A sense of society: entheseal change as an indicator of physical activity in the Post-Medieval Low Countries: potential and limitations

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Acts of Life: assessing the use of entheseal change as an indicator of social differentiation in post-medieval Aalst (Belgium)

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Abstract

Objectives

Lower levels of physical activity are often linked to higher socio-economic status in past societies. As an activity marker, changes at muscle attachment sites known as entheseal changes (EC) have been used with varying efficacy. This study investigates this proposed link between EC as a physical activity marker and socio-economic status within one well-defined temporo-geographic context.

Materials and Methods

EC data from 16 entheses in three skeletal collections from the post-medieval town of Aalst, Belgium, were evaluated using the Coimbra method. The skeletal assemblages represent distinct socio-economic groups, evidenced by historical and dietary isotope data. The Louis D'haeseleerstraat sample represents lower-class individuals (n=46), the Hopmarkt sample middle-class individuals (n=110), and the Saint-Martins church (n=13) upper-class individuals. EC data are tested for correlation to status, age, and sex.

Results

EC patterns did not differ significantly between the groups at any entheses except the M. iliopsoas and common extensor, where the higher class showed more EC. Within the populations, at the Hopmarkt sexual differences were only observed in the Achilles tendon attachment, whereas at the Louis D'haeseleerstraat sexual differences were present in the M. Triceps Brachii, M. Brachioradialis, and Quadriceps entheses. Only some entheses showed a significant correlation with age, and these were inconsistent between populations.

Discussion

EC are not a reliable indicator of socio-economic status in post-medieval Aalst. This could suggest that the hypothesis that richer people were less physically active oversimplifies the lives of people in the past. It could also suggest that EC is not a suitable proxy for physical activity, or that it cannot be used without in-depth knowledge of the types of activities performed by various socio-economic groups on top of consideration of all other etiological factors. This study thus illustrates the caution necessary when using EC as a proxy for social status in past societies.

Keywords

Musculoskeletal stress markers, activity markers, activity reconstruction, socio-economic status, social status, urban, monastic archaeology, guilds

6.1 Introduction

Division of labor is an essential aspect of the social stratification of a society. Less strenuous labor is often linked to higher socio-economic status (Alves Cardoso and Henderson 2010, Maggiano *et al.*, 2008, Mays *et al.*, 2009, Porčić and Stefanović 2009). Thus, patterns of physical activity have been used by bioarchaeologists as an indicator of social differentiation (e.g. Robb *et al,* 2001, Watkins 2012). To assess physical activity in bioarchaeology, many different osteological markers have been used (see Jurmain *et al.*, 2012 for an overview). One such activity marker is the variation in morphology at muscle attachment sites on bone known as entheseal change (EC) (Villotte and Knüsel 2013).

Studies in a host of different archaeological contexts have used EC to identify social differentiation and socio-economic status (e.g. Havelkova *et al.*, 2011, Palmer *et al.*, 2016, Rodrigues 2005, Schrader 2012). However, there is much debate as to the validity of EC as an indicator of physical activity (Jurmain *et al.*, 2012), with the etiological factors involved in EC expression still being identified and assessed for impact (Acosta *et al.*, 2017). Factors such as age (Alves-Cardoso and Henderson 2013) and body size (Godde *et al.*, 2018) have been shown to be more strongly correlated with EC than activity. Various recent studies have applied EC analysis on identified skeletal collections and found no consistent correlation with activity (Alves Cardoso and Henderson, 2010; Milella *et al.*, 2012, Michopoulou 2015, 2017). Yet, other studies did find correlations (e.g. Milella *et al.*, 2015 on an identified collection, Djukic *et al.*, 2018 on an archaeological collection). The current research aims to evaluate whether higher socio-economic status (SES) is correlated with lower levels of EC in a post-medieval, urban, Belgian town. Thus, this study will test the hypothesis that higher status individuals performed less strenuous physical activity, and whether EC can then be used to identify higher status groups. This research will add to our growing understanding of muscle markings and physical activity in the past, and of the utility of EC in bioarchaeology.

