Appendix III : Physical activity reconstruction

1 Bilateral Asymmetry

1.1 Methods

Next, %DA of measurements that showed significant right-left differences in the Wilcoxon signed ranks test, were recoded to calculate percentages of handedness among the whole population, but also between the sexes, layers, burial locations and age groups. In order to account for measuring error and fluctuating asymmetry, all %DAs smaller or higher than 0.5 were coded as 0, all positive values as 1 and all negative values as -1. A dominance in positive values would indicate a right-biased handedness, a negative one a left-biased handedness and 0 would suggest ambidexterity or that handedness was just not expressed enough in that measurement.

1. *Table 1 Codes for the chi-square tests and percentage calculations*

Code	Value
-1	Left-handed bias
0	No side bias
1	Right-handed bias

Chi-square tests of equivalency were used to determine whether the percentage of right or left-biased measurements deviated from a 50:50 distribution and Chi-square goodness of fit tests were used to determine whether the measurements deviated from an expected ratio of 1% ambidextrous people, 90% right-handed people and 10% left left-handed people.

Pearson's chi square tests were applied, to evaluate any differences between the sexes, age groups, layers and burial locations.

Crossed symmetry between the upper and lower limbs was determined after the method developed by Auerbach and Ruff (2006). Therefore, all the percentage asymmetries had to be recoded into dummy variables with -1 accounting for negative and 1 accounting for positive %DAs. Taking into account potential measurement error and fluctuating asymmetry, all %DA between <-0.5% and >0.5% were considered symmetrical and coded as 0. Next, the dummy variables of the upper limb measurements were summed with their lower limb counterparts. (ex. HuL with FeL) The values -2 and 2 represent left and right same side asymmetries respectively and 0 represents crossed symmetry. All values of -1 and 1 were not included in the test since they indicate that only the lower or upper limb presented an asymmetry. Taking absolute values of the added-up data, the frequencies of 2 and 0 were compared to an expected 50:50 frequency using a chi-square test of equivalences. A comparison with a 50:50 ratio assumes that, by comparing the number of individuals having crossed symmetry and those having one-sided asymmetry in the analysis sample to a hypothetical population with an equal representation of crossed symmetry and one-sided asymmetry, any significant differences between the two groups indicates that there is either a prevalence of crossed symmetry or one-sided asymmetry in the analysis sample. If the number of one-sided asymmetries is significantly higher than that of crossed symmetries, the assemblage displays an overall tendency towards one-sided asymmetry, if the number of crossed symmetries is significantly higher, the sample tends to show crossed symmetry.

For all tests, significances were taken at $p<0.05$. All statistical analyses were run in RStudio 2022.07.0, and some of the plots were made in Excel.

1.2 Distribution of all measurements

1.2.1 Distribution of all measurements by upper and lower limbs by sex

Figures 1-7 show the distributions of %DAs of all measurements. Every limb is represented in a separate graph. The distribution is given by boxplot diagrams. The bold line in the middle of the boxplot represents the median value, also called 50th percentile. The upper and lower lines closing off the box are the 75th and 25th percentile respectively. Percentiles indicate the degree of asymmetry as compared to the rest of the population. The whiskers reach from the minimum to the maximum values of each measurement, the pink dot indicates the mean and the dots above and below represent the outliers. These outliers could not be removed because there was no valid explanation for such high degrees of asymmetry. Outliers probably caused by measurement error or pathological lesions on the bone have already been removed.

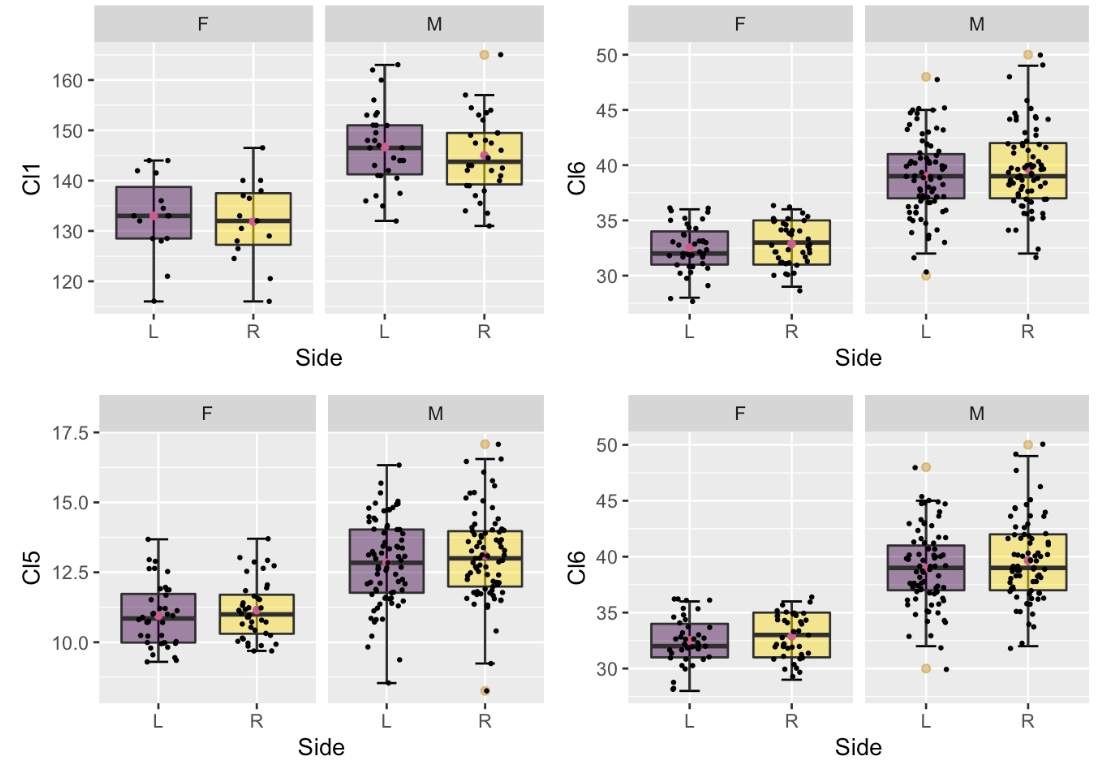


Figure 1 Boxplots showing the distribution of all direct measurements of the clavicle

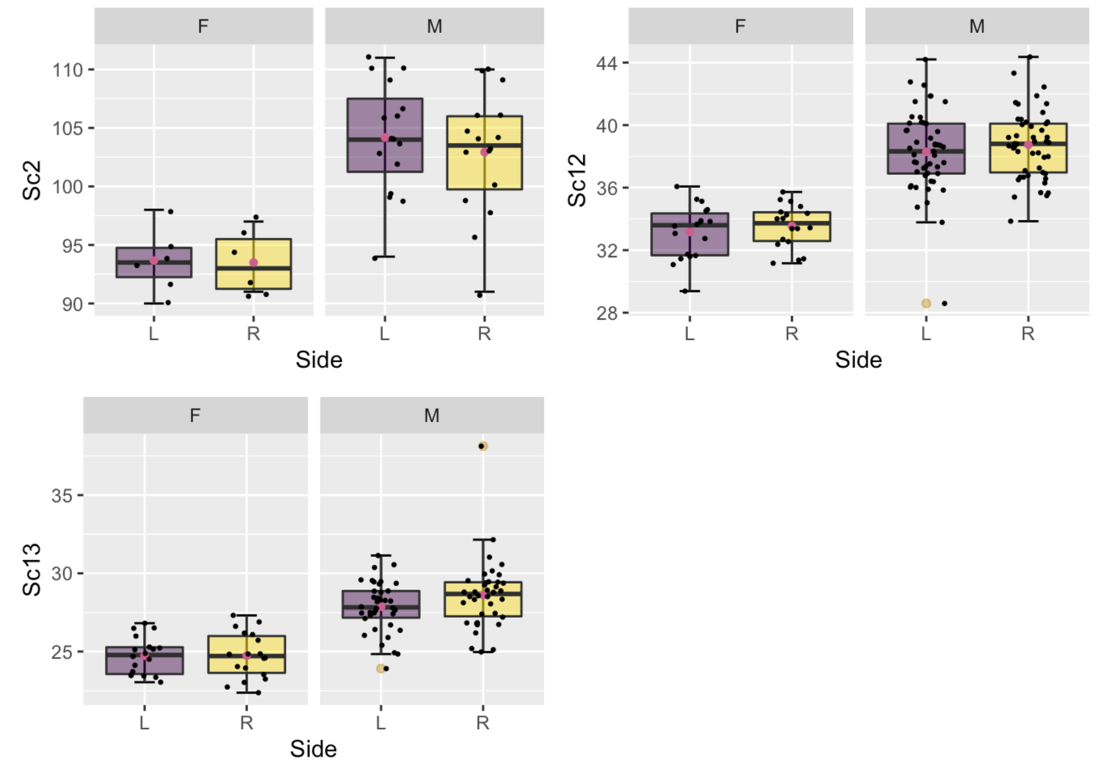


Figure 2 Boxplots showing the distribution of all direct measurements of the scapula

