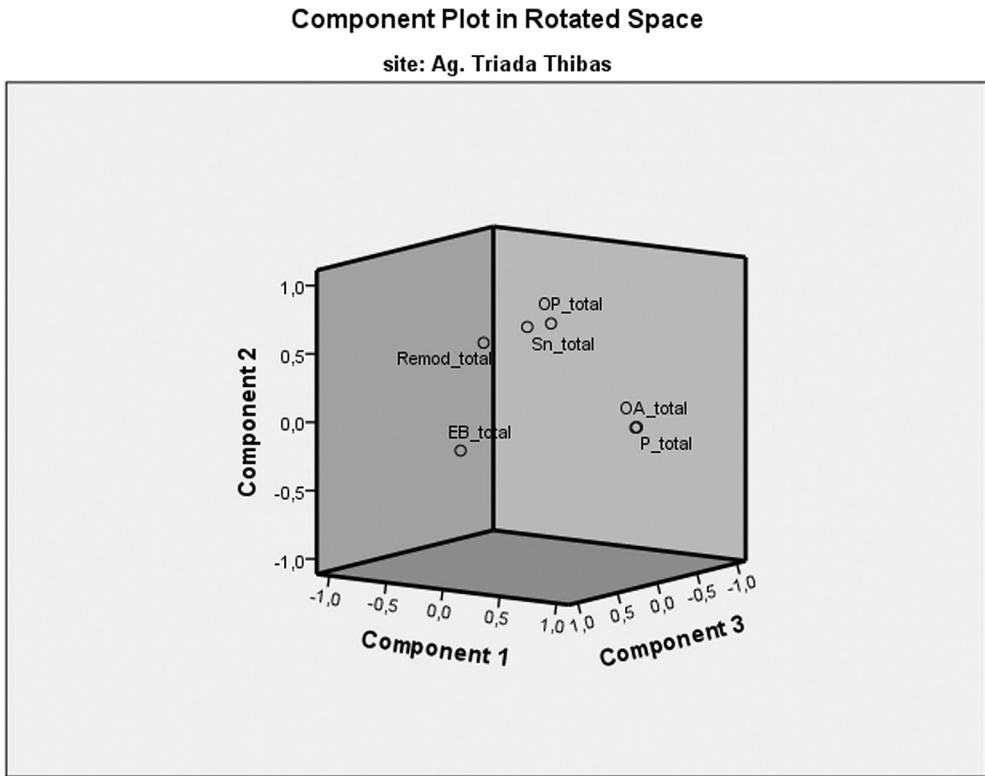**Component Plot in Rotated Space**

site: Ag. Triada Thibas

Fig. 5. Component plot regarding the activity indicators along the spine, for the population of Aghia Triada

statistically significant (Mann Whitney U, $Z = -1.686$, $p = 0.092$) (Table 4). In addition, the highest percentage of remodeling is observed in the younger individuals (18.9%, 33/175), whereas the middle ones present a frequency at 4.7% (7/150), and the difference between the above age groups is statistically significant (Mann Whitney U, $Z = -3.876$, $p < 0.001$).

The distribution of facet remodeling along the spine (including the sacrum), is also examined between the two sexes. Males present their highest frequencies in the 5th cervical (3 out of 7 vertebrae) and in the 1st thoracic vertebra (2 out of 5 vertebrae). Females, also present their highest percentage in the 5th cervical vertebra (42.9% – 3 out of 7 vertebrae) (Fig. 4).

Finally, correlations between the activity spinal indicators have been examined. OA exhibits its strongest (positive) correlation with pitting, and this correlation is statistically significant (Spearman correlation= 0.704). Osteophytes present a positive correlation with facet remodeling, which is also statistically significant, even though the correlation is not so strong (Spearman correlation = 0.155). Facet remodeling also exhibits positive and statistically significant correlations with eburnation and Schmorl's nodes (Table 5). Correlations between the above activity indicators are graphically presented in the Principal Component Analysis plot (Fig. 5). Facet remodeling, osteophytes and Schmorl's nodes

Table 5. Correlation matrix (Spearman's correlation coefficient) for the entire population

|	Osteoarthritis	Osteophytes	Eburnation	Pitting	Facet remodeling	Schmorl's nodes
Osteoarthritis	1.000	0.042	−0.005	0.704*	−0.035	−0.015
Osteophytes	0.042	1.000	−0.024	0.060	0.155*	0.073
Eburnation	−0.005	−0.024	1.000	−0.007	0.141*	−0.009
Pitting	0.704*	0.060	−0.007	1.000	−0.050	−0.021
Facet remodeling	−0.035	0.155*	0.141*	−0.050	1.000	0.156*
Schmorl's nodes	−0.015	0.073	−0.009	−0.021	0.156*	1.000