6.2 Materials

Three skeletal populations from the post-medieval town of Aalst, Belgium, are used, namely individuals from the Louis D'haeseleerstraat, the Hopmarkt, and the Saint Martin's church (figure 1). These collections were chosen because they represent three distinct socio-economic groups within one geographic context, i.e., the town of Aalst, and within a well-defined time-period (late 15th to late 18th century AD). In AD 1725 the town of Aalst was historically estimated to have a population of 8640 individuals (De Brouwer 1968). It was a thriving economic center renowned for its specialized crafts, most notably the cloth industry (Courteaux 1973), and its monopoly over the trade in hops (Aerts 1999). From eighteenth century surveys we know that the largest professions in the city were baking (bread bakeries), shopkeeping, tailoring, and different cloth industries such as yarn-making and blue-dyeing of cloth (De Schryver 2001). They were both the cornerstones of the post-medieval economy and the largest forms of employment for the people of Aalst. All specialized crafts were structured in guilds, which favored local, city-born apprentices in their admission system. Historical sources also suggest that a strong social distinction was made between the townspeople and 'outsiders' (so called 'niet-poorters'). When people did move into the town, they usually came from the immediate surrounding countryside (De Schryver 2001). This sociohistorical context allows us to assume a limited gene pool for the three skeletal collections, thus minimizing any potential effect of genetic variation on EC.

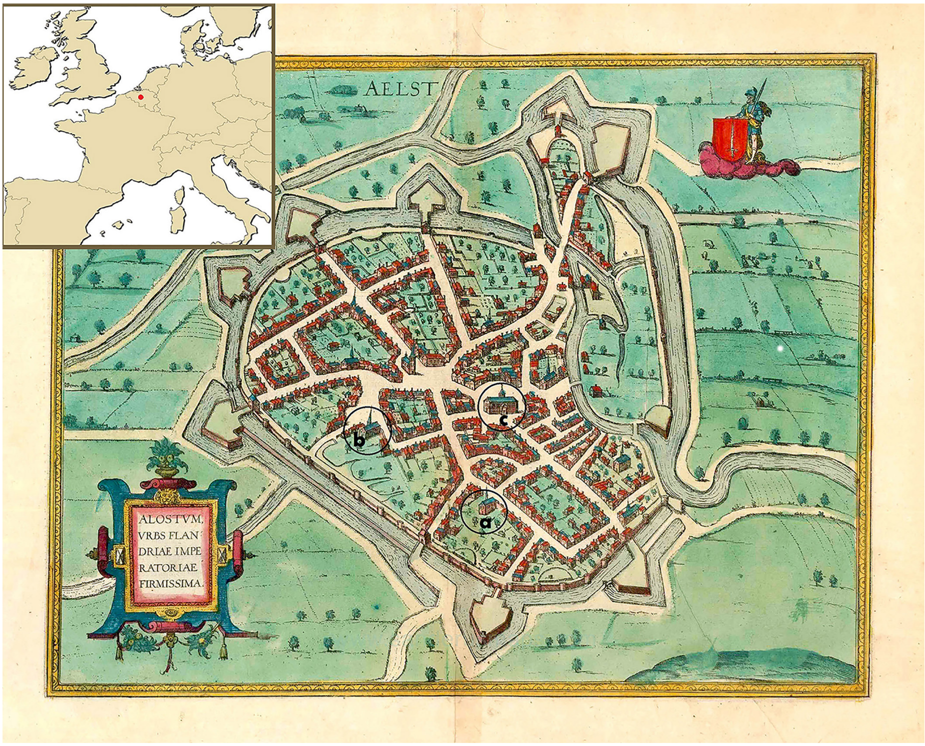

Figure 1: Map by Braun and Hogenberg from AD 1588, with the three sites discussed in this paper circled. a= Louis D'haeseleerstraat convent, b= Hopmarkt convent, c=Saint Martin's church. Location within Northwestern Europe in top left corner inset.

The first skeletal collection was excavated at the Louis D'haeseleerstraat. This site was the location of a female convent with a general population cemetery that was the least expensive place to be buried in post-Medieval Aalst (De Groote *et al.*, 2011). Thus, the skeletal population (n=46) represents individuals from the general population of low socio-economic status. The sisters of the Franciscan order started the convent around AD 1450. Later, in AD 1667, the sisters of the annunciation took over until the convent's termination by the French republic in AD 1797 (Bruggeman 2016, Bruggeman *et al,*. in prep). Thus, the individuals buried in this cemetery can be dated between AD 1450 and 1797.