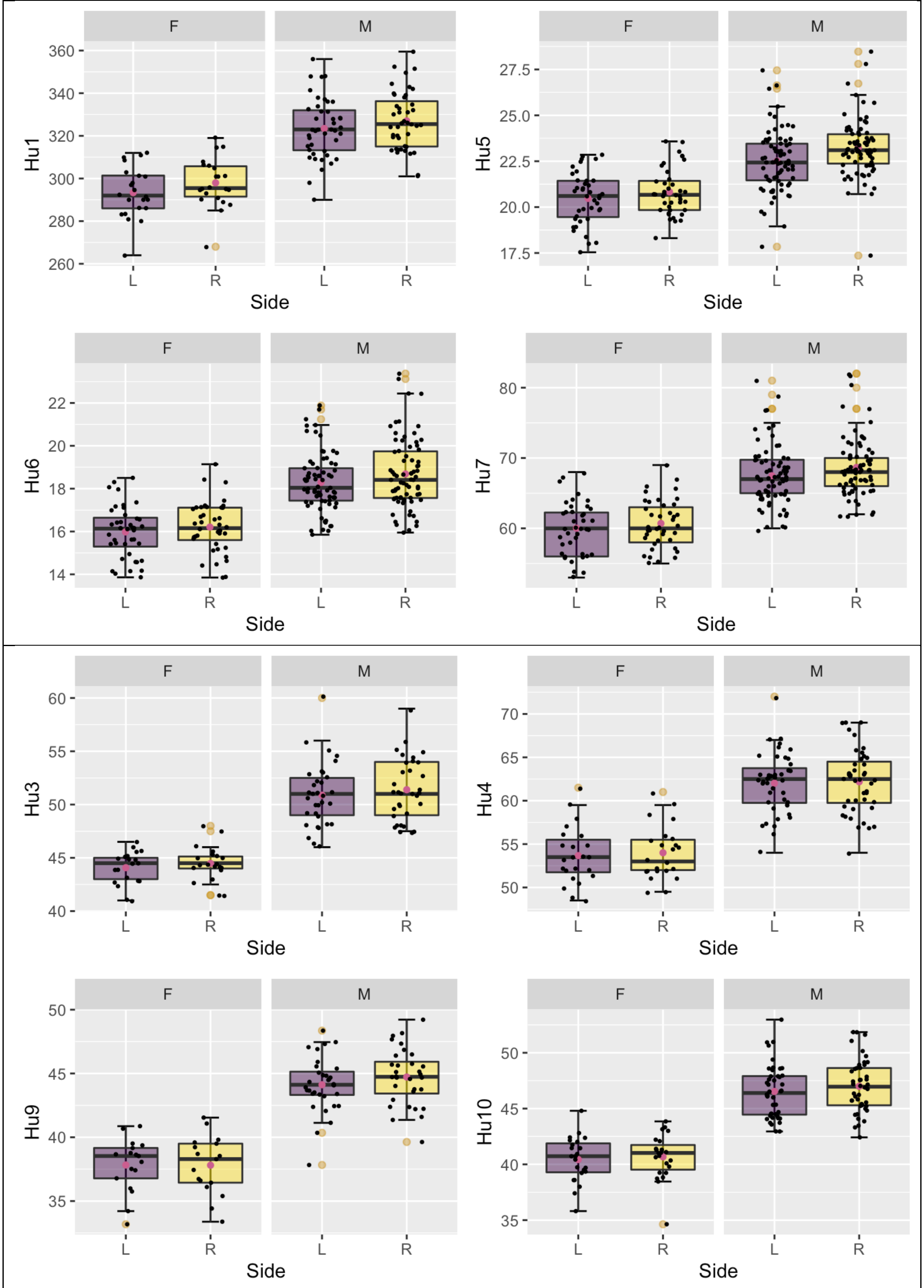


Figure 3 Boxplots showing the distribution of all direct measurements of the humerus

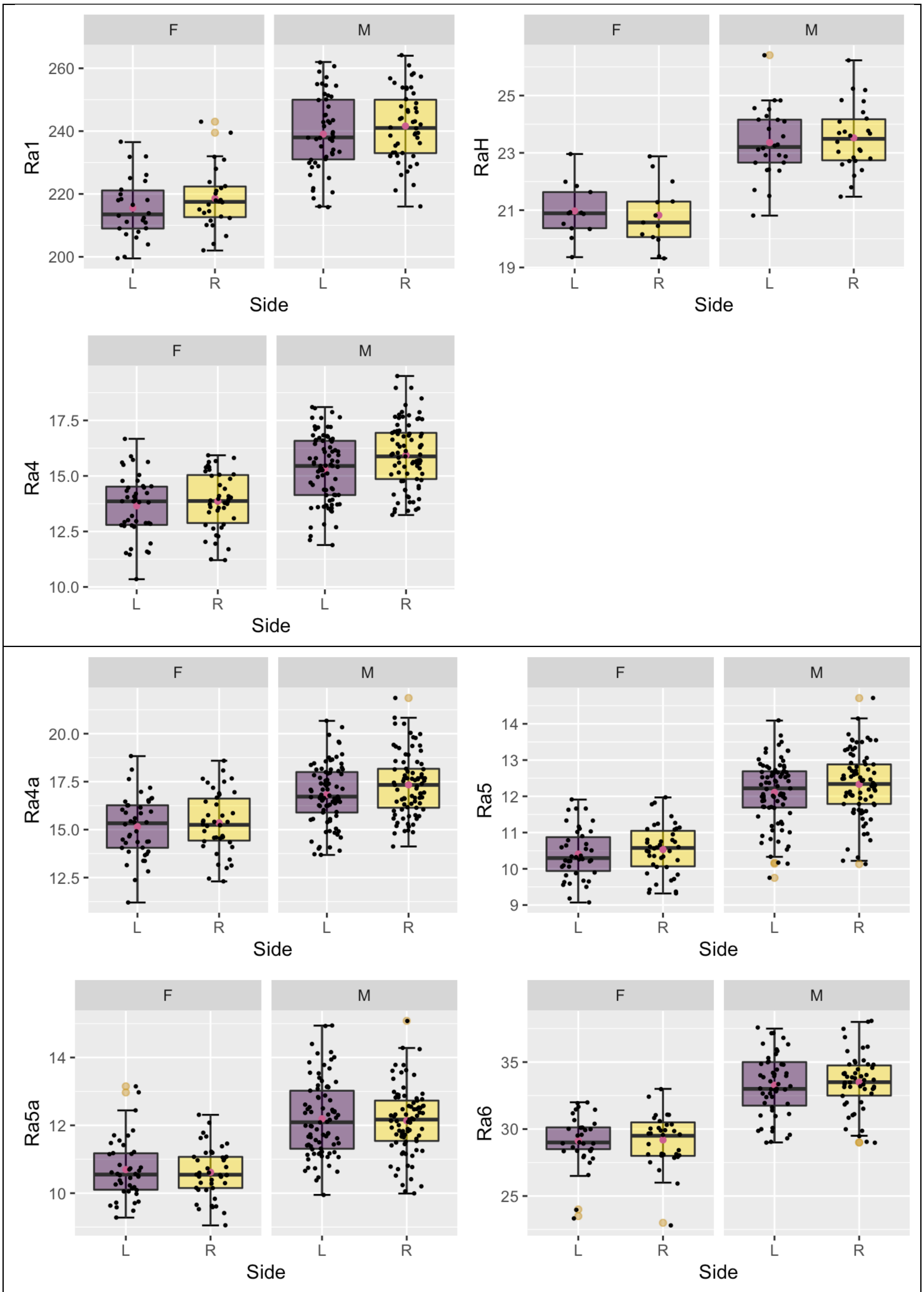


Figure 4 Boxplots showing the distribution of all direct measurements of the radius