* Level of significance, $p < 0.01$.
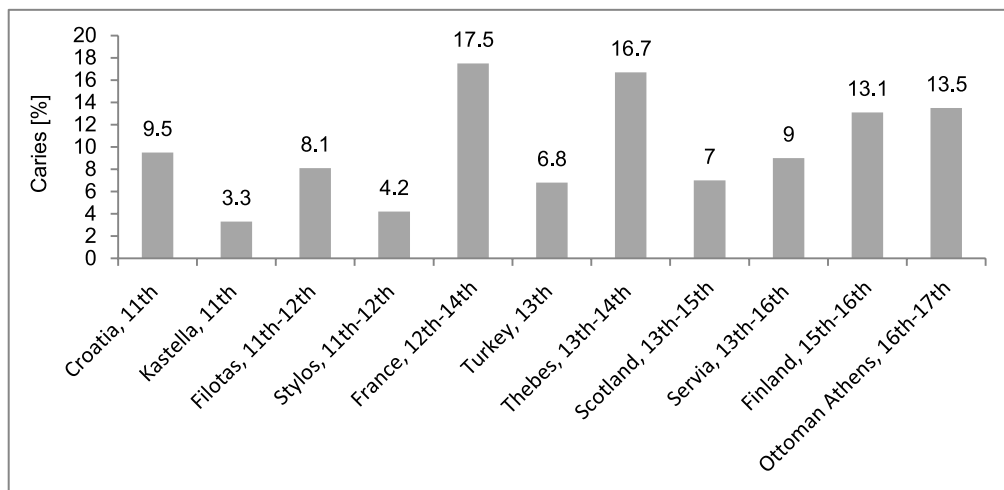
Fig. 6. Caries rates in medieval populations from Europe. For reasoning see text

Table 6. Component table explaining Figure 6

	Component		
	1	2	3
OA total	0.920	0.006	0.001
R total	−0.070	0.598	0.499
SN total	−0.055	0.639	−0.030
OP total	0.103	0.670	−0.102
EB total	0.017	−0.122	0.913
P total	0.921	0.006	−0.012

OA – osteoarthritis, R – facet remodeling, SN – Schmorl's nodes, OP – osteophytes, EB – eburnation, P – pitting.

are all grouped together under the 2nd component, whereas OA is grouped with pitting under the 1st component (Fig. 6, Table 5).

Discussion

Dietary patterns/ Dental caries and wear

The total caries percentage for our population is 16.7%, and according to the frequencies defined by Turner (1978), (1979); Schollmeyer and Turner (2004); our percentage falls within the agricultural diet (2.2–26.9%). This finding is in agreement with both the historical information supporting an agricultural economy (See Chapter 1.2) as well as with the isotopic investigation conducted at the Stable Isotope Unit, of N.C.S.R. "Demokritos", Athens, Greece. Accord-

ing to the collagen and apatite analysis the 16 adults were highly dependent on a C_3 and C_4 (i.e. millet) terrestrial based diet (forthcoming publication). Therefore, it is quite understandable that agricultural products rich in carbohydrates would be a main food source for the population under discussion, leading to significant carious lesions. Our caries rate is closer to the one originating from Vilarnau d' Amont in France (12–14th centuries A.D.) (17.5%) (Esclassan et al. 2009), and secondly to the ones in Ottoman Greece 13.5% (16–17th c. AD) (D.E. Michael's unpublished thesis) and Finland 13.1 % (Turku; 15–16th c. AD) (Varrela 1991) (Figure 6). Thebes' caries rate differs the most from other medieval populations from Greece, such as the one from Kastella (Crete, 11th century A.D.) 3.3% (Bourbou and Richards 2007; Bourbou 2009), from Filotas (Greek Macedonia, 11–12th centuries A.D.) 8.1% (Bourbou, 2006), and from Stylos (Crete, 11–12th centuries A.D.) 4.2% (Bourbou, 2009). Isotopic analysis concerning the above three Greek sites, has revealed that they represent the general 'Byzantine diet', which consists mainly of C_3 terrestrial foods, domesticated animals, dairy products and some amount of seafood (Bourbou 2013). Therefore, even though dental caries is associated with other factors aside from diet, such as oral hygiene, we may rather safely assume that Thebes' population was more dependent on carbohydrate food sources, compared to Filotas, Stylos and Kastella. In addition, Thebes' caries rate is also higher than the respective one of Bijelo Brdo (Croatia, 10–11th centuries A.D.) 9.5% (Vodanovic et al. 2005), of Iznik (Turkey, 13th century A.D.) 6.8% (Caglar et al. 2007), of Whithorn (Scotland, 13–15th centuries A.D.) 7% (Watt et al.