The second skeletal population, excavated at the Hopmarkt, contains individuals from the cloister garth and alleys of the former Carmelite monastery (n=110) (De Groote *et al.*, 2018; De Maeyer *et al.*, 2014). People were interred in the monastery from AD 1497 to 1797 (De Maeyer *et al.*, 2014). Burial in the cloister garth and alleys would have cost lay people more than being buried in the general cemetery, but was still cheaper than burial inside the church (De Groote *et al.*, 2011). Therefore, the Hopmarkt population represents middle-class individuals and clerics (De Groote *et al.*, 2011). Based on historical information, the middle class would have been largely made up by higher ranking members of the guilds and their families (De Schryver 2001). Both men and women were interred, as well as non-adults (<18 years), although there are relatively fewer children buried here than in the general cemetery (De Groote *et al.*, 2011).

In addition to the historical evidence of the middle-class status of the skeletal collection buried at the Hopmarkt, dietary isotopic analyses of the Hopmarkt and Louis D'haeseleerstraat collections further support their different social status. The stable isotope ratios of carbon (δ13C) and nitrogen (δ15N) from the men and women buried at The Hopmarkt, as published by Quintelier and colleagues (2014), attest to them eating a diet richer in animal protein, including more marine animals, than the individuals at the Louis D'haeseleerstraat, whose δ15N ratios were lower in both men and women (Palmer in press). In this socio-cultural context this richer diet is linked to higher social status (Polet and Katzenberg 2002, 2003).

The last skeletal population used in this study originates from inside the Saint Martin's church. This small subset of individuals (n=13) thus represents people buried in the most expensive of the three burial locations in post-medieval Aalst. Based on church building phases, this population is dated to AD 1655-1782 (De Groote and Moens 1999).

Only adult individuals are included for EC analyses, as EC presents differently in growing individuals (Villotte 2006) and a method to evaluate EC in growing individuals is still under development (Palmer *et al.*, 2017). Both men and women are included (table 1). Individuals for whom sex estimation was indeterminate, or for whom age could not be reliably assessed, were omitted. Individuals showing any kind of pathology that could influence EC (i.e., DISH and other bone-forming diseases, as specified by Henderson (2008)), or any kind of pathology which would have had a profound impact on their physical activity (i.e., pathologies which limited mobility, badly healed fractures, etc.) were also omitted. All osteological analyses were done by the first author.

	18-25 years		*26-35 years*		*36-50 years*		*50+ years*		*Total*
	F	**M**	**F**	**M**	**F**	**M**	**F**	**M**	
Louis D'haeseleerstraat	2	6	7	5	8	9	5	3	46
Hopmarkt	8	10	16	25	14	21	6	10	110
Saint Martin's Church	1	0	1	3	2	1	3	0	13

Table 1: Demographic composition of the three samples (F=female; M=male).

6.3 Methods

Individuals were grouped into male and female categories, and into four age categories, namely early young adult (18-25 years), late young adult (26-35 years), middle adult (36-50 years) and old adult (50+ years) (table 1). Age was estimated from the morphology of the auricular surface (Buckberry and Chamberlain 2002), pubic symphysis (Suchey and Brooks 1990), and sternal rib end (Işcan *et al.*, 1984), as well as through dental attrition (Maat 2001), cranial suture closure (Meindl and Lovejoy 1985), and the fusion state of late fusing epiphyses (i.e. the sternal end of the clavicle, spheno-occipital synchondrosis, iliac crest, and ischial tuberosities) (Schaefer *et al.*, 2009). Sex was estimated through from the cranium, mandible, and pelvis using the Workshop for European Archaeologists guideline (Ferembach *et al.*,1980) and Phenice (1969), and through metrics (McCormick *et al.*, 1991, Stewart 1979, and Steyn and Işcan 1999).

Entheseal change was recorded using the Coimbra method (Henderson *et al.*, 2016) with the update for the M. biceps brachii on the radius (Henderson *et al.*, 2017a). Sixteen entheses were analyzed for EC, nine on the upper limb and seven on the lower limb. Only fibrocartilaginous attachment sites are used as the method is designed for these. Specifically, on the humerus, the M. supscapularis, M. supra-and infraspinatus, M. teres minor, common extensor (figure 2), and common flexor are used. On the ulna, the M. brachialis and M. triceps brachii are analyzed, and on the radius the M. brachioradialis and M. biceps brachii attachment sites are recorded. For the lower limb, the M. iliopsoas, M. gluteus minimus and M. gluteus medius on the femur, the M. quadriceps and M. popliteus on the tibia, the M. quadriceps on the patella, and the Achilles tendon on the calcaneus are recorded. All entheses will be analyzed and tested separately, as each enthesis has a unique pattern and spectrum of potential change. To test for asymmetry, Wilcoxon paired t-tests are performed (Noldner *et al.*, 2013), and to test for correlation with age, sex, and site/social status, Pearson's chi squares are done. It must be noted that the Saint Martin's church sample is small. It was included in the statistical testing but due to its small sample size, test results from this site will be less reliable. All statistical tests are performed using IBM SPSS 23. Statistical significance is set at $p \leq 0.05$.