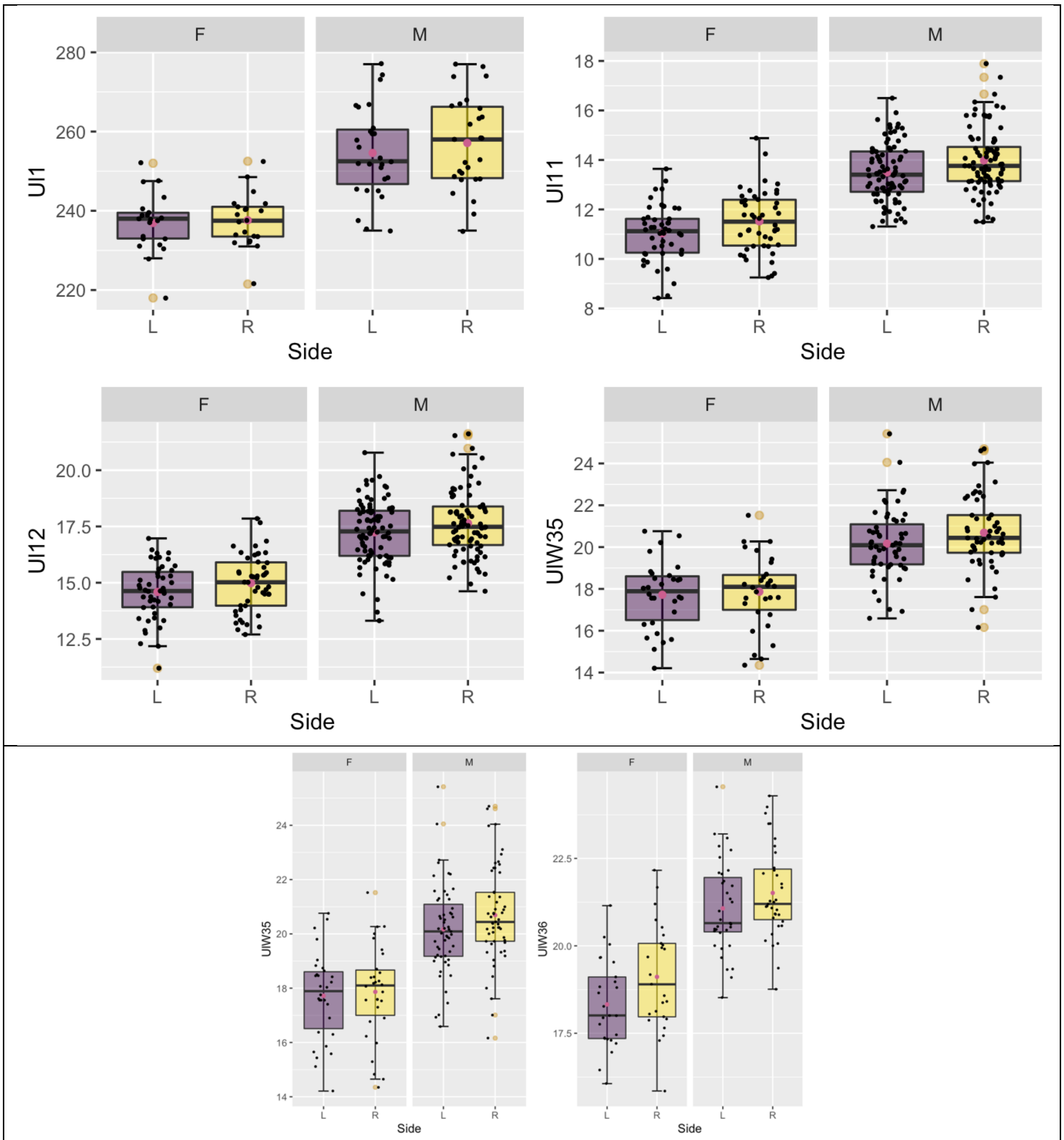
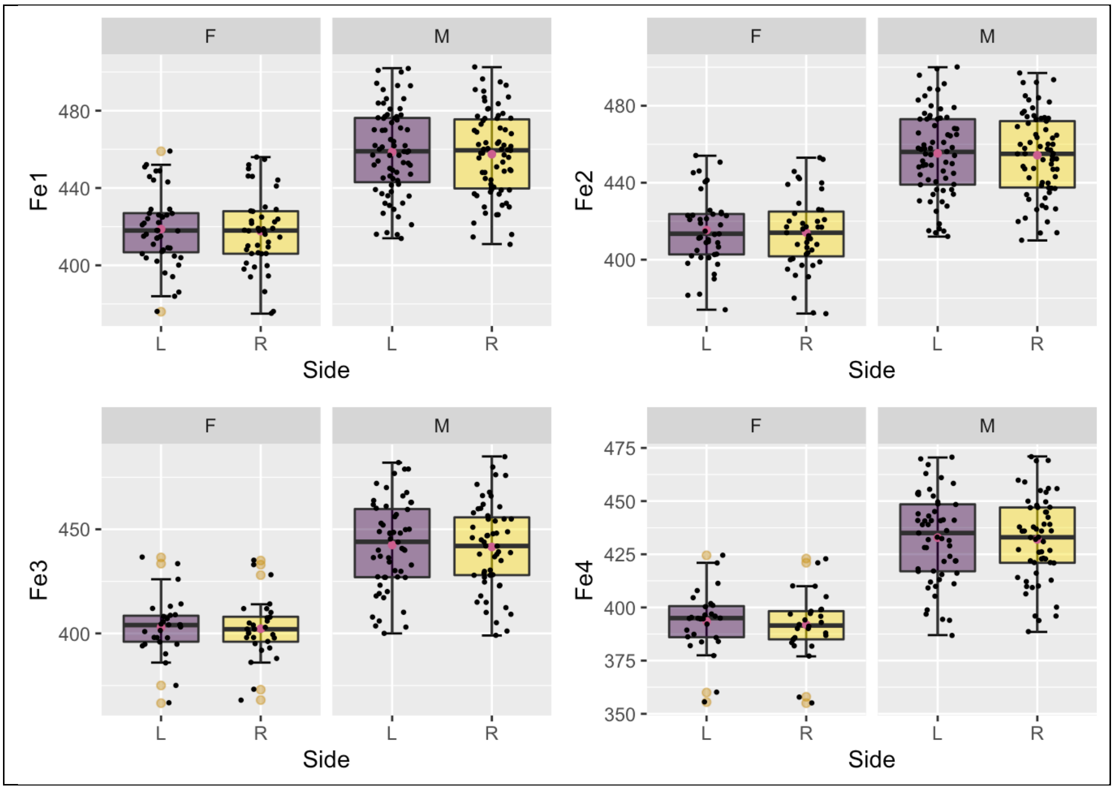
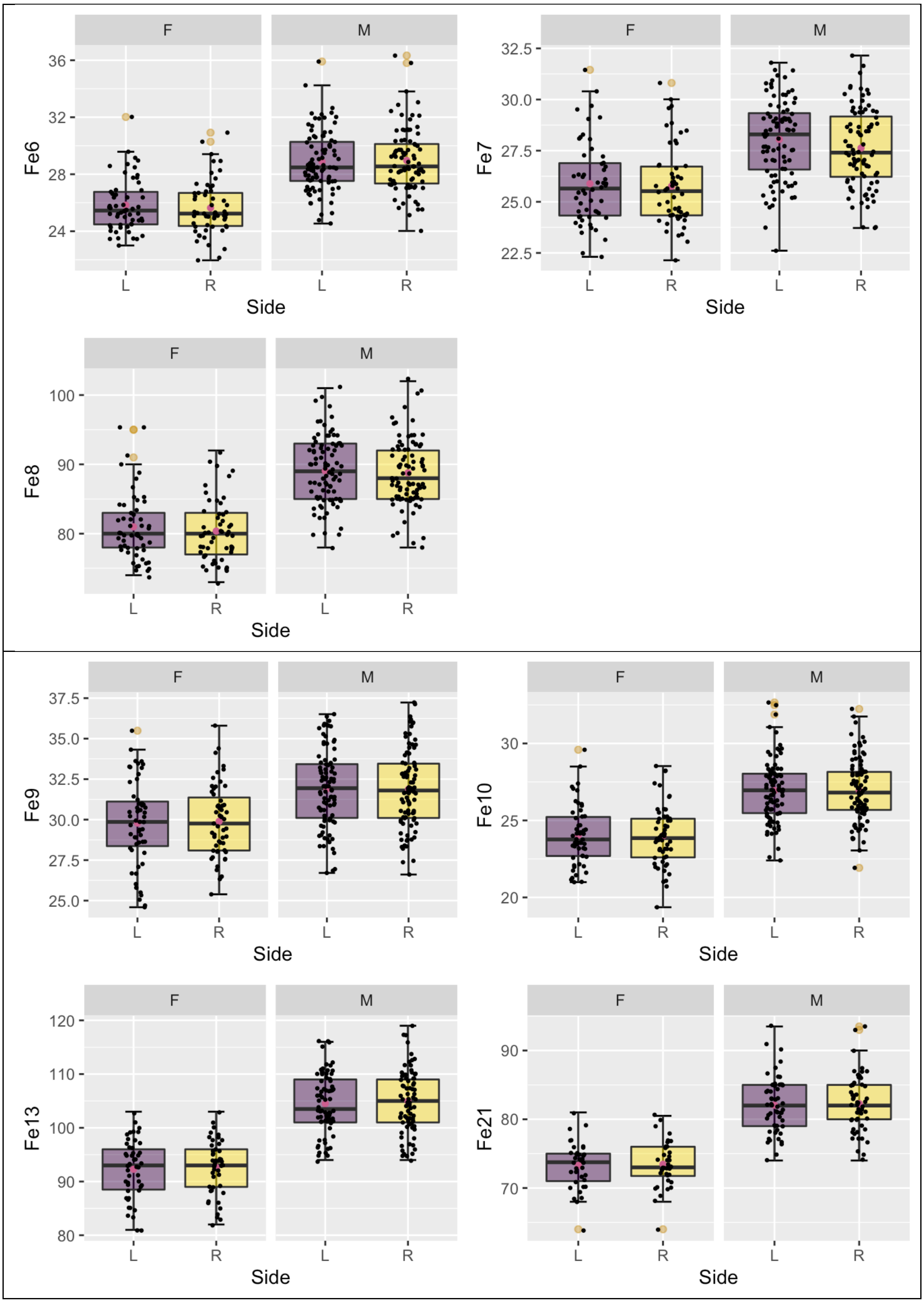