1997), of Valjevo (Serbia, 14–16th centuries A.D.) 9% (Djuric-Srejic 2001).

Males present significantly higher caries rate and severity when compared to females (25.5% males, 9.9% females). The above results are not so consistent with the general tendency of females presenting higher caries rates, both in ancient and modern populations (Walker and Hewlett 1990; Hillson 2001). Earlier eruption of teeth, biocultural differences, changes in salivary composition during pregnancy and lactation are the main factors of this difference between the sexes (Larsen 1997; Walker and Hewlett 1990; Laine 2002). Therefore, it could be proposed that males were exposed to higher rates of carbohydrates, than females. However, the isotopic investigation revealed that females were the ones probably consuming more agricultural products, such as millet in relation to males. Hence the stated differentiation between males and females could be attributed to the factors of age or of ante mortem tooth loss (AMTL). Caries presents a significantly positive correlation to age (Spearman's coefficient 0.212; $p = 0.017$). On the other hand though, males and females show almost the same number of teeth in the middle age category (18 male teeth vs. 20 females teeth). Therefore, it couldn't be supported that males present a higher caries frequency and severity due to age. In addition, no significant differentiation was observed between males and females regarding AMTL (14 teeth in males vs. 20 teeth in females).

Likewise Thebes, males of Vilarnau d' Amont presented higher caries rate in relation to females (Esclassan et al. 2009). The possible explanation for the difference noted in that French population was associated with the higher burden

of labor that males had in rural medieval populations in France (Laurioux 2002). Therefore, we could assume that males in Thebes, due to harder occupational activity, consumed more food leading them to higher caries rates. However, the activity patterns between the sexes in Thebes are almost similar. Other factors that could lead males to present higher caries frequencies than females are oral hygiene and dental wear.

Dental caries presents a positive correlation with wear (Spearman's coefficient= 0.364), and this correlation is statistically significant. However, severe wear (stages 6 to 8), presents a negative correlation with caries, although not statistically significant. The general wear pattern in Thebes is not so consistent with the one from the majority of European medieval populations. Tooth wear in the Middle Ages was quite intense, abrasive, rapid and generalized, due to the consumption of large amounts of abrasive food (d' Incau and Rouas 2003). However, our population does not show such intensive wear, since its highest percentages are noted in the middle stages of dentine exposure. Thus, it appears that the population consumed soft and refined food items, due to Thebes' agricultural economy. In addition, even though males are the only ones exhibiting severe dental wear, females are the ones presenting higher wear frequencies in stages 2 and 3, i.e. slight to moderate wear. Hence, it could be proposed that the slight to moderate stages of wear more observed in females protected them from carious lesions (caries-attrition competition hypothesis, See Chapter 1.3).

All in all, the dental analysis confirmed the agricultural profile suggested by both the literary sources and the isotopic investigation. Nevertheless, contrary to our second hypothesis, males show higher caries rates in relation to females, even though the noted differentiation is probably attributed to other factors, such as oral hygiene or wear, rather to the consumption of more carbohydrates.

Activity patterns/OA, Facet remodeling and Schmorl's nodes

OA frequencies are very low in both sexes, whereas osteophytes' frequencies are quite higher for both males and females. In particular, females present significantly higher percentage of osteophytes than males. In addition, osteophytes are significantly observed in the younger adult category (20–35 years old). Osteophytes are one of the four diagnostic criteria of OA, and as it has been already noted, the epidemiology of OA is highly influenced by age. However, the strong presence of osteophytes in younger adults cannot be attributed to age; on the contrary it can be associated with physical activity. Furthermore, the higher frequency of osteophytes in females should not be solely attributed to the effect of occupational stress. OA, especially along the spine, is highly associated to genetic influences (Sambrook et al. 1999, Spector and MacGregor 2004), and some studies have documented that this hereditary effect is stronger in females than in males (Wilson et al. 1990, Bergink et al. 2003, Spector and MacGregor 2004). On the other hand though, the older age group (adults 51+), is entirely consisted of males, therefore the strongest presence of osteophytes in females cannot be attributed to age.