Figure 2: Example of entheseal changes occurring at the common extensor attachment site on the lateral epicondyle of the humerus. L: enthesis on the right humerus with no EC. R: enthesis on the left humerus with bone formation in zone 1 (visible as lipping along the edge) and porosity and bone formation in zone 2.

6.4 Results

Old adults have been shown to be less reliable for activity reconstruction (Niinimäki *et al.*, 2013), therefore the Hopmarkt and Louis D'haeseleerstraat samples were compared without the old age category individuals as well as with these 50+ year individuals. Both samples gave the same results (appendix C), therefore the old adults were included in the sample to achieve a larger sample size and generate more robust statistical comparisons.

For the Louis D'haeseleerstraat sample, no statistically significant asymmetry was found between the left and right sides for any of the analyzed muscle attachment sites (table 2). For the Hopmarkt, only the right quadriceps enthesis on the patella scored statistically higher than the left (p=0.023, Z=-2.271, n=66). For the Saint Martin's church, no statistically significant asymmetry was found either, although statistical analyses were not possible for all entheses here due to the small sample size. Because of this lack of asymmetry for all EC at all sites except the patellar quadriceps attachment site at the Hopmarkt, left and right sides are combined for further analyses. When both left and right sides were recorded for an individual, the maximum score is used; when only the left or right side was recorded, that score is used.

6.4.1 Status

Of all entheses included in this study, only two showed any correlation with social status (table 3). The first is the common extensor enthesis on the distal humerus, which had a statistically significant relationship with status when comparing the two main sites. i.e., the Louis D'haeseleerstraat (lowest class) and Hopmarkt (middle class) (p=0.044, $\chi(1)=11.414$, n=106). In this case, there was more EC at the common extensor in the Hopmarkt sample. The second is the M. iliopsoas, which showed more EC in the high status Saint Martin's church sample when compared to the Louis D'haeseleerstraat sample(p=0.029, χ(1)=10.832, n=35). For all other entheses, no relation to status was found when comparing the three sites.