Figure 5 Boxplots showing the distribution of all direct measurements of the ulna



F
M
Fe1
480
440
400
L
R
Side
Fe2
Fe3
450
Fe4
475
425
375
350



Fe6
Fe7
Fe8
Fe9
Fe10
Fe13
Fe21
F
M
L
R
Side

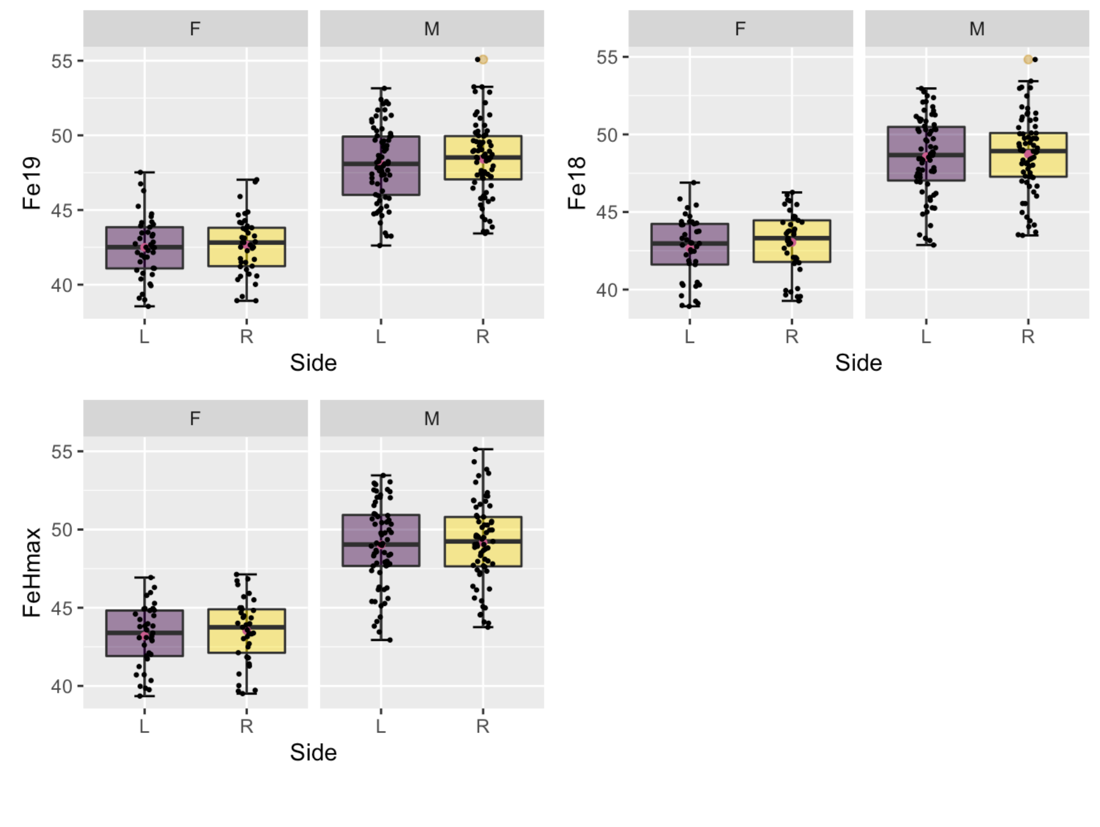
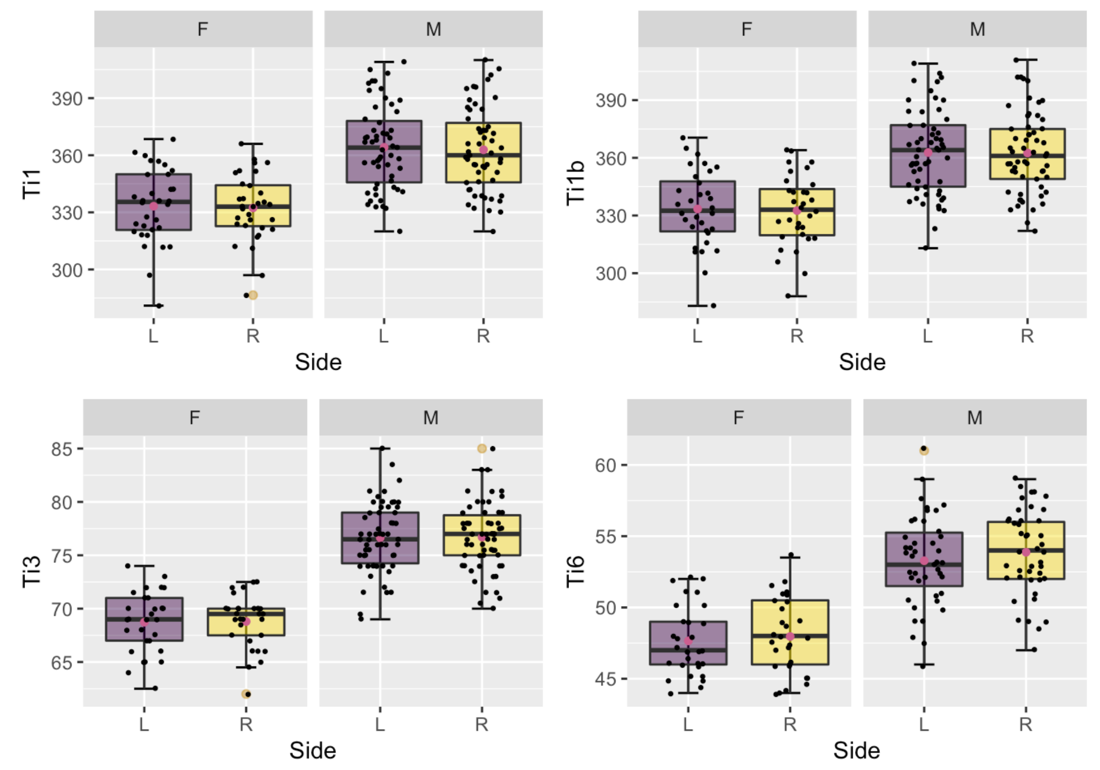


Figure 6 Boxplots showing the distribution of all direct measurements of the femur