Moreover, the two sexes present almost equal frequencies in spinal facet remodeling. In addition, facet remodeling's distribution pattern along the spine is

also quite similar between males and females. Both sexes present high rates in the cervical vertebrae (and especially in the 5th ones). On the contrary, the presence of spinal remodeling in the upper thoracic vertebrae is quite stronger in males, than in females. Load-carrying by tumpline, or on the head, have been associated with a peak in OA in the upper thoracic, the middle and lower thoracic, as well as the mid-cervical and lower lumbar vertebrae (Shore 1935; Steward 1979; Kilgore 1984; Jurmain 1990; Bridges 1994; Lovell 1994). However, a peak in OA specifically in the T1 (1st) thoracic vertebra has been associated with the method of carrying creels (Merbs 1983; Miles 1989; Sofaer-Derevenski 2000). There is no documented source informing us that carrying creels was a method of burden-carrying in medieval Thebes, therefore we cannot attribute the noted peak in T1 in males, to this specific method. However, it is possible that males in Thebes may have carried loads in a way that their 1st thoracic vertebra was affected more than females (we cannot be certain, due to our small sample). Consequently, even though the two sexes present no quantitative difference in facet remodeling, there seems to be some difference in the methods of load-carrying, leading us to the probability of a gender division of labor. Although, we have no specific information concerning the exact methods of load-carrying in Thebes, we can assume that loads were carried in several ways, such as on the head, with hands, or on the back. Moreover, we can safely assume that yarn was carried, probably in baskets, in order to be washed by workers in the river of 'Dirki', and later used in the processing of silk. Our population from Thebes can be compared to the one originated from 13th century Wharram Percy (United Kingdom). In the English population males were the ones presenting a higher frequency in remodeling (Sofaer-Derevenski 2000), whereas in Thebes the two sexes present equal rates. In addition, the entire English population presents its highest frequencies in the first thoracic vertebra, as do males in Thebes, although the distribution of remodeling along the spine in our sample is much more extensive than that of Wharram Percy, leading us to the hypothesis than physical activity was probably more intense in Thebes for both sexes.

Males present higher frequency of Schmorl's nodes than females, even though this difference is not statistically significant. The simultaneous presence of Schmorl's nodes and osteophytes on a joint surface is associated with pain and more intense physical activity (Faccia and Williams 2008). This positive correlation between the above indicators is also noted in our population, although it is not statistically significant. However, in Thebes, two other positive and statistically significant correlations between the activity indicators under study have been observed. Facet remodeling and Schmorl's nodes, as well as facet remodeling and osteophytes, present between them a positive and statistically significant correlation, albeit the aforementioned correlations are not so strong. Even though, the above activity indicators result from different causes, it is only natural to expect that the simultaneous presence of the above in a population, ancient or modern could be associated with more intense physical activity. The correlation between Schmorl's nodes and facet remodeling has also been found in three other populations from Greece; in ancient Corinth (Geometric

Period-5th c. AD.) (Michael et al., 2017) in Corfu (7th century B.C.–2nd century A.D.) and in the Modern Reference Skeletal Collection of the Department of Animal & Human Physiology, Athens University, (2nd half of 20th century) (D.E. Michael's unpublished thesis). Moreover, the correlation between osteophytes and facet remodeling has also been found in ancient Corinth (Michael et al., 2017). Consequently, we cautiously propose the study of the above two correlations, as activity indicators in ancient and even modern populations.

Based on the information presented above, it appears that both sexes had an intense physical activity in medieval Thebes. Contrary to our 4th hypothesis, males and females present similarly intense activity patterns, suggesting that women worked outdoors probably as hard as men, and were not restricted solely to their household activities. These findings are consistent with the historical information that is available for this population. Although, we are in no position knowing which activities were undertaken by each of the two sexes, a gender division of labor is not excluded.

Concluding, dental results confirm historical information of medieval Thebes having an agricultural economy and are also in agreement with isotopic data. Males show significantly higher caries rates in relation to females, even though the noted difference is probably not associated to the consumption of more carbohydrates. In addition, our findings suggest very intense physical activity for both sexes, whereas the distribution of facet remodeling along the spine could indicate a possible gender division of labor. Our study proposes two positive correlations; between facet remodeling and osteophytes, and between Schmorl's nodes and facet remodelling; as activity indicators in past or/and modern populations. Finally, we strongly encourage the inclusion of spinal facet remodelling in studies focusing on occupational stress.

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Authors' contributions

DEM conducted the research, the statistical analysis and wrote the largest part of the paper. EI offered valuable information regarding the historical context of the population under study, SKM offered his guidance for conducting the specific research.

Conflict of interest

The author declares that there is no conflict of interests.

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