	Louis D'Haeseleerstraat					*Hopmarkt*					*Saint-Martin's church*				
	n	**mean**	**SD**	**Z**	**p**	**n**	**mean**	**SD**	**Z**	**p**	**n**	**mean**	**SD**	**Z**	**p**
L M. Subscapularis	25	1.24	1.589			45	1.4	1.572			11	0.73	1.421		
R M. Subscapularis	35	1.26	1.633	-0.9	0.379	49	1.45	1.990	-0.42	0.672	11	1.09	1.044	-0.37	0.713
L M. Supra+Infraspinatus	24	0.33	0.637			35	0.89	1.345			12	0.75	0.866		
R M. Supra+Infraspinatus	31	0.74	0.999	-1.4	0.177	35	1.43	2.187	-1.04	0.297	10	1.20	1.549	-1.82	0.068
L Extensor	26	0.58	0.902			43	0.95	1.308			8	1.38	1.061		
R Extensor	31	0.42	0.923	-1.0	0.317	47	0.85	1.021	-1.00	0.317	6	0.67	0.516	-1.63	0.102
L Flexor	27	0.11	0.320			35	0.29	0.710			4	0.50	0.577		
R Flexor	26	0.15	0.368	-1.0	0.317	49	0.39	0.702	-2.00	0.460	0				
L M. Teres Minor	20	0.20	0.410			30	0.53	0.900			6	0.17	0.408		
R M. Teres Minor	24	0.17	0.381	-1.4	0.157	35	0.60	0.775	-1.00	0.317	5	0.20	0.447	0.00	1.000
L M. Brachialis	36	1.14	1.313			69	0.74	0.816			10	1.00	1.491		
R M. Brachialis	39	0.90	1.252	-0.6	0.564	77	0.62	0.859	-0.22	0.830	9	0.67	1.000	0.00	1.000
L M. Triceps Brachii	31	1.13	1.204			56	1.16	1.262			7	0.57	0.535		
R M. Triceps Brachii	36	0.86	0.990	-0.3	0.782	64	1.20	1.184	0.00	1.000	6	1.00	0.632	-1.00	0.317
L M. Brachioradialis	15	0.40	0.828			37	0.59	0.686			8	0.63	0.744		
R M. Brachioradialis	23	0.39	0.499	0.0	1	46	0.76	0.736	-0.43	0.671	3	0.67	1.155	-1.00	0.317
L M. Biceps Brachii	34	1.06	1.043			68	1.32	1.354			10	1.10	1.101		
R M. Biceps Brachii	38	1.16	1.151	-0.9	0.372	72	1.50	1.394	-0.59	0.559	8	1.63	1.598	-0.54	0.589
L M. Iliopsoas	25	1.08	1.038			47	1.32	1.431			3	2.00	1.000		
R M. Iliopsoas	24	1.04	0.908	-1.6	0.102	52	1.02	1.129	-1.07	0.284	4	2.00	2.309		
L M. Gluteus Minimus	24	0.38	0.495			44	1.14	1.391			3	0.00	0.000		
R M. Gluteus Minimus	27	0.52	0.700	-1.3	0,18	51	1.18	1.466	-0.66	0.507	3	1.67	2.082		
L M. Gluteus Medius	21	0.57	0.676			31	0.84	1.068			3	0.00	0.000		
R M. Gluteus Medius	20	0.75	0.851	-0.6	0.577	37	0.86	1.032	-1.16	0.248	1	0.00			
L Quadriceps (tibia)	29	0.76	0.636			45	1.11	1.112			9	0.89	0.782		
R Quadriceps (tibia)	27	0.78	0.751	0.0	1	40	1.15	1.167	-1.21	0.225	5	1.00	1.000	0.00	1.000
L M. Popliteus	34	0.53	0.788			69	0.49	0.720			7	1.14	0.900		
R M. Popliteus	34	0.62	0.817	-0.4	0.655	67	0.55	0.724	-1.39	0.166	6	0.83	1.329	0.00	1.000
L Quadriceps (patella)	18	0.72	0.895			30	1.33	1.124			8	1.13	1.246		
R Quadriceps (patella)	17	0.65	0.786	-1.0	0.317	36	1.28	1.256	-2.27	0.023	6	0.83	1.329	0.00	1.000
L Achilles	23	0.96	0.976			24	1.79	1.103			3	1.00	1.000		
R Achilles	22	1.09	0.921	-1.0	0.317	34	1.65	0.950	-0.45	0.655	6	1.17	0.753	0.00	1.000

Table 2: Wilcoxon paired t-test for asymmetry per entheses in the three skeletal collections. Statistically significant asymmetry in bold, mean values and SD added for left and right sides.

	Louis D'Haeseleerstraat vs. Hopmarkt			*Louis D'Haeseleerstraat vs. Saint-Martin's church*			*Hopmarkt vs. Saint-Martin's church*		
	n	**χ(1)**	**p**	**n**	**χ(1)**	**p**	**n**	**χ(1)**	**p**
M. Subscapularis	107	8.877	0.262	51	2.792	0.834	80	2.107	0.954
M. Supra+Infraspinatus	89	6.663	0.465	48	5.393	0.249	65	4.175	0.759
Extensor	106	11.414	0.044	18	8.844	0.065	76	5.307	0.380
Flexor	93	3.888	0.274	39	1.82	0.177	62	2.364	0.500

M. Teres Minor	82	6.031	0.197	39	0.145	0.703	57	1.115	0.892
M. Brachialis	135	6.997	0.221	55	2.125	0.832	102	9.426	0.051
M. Triceps Brachii	116	3.018	0.697	48	5.089	0.278	80	3.811	0.577
M. Brachioradialis	87	3.755	0.440	36	0.303	0.860	67	0.490	0.974
M. Biceps Brachii	133	1.627	0.898	52	6.945	0.225	101	5.907	0.315
M. Iliopsoas	94	2.779	0.734	35	10.832	0.029	71	7.417	0.191
M. Gluteus Minimus	95	9.327	0.156	37	7.074	0.070	68	7.840	0.250
M. Gluteus Medius	75	2.488	0.478	28	2.900	0.405	53	4.148	0.246
Quadriceps (tibia)	87	6.094	0.297	41	0.221	0.895	64	1.394	0.925
M. Popliteus	114	1.023	0.796	45	3.893	0.273	85	4.310	0.230
Quadriceps (patella)	69	5.738	0.333	30	4.379	0.223	53	5.175	0.395
Achilles	67	10.067	0.073	32	0.732	0.866	45	3.415	0.636

Table 3: Pearson's Chi squares for relationship between site and EC scores. Statistically significant correlations in bold.