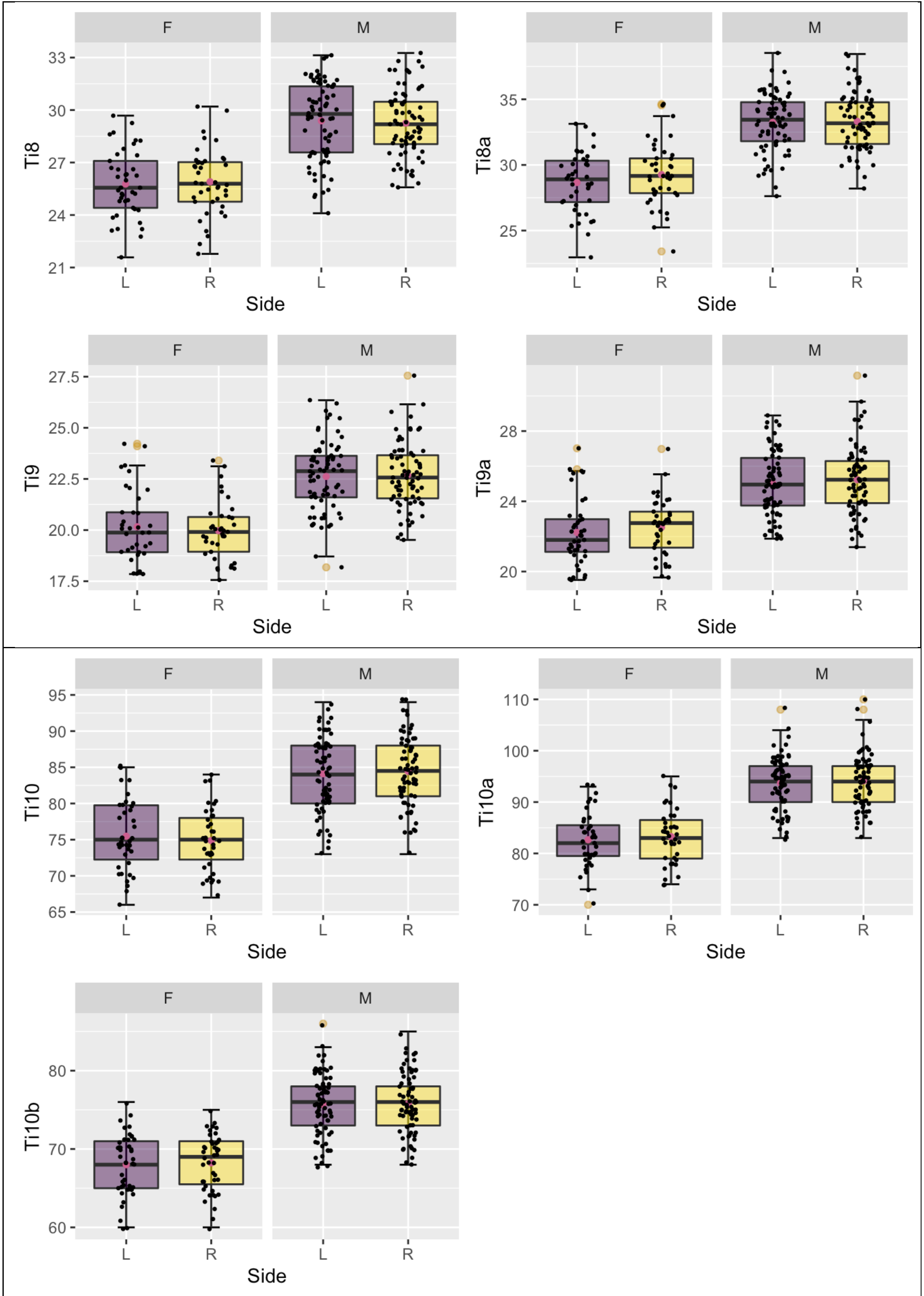


Figure 7 Boxplots showing the distribution of all direct measurements of the tibia

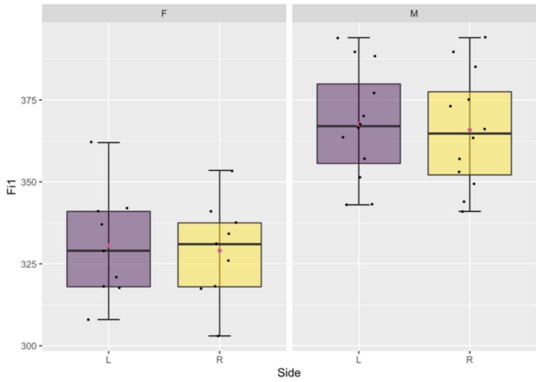


Figure 8 Boxplots showing the distribution of all direct measurements of the fibula

1.3 Directional Asymmetry

1.3.1 Differences in Directional asymmetry between women and men

The significant results of the Mann-Whitney U tests ($p<0.05$) for differences between males and females, the directional and absolute asymmetries, and the mean, median and standard deviation of the %DA for the pooled sample are shown in Table 2. Means and medians are calculated using N, the total number of individuals from the sample considered in the test for each measurement. Only statistically significant values represent directional asymmetry, and only significant measurements have been presented in Table 2.

After testing for differences in directional asymmetries between males and females, 5 measurements showed significantly higher degrees of asymmetry in men then in women, namely Sc13, Hu9, Ra4, Ra4a and Ti8a. Since 2 of those measurements involve joints, this might hint at a slightly differential physical load or movement patterns in females than in males. Due to these differences between males and females, all further comparisons were conducted for males and females separately.

Table 2 Significant %DA between males and females

Measurement	Sex	max	min	mean	median	sd	W	p-value	n
Sc13	F	4.25	-7.53	-0.04	-0.04	3.03	228	0.0458	18
	M	8.74	-5.67	1.83	1.85	3.60			38
Hu9	F	6.04	-7.27	-0.07	0.16	2.67	171	0.0338	17
	M	6.90	-3.90	1.36	1.05	2.24			32
Ra4	F	17.06	-13.20	1.59	0.88	6.54	1258	0.0183	42
	M	15.31	-16.82	4.04	4.43	5.27			81
Ra4a	F	14.88	-6.36	1.38	0.52	4.78	1367	0.0496	43
	M	13.86	-12.01	2.90	2.61	4.82			81
Ti8a	F	10.22	-14.88	1.87	2.92	5.14	2488	0.0122	48
	M	10.16	-7.23	0.44	0.23	3.68			82

1.3.2 c.4. Difference in asymmetry patterns between age groups

A Kruskal-Wallis test was used to determine whether there is any difference in the degree of asymmetry in males and females between the age groups. Differences between adults (20-39 years), mature (40-59 years) and senile individuals (60+ years) were calculated by Kruskal-Wallis tests and significant results were followed up with pairwise Wilcoxon post-hoc tests. In order to maximise sample size in each group, Young Adults and Adults as well as Mature I and II were grouped together for this analysis.

Regarding directional asymmetry (%DA) three measurements (Cl4, Fe4 and Ti9) show significant bilateral asymmetry differences in females and 3 (Sc12, Hu6, UlW35) show differences in males. Sc12, Cl4, UlW35, Fe4 and Ti9a showed a more right-biased degree of directional asymmetry in Adults than in Matures, and whilst in Sc12 and Cl4 the trend was the same between Matures and Seniles, in Ti9a, Fe4 and UlW35, Seniles had a slightly more right-biased asymmetry than Matures but not more than Adults. But posthoc tests did not reveal any significant differences anymore between the groups except between Adults and Matures of UlW35 ($p<0.03$) and Fe4 ($p<0.04$). The opposite pattern was observed for Hu6, where Matures showed the most right-biased pattern compared to Adults ($p<0.02$) and Seniles (Table 3).