6.4.2 Sex

Most entheses analyzed in this study showed no correlation with sex (table 4). Correlation was evaluated for each site separately. At the Louis D'haeseleerstraat (lowest class), the M. triceps brachii showed higher EC scores in women (p=0.012, χ(1)=12.789, n=42), whereas the quadriceps entheses on the tibia showed higher EC scores in men (p=0.018, χ(1)=8.067, n=32). At the Hopmarkt, there were no statistically significant correlation between any of the entheses and sex. Finally, at the Saint Martin's church, the M. biceps brachii showed higher EC scores in men (p=0.019, χ(1)=10, n=10), although it must be noted that this is based on just 10 individuals (6 women and 4 men).

	Louis D'Haeseleerstraat			*Hopmarkt*			*Saint-Martin's church*		
	n	**χ(1)**	**p**	**n**	**χ(1)**	**p**	**n**	**χ(1)**	**p**
M. Subscapularis	39	4.487	0.611	68	7.735	0.357	12	5.200	0.267
M. Supra+Infraspinatus	36	1.522	0.677	53	8.745	0.271	12	6.333	0.176
Extensor	39	4.692	0.320	67	3.967	0.554	9	3.600	0.308
Flexor	35	-0.144	0.393	58	1.735	0.629	4	1.333	0.248
M. Teres Minor	32	1.205	0.272	50	2.060	0.725	7	1.120	0.290
M. Brachialis	44	5.201	0.392	91	0.986	0.805	11	3.942	0.414
M. Triceps Brachii	42	12.789	0.012	74	3.895	0.565	6	3.000	0.223
M. Brachioradialis	28	6.304	0.043	59	3.828	0.430	8	1.333	0.513
M. Biceps Brachii	42	7.772	0.169	91	4.041	0.543	10	10.000	0.019
M. Iliopsoas	29	3.028	0.387	65	9.553	0.089	2	6.000	0.112
M. Gluteus Minimus	32	2.083	0.353	63	7.836	0.250	5	2.222	0.329
M. Gluteus Medius	25	1.407	0.704	50	3.974	0.264	3		
Quadriceps (tibia)	32	8.067	0.018	55	7.043	0.217	9	3.263	0.196
M. Popliteus	37	0.866	0.834	77	2.844	0.416	8	3.333	0.343
Quadriceps (patella)	23	4.191	0.242	46	4.710	0.452	7	3.080	0.214
Achilles	27	2.914	0.405	40	16.455	0.019	13	2.270	0.518

Table 4: Pearson's Chi squares for relationship between sex and EC scores at the three sites. Statistically significant correlations in bold. The M. Gluteus medius correlation with sex could not be calculated at the Saint Martin's church as too few individuals were available for analysis.

6.4.3 Age

Entheses were tested for correlation with age per site. At the Louis D'haeseleerstraat, only the M. supra-and infraspinatus on the proximal humerus (p=0.020, χ(1)=19.746, n=36), M. gluteus medius attachment site on the proximal femur (p=0.001, χ(1)=28.897, n=25) and Achilles tendon entheses on the calcaneus had a statistically significant correlation with age(p=0.018, χ(1)=20.013, n=27) (table 4). At the Hopmarkt, the M. supra-and infraspinatus and Achilles entheses were also significantly correlated with age (respectively p=0.036, χ(1)=33.982, n=53, and p=0.004, χ(1)=33.582, n=40), as were the common extensor enthesis (p=0.008, χ(1)=31.167, n=67), the M. biceps brachii (p=0.027, χ(1)=27.272, n=91), M. iliopsoas (p=0.012, χ(1)=29.878, n=65) and M. gluteus minimus (p=0.024, χ(1)=31.754, n=63). No significant correlations between EC and age were found at the Saint Martin's church site.

	Louis D'Haeseleerstraat			*Hopmarkt*			*Saint-Martin's church*		
	n	**χ(1)**	**p**	**n**	**χ(1)**	**p**	**n**	**χ(1)**	**p**
M. Subscapularis	39	21.639	0.248	68	30.559	0.081	12	12.580	0.4
M. Supra+Infraspinatus	36	19.746	0.02	53	33.982	0.036	12	1.067	0.324
Extensor	39	15.18	0.232	67	31.167	0.008	9	10.125	0.34
Flexor	35	4.583	0.205	58	15.571	0.076	4		
M. Teres Minor	32	1.865	0.601	50	13.151	0.358	7	0.0467	0.792
M. Brachialis	44	23.046	0.083	91	4.590	0.868	11	11.825	0.46
M. Triceps Brachii	42	17.915	0.118	74	20.671	0.148	6	1.500	0.827
M. Brachioradialis	28	7.661	0.264	59	10.433	0.578	8	4.000	0.406
M. Biceps Brachii	42	9.134	0.870	91	27.272	0.027	10	5.333	0.804
M. Iliopsoas	29	9.425	0.399	65	29.878	0.012	6	8.250	0.220
M. Gluteus Minimus	32	7.902	0.245	63	31.754	0.024	5	5.556	0.235
M. Gluteus Medius	25	28.897	0.001	50	11.723	0.229	3		
Quadriceps (tibia)	32	6.044	0.418	55	19.659	0.185	9	5.925	0.432
M. Popliteus	37	13.409	0.145	77	13.334	0.148	8	7.467	0.280
Quadriceps (patella)	23	9.626	0.382	46	11.842	0.706	7	3.500	0.478
Achilles	27	20.013	0.018	40	33.582	0.004	13	7.728	0.562

Table 4: Table 3: Pearson's Chi squares for relationship between age and EC scores at the three sites. Statistically significant correlations in bold.

6.5 Discussion

The historical and dietary isotope data on these three skeletal collections, paired with their archaeological context, provide clear evidence of the social classes they represent. The EC data, however, do not reflect the different socio-economic groups. It must be noted that the high-class group had a very limited sample size (13 individuals), making any results when comparing this group to the other two groups inevitably less robust.

Only the common extensor was significantly correlated with status when comparing the low to the middle-class group, and the iliopsoas when comparing low to high class group. In both these entheses, the high-class group had higher levels of EC than the low-class group. If EC were a direct indicator of strenuous physical activity, this would mean the higher-class individuals were more physically active than the lower-class in activities using these two muscles. However, there are caveats for the positive correlation between EC and socio-economic status for both these entheses. The common extensor was one of the EC positively correlated with age in the middle-class group, but not in the lower-class group, which signifies that other etiological factors might have (co-)created this correlation. The other potential sign of difference in activity between the socio-economic groups, namely increased EC levels in higher-class M. iliopsoas, is also not a very reliable correlation, given that the higher-class iliopsoas sample consists of just six individuals. For all entheses except these two, there was no statistically significant correlation between EC and status. Thus, EC did not provide a useful proxy for social differentiation in this Flemish post-medieval urban context.

It is possible that the levels of physical activity in which the different socio-economic groups engaged were not different enough to show up in the skeletal record. Perhaps we over-simplify the lives of people in the past when we divide a society into socio-economic groups and postulate that this will determine their daily lives to such an extent that their bodies and skeletons will reflect social status. The broad spectrum of physical activities represented by the different crafts which dominated the Aalst economy could also potentially obscure any activity patterns resulting from social status. From an osteoarchaeological perspective, the specialized trades represent a wide spectrum of physical activities. Shopkeeping would not necessarily require intensive manual labor, but it could well require standing for prolonged periods of time. Dyeing cloth, on the other hand, was a tasking physical craft, while tailoring would require more fine motor skills but less extensive use of large muscle groups. Thus, individuals with similar socio-economic status could have engaged in very different physical activities in their professional lives. Finally, it is also possible that EC data recorded macroscopically on the human skeleton are not a sufficiently direct reflection of physical activity load for them to be used to assess activity patterns in this context.

Alongside this primary research question of correlation between socio-economic status and EC, correlations between EC and sex and age are also assessed for in the three skeletal collections. The correlations between sex and EC were not consistent between the three groups. The lower-class population represented by the Louis D'haeseleerstraat showed some significant differences between men and women. The M. triceps brachii, an important biomechanical element of the upper body, essential in the extension of the forearm (Landin *et al.*, 2018) displayed more EC in women than men in this lower-class cemetery. In a contemporary Dutch rural collection for which high levels of physical activity were present, the M. triceps brachii was also more pronounced in women than men (Palmer *et* *al.*, 2016). This could indicate that the lower-class women of Aalst performed strenuous manual labor, similar to the activity pattern of a more rural setting.