Table 3 %DA between the three age groups in males and females

Measurement	Sex	Age	max	min	mean	median	sd	W	p-value	n
Sc12	F	Adult	10.24	-3.18	1.17	0.10	3.86	1.7170	0.4238	10
		Mature	3.66	-0.43	1.75	2.09	1.51			5
		Senile	1.67	-1.40	0.24	0.44	1.54			3
	M	Adult	5.20	-3.44	1.35	1.10	1.87	**7.5110**	**0.0223**	22
		Mature	7.45	-3.85	0.61	-0.02	2.58			21
		Senile	3.67	-7.01	-1.58	-1.82	3.46			6
Cl4	F	Adult	19.55	-10.94	3.99	4.81	7.20	**7.5369**	**0.0231**	20

Measurement	Sex	Age	max	min	mean	median	sd	W	p-value	n
		Mature	19.79	-2.91	1.11	-1.24	5.81			14
		Senile	6.09	-13.91	-3.48	-3.96	6.73			6
	M	Adult	12.32	-10.24	1.53	0.32	6.43	0.4144	0.8129	32
		Mature	15.61	-17.08	1.54	2.24	7.71			35
		Senile	18.13	-7.11	5.39	3.84	9.75			10
Hu6	F	Adult	8.79	-3.19	1.26	0.82	3.06	0.2979	0.8616	16
		Mature	6.91	-7.81	1.61	1.93	3.14			19
		Senile	4.67	-1.56	-1.29	1.23	3.75			5
	M	Adult	9.09	-4.89	0.61	1.26*	3.61	**7.9154**	**0.0191**	30
		Mature	11.02	-1.92	3.55	2.91*	3.60			31
		Senile	10.01	-4.11	1.80	2.02	3.74			14
UlW35	F	Adult	13.27	-7.93	2.20	1.79	5.26	2.2397	0.3263	16
		Mature	5.46	-10.56	-0.93	-1.78	4.62			13
		Senile	-0.46	-0.46	-0.46	-0.46	-			1
	M	Adult	8.95	-3.24	4.04	4.21*	3.42	**6.6662**	**0.0357**	24
		Mature	6.29	-8.62	1.13	1.42*	3.51			22
		Senile	12.26	-9.16	1.90	2.67	6.89			9
Fe4	F	Adult	2.12	-1.87	0.01	-0.20*	0.93	**6.7646**	**0.0340**	14
		Mature	0.13	-2.82	-1.05	-0.76*	0.94			9
		Senile	0.00	-1.00	-0.31	-0.14	0.40			5
	M	Adult	1.32	-1.89	-0.25	-0.32	0.91	0.4327	0.8055	23
		Mature	1.67	-3.08	-0.09	0.00	1.01			23
		Senile	1.21	-2.39	-0.23	-0.46	1.12			9
Ti9a	F	Adult	9.89	-6.81	2.65	3.34	4.28	**6.2277**	**0.0444**	17
		Mature	5.97	-15.13	-1.06	-0.45	5.50			16
		Senile	10.30	-0.69	3.73	2.48	3.97			8
	M	Adult	10.69	-15.94	0.01	0.63	5.55	1.7813	0.4104	32
		Mature	7.90	-6.61	0.88	1.15	4.05			26
		Senile	10.41	-4.39	2.20	2.41	4.15			16

bold*=significant bias*

1.3.3 Difference in asymmetry patterns between socio-economic groups

As mentioned already in the previous chapters, church and cemetery burials are thought to reflect different social classes. The cemetery burials are presumed to be belong to people of a lower social class than those buried inside the church and the monastery complex. Furthermore, even within the cemetery, it is often assumed that people buried farther away from the church were also of a lower social class than those who could afford to be buried closer to the church. In order to detect any differences between people from different social classes in Luxembourg City, burials were separated into 2 categories based on their position in relation to the church: those buried inside the church or the monastery complex and those buried on the cemetery. In a second step, for the statistically significant measurements, burials from within the church were compared to the burials from close to church as well as those from the middle and far back of the cemetery. Lastly, with the aim to detect any changes over time, all burials were compared across the different layers detectable in the site. In order to maximise sample size, they were only compared between the upper layer 1 and the grouped lower layers 2 and 3. Burials from Layer 1 represent the late postmedieval, and burials from Layer 2 and 3 represent the early postmedieval and late medieval periods. In order not to further reduce sample sizes in each group, no distinctions were made between males and females. For all analyses, only the statistically significant differences are displayed.

1.3.3.1 Difference between cemetery and church burials

The most notably significant difference between burial locations is observed in the degree of asymmetry of the leg bones, namely the measurements Fe1, Fe8, Fe9, Fe19, Ti3 and Ti10b. No significant difference was found in the arm or shoulder measurements. In females, Fe8 shows a higher median %DA in the cemetery than in the church and the opposite holds true for Fe9 and Ti3. In males, Fe1, Fe9, Fe19 and Ti10b show higher median %DA in the church (Table 4). Concerning %AA, in females, Ra5, Fe6, Fe8 and Fe9 show a significant difference in degree of asymmetry and in males Cl6 and Fe6. Cl6, Ra5, Fe6 in males and Fe9 display higher degrees of absolute asymmetry in the church sample and Fe6 in females as well as Fe8 display more asymmetry in the cemetery (Table 4).

Table 4 %DA between church and cemetery burials in males and females.

Measurement	Sex	Location	max	min	mean	median	sd	W	p-value	n
Fe1	F	Cemetery	1.66	1.66	1.66	1.66	1.66	245	0.3107	17
		Cloister	-3.47	-3.47	-3.47	-3.47	-3.47			6
	M	Cemetery	-0.29	-0.29	-0.29	-0.29	-0.29	**632.5**	**0.0417**	37
		Cloister	-0.13	-0.13	-0.13	-0.13	-0.13			8
Fe8	F	Cemetery	1.28	1.28	1.28	1.28	1.28	**167**	**0.0086**	20
		Cloister	0.11	0.11	0.11	0.11	0.11			6
	M	Cemetery	-2.08	-2.08	-2.08	-2.08	-2.08	861	0.4661	42
		Cloister	-0.67	-0.67	-0.67	-0.67	-0.67			11
Fe9	F	Cemetery	-0.42	-0.42	-0.42	-0.42	-0.42	**134**	**0.0045**	22
		Cloister	0.78	0.78	0.78	0.78	0.78			6
	M	Cemetery	3.39	3.39	3.39	3.39	3.39	**1,018**	**0.0440**	43
		Cloister	-1.68	-1.68	-1.68	-1.68	-1.68			11
Fe19	F	Cemetery	-0.10	-0.10	-0.10	-0.10	-0.10	125	0.6569	15
		Cloister	-0.11	-0.11	-0.11	-0.11	-0.11			4
	M	Cemetery	1.03	1.03	1.03	1.03	1.03	**220**	**0.0263**	39
		Cloister	0.32	0.32	0.32	0.32	0.32			5
Ti3	F	Cemetery	-1.30	-1.30	-1.30	-1.30	-1.30	**28**	**0.0366**	14
		Cloister	-0.57	-0.57	-0.57	-0.57	-0.57			2
	M	Cemetery	-0.85	-0.85	-0.85	-0.85	-0.85	334.5	0.7242	29
		Cloister	0.71	0.71	0.71	0.71	0.71			8
Ti10b	F	Cemetery	1.55	-5.41	0.11	1.55	-5.41	192	0.9485	17
		Cloister	3.28	0.00	0.94	3.28	0.00			5
	M	Cemetery	3.68	-2.63	-0.04	3.68	-2.63	**507**	**0.0446**	31
		Cloister	2.60	-1.29	0.44	2.60	-1.29			12

bold*=significant bias*

1.3.3.2 Difference between distance to church

In a next step, those values that displayed statistically significant differences in %DA were also examined by their distance to church. By comparing cloister burials, those close to, midway to and those far from the church, potential differences in directional asymmetry in relation to proximity to the church can be detected. Only Fe8 and Fe9 of women show any statistically relevant differences in relation to proximity to church. Female Fe8 displays higher left-biased degree of asymmetry in people buried far away from the church whereas those buried inside show on average no asymmetry. ($p<0.01$). Fe9 shows a significant difference between church burials and those buried midway to church ($p<0.005$) and between burials close to the church and those buried in the middle of the cemetery ($p<0.05$). In both cases, people buried inside and close to the church display a right-biased median %DA and those buried in the middle a left-biased. Overall, in Fe 8 and Fe9 there is a trend to left-biased %DA further away from the church, but in Fe9 of males, albeit non-significant, the trend is the opposite. (Table 5)

Table 5 %DA between burials from, close to, midway to and far from the church in males and females

Measurement	Sex	Location	max	min	mean	median	sd	W	p-value	n
Fe8	F	Cloister	1.31	-1.20	0.11	0.00*	0.88	**10.1816**	**0.0171**	14
		Close	1.12	-3.21	-0.65	0.00	1.28			11
		Mid	3.92	-4.88	-0.81	-1.16	2.23			24
		Far	0.00	-5.41	-1.87	-1.36*	1.66			9
	M	Cloister	3.28	-6.67	-0.69	0.00	2.42	1.3787	0.7105	22
		Close	3.31	-3.39	0.16	0.00	1.68			15
		Mid	3.68	-5.71	-0.32	0.00	1.85			38
		Far	2.38	-3.28	-0.36	0.00	1.68			18
Fe9	F	Cloister	11.43	-6.90	2.93	3.23*	4.94	**14.4802**	**0.0023**	12
		Close	9.62	-3.20	2.27	1.67&	3.93			11
		Mid	2.96	-9.50	-1.36	-1.60*&	2.66			27
		Far	3.32	-9.86	-0.64	0.13	3.81			9
	M	Cloister	4.03	-8.37	-1.68	-1.53	3.66	4.4206	0.2195	22
		Close	3.58	-5.05	-0.22	-1.04	2.90			15
		Mid	7.78	-8.85	0.48	0.79	4.18			39
		Far	6.69	-13.42	0.10	0.57	4.66			18

bold*=significant bias*

1.3.3.3 Difference between cemetery and church burials by Layer

In order to account for any influence of burial time on the comparisons between church and cemetery burials, individuals from Layer 1 were compared between the two burial locations separately of those from Layer 2. In median %DA values, only individuals from Layer 2 showed significant directional asymmetry differences between burial locations. Cl6, Hu4, Ra4, Fe1, Fe2 and Fe21 show more of a right bias in the Cloister than in the cemetery and the opposite pattern is found in the measurements UlW36 and Ti6. (Table 6)

Table 6 %DA between burials from the church and the cemetery in Layer 1 and 2

Measurement	Layer_dual	Location	max	min	mean	median	sd	W	p-value	N
Cl6	1	Cemetery	10.53	-7.23	1.04	0.00	3.25	270.5	0.6637	39
		Church	12.66	-7.59	1.06	2.30	5.00			15
	2	Cemetery	17.28	-5.71	1.39	0.00	4.27	**220.5**	**0.0259**	51
		Church	13.04	0.00	4.63	2.60	4.85			14
Hu4	1	Cemetery	3.92	-3.51	0.60	0.00	1.97	99.5	0.1711	21
		Church	2.87	-5.13	-0.85	-0.80	2.76			7
	2	Cemetery	5.31	-4.78	0.03	0.00	2.07	**60**	**0.0155**	29
		Church	5.97	-0.79	2.04	2.04	2.01			9
Ra4	1	Cemetery	17.06	-7.44	4.08	4.18	5.30	263	0.3725	39
		Church	10.95	-2.99	5.14	6.27	4.51			16
	2	Cemetery	11.98	-16.82	1.09	1.20	5.87	**300**	**0.0303**	51
		Church	16.83	-4.44	6.26	4.74	6.02			16
UlW36	1	Cemetery	11.96	-3.98	3.05	2.66	3.76	48	0.6244	16
		Church	5.26	0.30	3.28	3.99	1.92			7
	2	Cemetery	10.41	-2.94	3.80	3.47	3.67	**226**	**0.0048**	26
		Church	4.95	-2.31	0.48	0.00	1.99			11
Fe1	1	Cemetery	1.61	-2.73	-0.34	-0.24	0.92	265	0.7053	33
		Church	0.96	-1.69	-0.42	-0.47	0.76			15
	2	Cemetery	1.93	-4.17	-0.04	0.11	1.04	**568**	**0.0149**	57
		Church	2.30	-2.15	-0.63	-0.87	1.24			10
Fe2	1	Cemetery	1.61	-2.24	-0.42	-0.37	0.87	231	0.7219	33
		Church	2.32	-2.08	-0.23	-0.37	1.07			15
	2	Cemetery	3.39	-3.47	-0.08	-0.11	1.11	130	0.6406	55
		Church	2.08	-2.04	-0.46	-0.67	1.17			9
Fe21	1	Cemetery	2.33	-2.99	0.49	0.63	1.20	132	0.3031	30
		Church	5.26	-3.59	0.17	0.00	2.73			7
	2	Cemetery	3.97	-6.54	-0.03	0.00	1.72	**157**	**0.0177**	52
		Church	2.38	-1.34	0.88	1.18	1.23			8
Ti6	1	Cemetery	3.02	-2.25	0.42	0.00	1.73	88	0.6318	18
		Church	7.55	-4.44	0.82	0.00	3.40			11
	2	Cemetery	8.00	-5.03	1.53	1.96	2.73	**374**	**0.0053**	44
		Church	0.92	-5.61	-0.81	0.00	2.13			8

bold*=significant bias*

1.3.4 Difference in asymmetry patterns between the late medieval and postmedieval periods

Lastly, with the aim to detect any changes over time, all burials were compared across two different time periods. Burials from Layer 1 represent the late postmedieval and burials from Layer 2 represents the early postmedieval and late medieval periods.

1.3.4.1 Difference by Sex

Amongst the sexes, only two measurements show significant differences in median %DA between the two Layers. Females from Layer 1 display significantly higher median %DA than those from Layer 2 in Hu9 and Fe19. (Table 7)

Table 7 %DA between Layer 1 and 2 in males and females.

Measurement	Sex	Layer_dual	max	min	mean	median	sd	W	p-value	N
Hu9	F	1	6.04	-0.62	1.42	1.03	2.07	**62**	**0.0111**	8
		2	0.61	-7.27	-1.40	-0.74	2.51			9
	M	1	6.90	-3.90	1.51	1.17	2.60	148	0.4195	18
		2	4.65	-1.71	1.17	0.75	1.72			14
Fe19	F	1	2.75	-0.80	0.96	1.17	0.96	**289**	**0.0446**	15
		2	3.52	-4.69	0.04	0.27	1.70			28
	M	1	6.72	-3.00	1.05	0.89	1.87	828	0.1169	35
		2	3.03	-3.19	0.33	0.58	1.52			39

bold*=significant bias*

1.3.4.2 Difference by Location

Since %DA showed some significant differences between the layers and between burial location, it was decided to also check for any differences between the layers within each of the two burial locations, namely the church complex and the cemetery. Only measurements which showed statistically significant differences are reported in Table 8 for %DA. Three of the statistically significant differences in %DA were found among the church burials, namely Hu3 and Hu4 which showed a higher median %DA in Layer 2 than in Layer 1 and UlW36, which shows the opposite pattern. Among the cemetery burials, Hu10, Ra4, Ra5 and Fe19 all showed a higher median %DA in Layer 1 as opposed to Layer 2.

Table 8 %DA between Layer 1 and 2 in church and cemetery burials

Measurement	Location	Layer_dual	max	min	mean	median	sd	W	p-value	n
Hu3	Cemetery	1	4.26	-1.13	1.14	0.92	1.88	133.5	1.0000	14
		2	4.60	-4.08	0.84	1.09	2.13			19
	Church	1	1.98	-1.94	0.07	0.00	1.28	**20.5**	**0.0291**	9
		2	2.90	-2.25	1.38	1.98	1.43			11
Hu4	Cemetery	1	3.92	-3.51	0.60	0.00	1.97	370.5	0.1918	21
		2	5.31	-4.78	0.03	0.00	2.07			29
	Church	1	2.87	-5.13	-0.85	-0.80	2.76	**12.5**	**0.0500**	7
		2	5.97	-0.79	2.04	2.04	2.01			9
Hu9	Cemetery	1	6.90	-3.90	1.81	1.17	2.47	**207**	**0.0185**	20
		2	3.32	-2.92	0.18	0.35	1.65			14
	Church	1	2.12	-3.45	0.41	0.80	2.02	27	1.0000	6
		2	4.65	-7.27	0.15	0.56	3.35			9

Measurement	Location	Layer_dual	max	min	mean	median	sd	W	p-value	n
Ra4	Cemetery	1	17.06	-7.44	4.08	4.18	5.30	**1,262**	**0.0297**	39
		2	11.98	-16.82	1.09	1.20	5.87			51
	Church	1	10.95	-2.99	5.14	6.27	4.51	149	0.8782	16
		2	16.83	-4.44	5.33	4.53	6.28			18
Ra5	Cemetery	1	12.14	-7.35	2.57	2.68	4.37	**1,243.5**	**0.0430**	39
		2	11.75	-12.22	0.76	0.98	3.86			51
	Church	1	9.29	-8.40	2.03	2.52	5.05	153	0.7722	16
		2	8.57	-3.44	1.73	2.16	3.47			18
UlW36	Cemetery	1	11.96	-3.98	3.05	2.66	3.76	181	0.4968	16
		2	10.41	-2.94	3.80	3.47	3.67			26
	Church	1	5.26	0.30	3.28	3.99	1.92	**65**	**0.0154**	7
		2	4.95	-2.31	0.48	0.00	1.99			11
Fe19	Cemetery	1	3.57	-3.00	0.80	0.89	1.46	**1,421**	**0.0332**	39
		2	3.52	-4.69	0.09	0.27	1.63			58
	Church	1	6.72	-0.15	1.81	1.53	2.03	58	0.5516	11
		2	3.03	-0.80	0.95	0.71	1.13			9

bold*=significant bias*

1.4 Handedness

1.4.1 Results: Handedness in the whole population

In order to determine handedness in the sample, percentages of left and right-biased asymmetries were calculated based on directional asymmetry scores (%DA). Only measurements that showed strong degrees of asymmetry in the pairwise raw data comparison were selected for determination of handedness. Therefore, %DAs of those measurements were recoded into dummy variables. In order to account for possible measurement error and fluctuating asymmetry, all %DA values < or > 0.5% were recorded as 0. A chi-square test for goodness of fit was applied to determine whether side biases differed from the random distribution.