This sex difference in M. triceps brachii EC could also point to differing gendered divisions of labor within the different socio-economic groups. There is an anatomical difference in the elbow between men and women which could also form part of the reason for this higher level of EC in women. The angle of the elbow differs between the sexes, being angled slightly more away from the body in women (Paraskevas *et al.*, 2004, Yilmaz *et al.*, 2005). This greater angle changes the angle of pull of the attaching muscles slightly, which could potentially make the enthesis more susceptible to EC.

At the Louis D'haeseleerstraat, the males exhibited significantly higher EC scores than the women at the quadriceps attachment on the tibia, although the attachment of the quadriceps on the patella showed no significant correlation with sex. While it must be noted that the sample size for the tibia was higher than for the patella (n=32 and n=23 respectively), this highlights how different attachment sites, even of the same muscle, can give different results when analysed for EC. The fact that the lowest class population showed statistically significant correlations between sex and EC in both the upper and lower limb whereas the middle- and higher class populations showed none could point to a different division of labor between the classes. However, as only two of the sixteen entheses were significantly correlated with sex this hypothesis remains uncertain. The highest-class sample, as represented by the Saint-Martin's church individuals, like the middle class Hopmarkt sample, did not show any significant correlations between EC and sex, yet sample size limits possible interpretations (n=13).

In much the same fashion as the correlations between sex and EC, in the current study, only some entheses were correlated with age, and these were not consistent across the three skeletal populations. This is remarkable, as in most studies on muscle attachment site morphology, age is positively correlated with higher levels of EC (Meyer *et al.*, 2011), both when age is assessed osteologically (e.g., Weiss 2007, Molnar *et al.*, 2011, Michopoulou *et al.*, 2017, Palmer *et al.*, 2018) and when it is known archivally (e.g. Alves Cardoso and Henderson 2010, Milella *et al.*, 2012, Villotte *et al.*, 2010). At the Saint Martin's church sample, none of the entheses were significantly correlated with age, although this could be due to the limited sample size. At the Louis D'haeseleerstraat, three entheses were positively correlated for EC with age, the M. supra-and infraspinatus, the M. gluteus medius and the Achilles. EC at the Achilles and the M. supra-and infraspinatus were also positively correlated with age at the Hopmarkt, along with EC at the common extensor, M. iliopsoas, and M. gluteus minimus. This result, with correlations for some EC with age but not for others, and with only the Achilles and M. supra-and infraspinatus consistently correlated with age in the two largest populations, suggests that, at least in this population, other factors than age were influencing EC to a greater extent. This hypothesis is supported by a study on archivally identified laborers (i.e., a group with high physical activity levels), where age contributed a maximum of 44% to EC (Henderson *et al.*, 2017b). Furthermore, the effect of age has been shown to vary between entheses in other studies as well; Henderson and colleagues (2012) analyzed five entheses in a male sample and found that one trait of EC incorporated in the Coimbra method, namely bone formation, was correlated with age in the common extensor, M. subscapularis, left M. iliopsoas and left Achilles, but not with the M. biceps brachii, nor the right side of the two lower limb entheses. These results partially overlap with the Hopmarkt results, where the common extensor, M. iliopsoas and Achilles were correlated with age.

6.6 Conclusion

EC are not a reliable indicator of social status in the post-medieval town of Aalst based on the sixteen entheses used in this study. Socio-economic status of the three skeletal assemblages was known through archival data and dietary isotopes, but no consistent correlation between EC and status was found. Correlations between sex and EC differed between the three socio-economic groups, which could point to a potential difference in their division of labor. Age was not consistently correlated with EC at the three sites. Few entheses were positively correlated with age, and only two were correlated with age in the two largest skeletal collections: , namely the M. supra- and infraspinatus and the Achilles. This could indicate that some entheses, such as these two, are more susceptible to age-related changes than others. The inconsistency in correlations between EC, age, and sex could also indicate that other etiological factors are at play. Furthermore, it is also possible that our assumption that richer individuals performed less physical activity than poorer people in this sociohistorical context is an oversimplification of the lives these people led. The current research thus illustrates that EC cannot be used as a marker for socio-economic groups in this context, and that caution is necessary when trying to infer social differentiation through EC in skeletal populations.

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