The random distribution values were based on the fact that 90% of people are right-handed and 10% left-handed with about 1% displaying ambidexterity (Hardyck & Petrinovich 1977; Annett 2001; Holder 2001; Papadatou-Pastou *et al.* 2008, 2020).

The analysis revealed that all measurements differed significantly from that pattern when all values </> 0.5 were counted as indeterminate. The test was then repeated by comparing only right and left biased measurements, and the same results were obtained.

Due to all measurements deviating from the assumed pattern of handedness, the chi-square test for equivalency was performed on all measurements, omitting the “indet” category in order to determine whether right and left biased values differed significantly from a 50:50 distribution.

Here as well, the majority of measurements differed significantly from a 50:50 distribution, the exceptions being Sc13, Ra4, Ra5, Fe1, Ti1 and Ti8a. This means that the majority of measurements displays a significant side bias. Overall, 16 measurements (76%) from the upper and 7 (54%) measurements from the lower limbs displayed a significant right-biased asymmetry, whereas only 2 (9.5%) from the upper and 3 (23%) from the lower limbs show a significant left bias.

The Pearson's chi square tests comparing handedness between the different groups reveals that right-handedness was predominant among all age groups, burial layers, burial locations, and the sexes. Fe1 and Fe19 show a significant difference between church and cemetery, with people buried in the cemetery displaying more right-biased values in Fe1 and more left-biased values in Fe19, than those buried in the church. However, when looking at distance to the church, only Hu5 and Hu9 display significant differences among the burial groups, however these differences are likely due to the very small sample sizes in several of the analysed groups. Among the two grouped layers and the three layers, only Ra5 shows a significant difference, with people from layer 2 showing a stronger right-bias than those from layer 1. Ti10a also displays a significant difference between the three layers, which is caused by the very small and unequal sample sizes within layer 3.

Regarding differences between age groups, only Cl1 and Ti9a indicate any differences, but this is due to the very small sample sizes in the indeterminate group. But for Ti9a, matures show more right-biased values whereas seniles show more left-biased values.

The sexes showed the most variability in left- or right-biased asymmetries, namely in Hu5, Ra4, UlW35, Fe7 and Ti10a. Only in Fe7 though, males display significantly more left-biased values and females slightly more right-biased values, in all other measurements, there is a same side dominance but to different degrees. (Table 9)

Table 9 Percentage of left- and right-bias for the whole population

Measurement	**indet**	**L-biased**	**R-biased**	**Total**	**Ch2 goodness of fit**		**Chi2 of equivalency**	
					X^2	**p-value**	**X^2**	**p-value**
Sc2	4 (18.18%)	15 (68.18%)	3 (13.64%)	22 (100.00%)	158.84	3.2238E-35		
Sc12	1 (1.49%)	24 (35.82%)	42 (62.69%)	67 (100.00%)	54.40	1.5353E-12	4.91	**0.0267**
Sc13		22 (39.29%)	34 (60.71%)	56 (100.00%)	53.37	2.7698E-13	2.57	0.1088
Cl1	2 (4.44%)	29 (64.44%)	14 (31.11%)	45 (100.00%)	165.48	1.1651E-36	5.23	**0.0222**

Measurement	indet	L-biased	R-biased	Total	Ch2 goodness of fit		Chi2 of equivalency	
					X^2	p-value	X^2	p-value
Cl6	48 (41.03%)	20 (17.09%)	49 (41.88%)	117 (100.00%)	1911.15	0.00000000	12.19	**0.0005**
Hu1	3 (4.62%)	5 (7.69%)	57 (87.69%)	270 (100.00%)	8.74	0.01262932	43.61	**0.0000**
Hu3	13 (24.53%)	10 (18.87%)	30 (56.60%)	53 (100.00%)	304.70	6.8352E-67	10.00	**0.0016**
Hu5		29 (25.22%)	86 (74.78%)	105 (100.00%)	29.59	5.3397E-08	28.25	**0.0000**
Hu6		33 (28.70%)	82 (71.30%)	115 (100.00%)	44.66	2.3418E-11	20.88	**0.0000**
Hu7	36 (31.58%)	12 (10.53%)	66 (57.89%)	114 (100.00%)	1078.83	5.428E-235	37.38	**0.0000**
Hu9		14 (28.57%)	35 (71.43%)	49 (100.00%)	18.78	1.4687E-05	9.00	**0.0027**
Hu10		24 (35.82%)	43 (64.18%)	67 (100.00%)	49.63	1.8532E-12	5.39	**0.0203**
Ra1	3 (4.00%)	11 (14.67%)	61 (81.33%)	75 (100.00%)	9.42	0.00902123	34.72	**0.0000**
Ra4		66 (53.66%)	57 (46.34%)	123 (100.00%)	260.50	1.3379E-58	0.66	0.4171
Ra4a		33 (26.83%)	90 (73.17%)	123 (100.00%)	38.71	4.9236E-10	26.41	**0.0000**
Ra5	31 (37.35%)	21 (25.30%)	31 (37.35%)	83 (100.00%)	1143.70	4.46E-249	1.92	0.1655
Ul1	4 (8.33%)	12 (25.00%)	32 (66.67%)	48 (100.00%)	40.75	1.4177E-09	9.09	**0.0026**
Ul11	1 (0.77%)	45 (34.62%)	84 (64.62%)	130 (100.00%)	95.38	1.9417E-21	11.79	**0.0006**
Ul12		44 (33.59%)	87 (66.41%)	131 (100.00%)	80.98	2.2747E-19	14.11	**0.0002**
UlW35		25 (29.41%)	60 (70.59%)	85 (100.00%)	35.59	2.4376E-09	14.41	**0.0001**
UlW36	1 (1.67%)	12 (20.00%)	47 (78.33%)	60 (100.00%)	8.07	0.01772317	20.76	**0.0000**
Fe1	7 (6.09%)	63 (54.78%)	45 (39.13%)	115 (100.00%)	310.58	3.6204E-68	3.00	0.0833
Fe4	5 (6.02%)	48 (57.83%)	30 (36.14%)	83 (100.00%)	251.44	2.5193E-55	4.15	**0.0415**
Fe7	1 (0.70%)	82 (57.75%)	59 (41.55%)	142 (100.00%)	384.54	3.153E-84	3.75	**0.0528**
Fe8	50 (34.97%)	57 (39.86%)	36 (25.17%)	143 (100.00%)	1854.54	0.00000000	4.74	**0.0294**
Fe13	50 (40.65%)	26 (21.14%)	47 (38.21%)	123 (100.00%)	1987.44	0.00000000	6.04	**0.0140**
Fe18		39 (35.14%)	72 (64.86%)	111 (100.00%)	77.92	1.0736E-18	9.81	**0.0017**
Fe19		37 (32.74%)	76 (67.26%)	113 (100.00%)	64.94	7.7021E-16	13.46	**0.0002**
FeHmax		35 (33.65%)	69 (66.35%)	104 (100.00%)	64.65	8.9282E-16	11.12	**0.0009**
Fe21	23 (25.27%)	25 (27.47%)	43 (47.25%)	91 (100.00%)	585.32	7.943E-128	4.76	**0.0290**
Ti1	8 (9.20%)	48 (55.17%)	31 (35.63%)	87 (100.00%)	277.67	5.0642E-61	3.66	0.0558

Measurement	indet	L-biased	R-biased	Total	Ch2 goodness of fit		Chi2 of equivalency	
					X^2	p-value	X^2	p-value
Ti8a	1 (0.87%)	47 (40.87%)	67 (58.26%)	115 (100.00%)	131.68	2.5463E-29	3.51	0.0610
Ti9a	1 (0.87%)	43 (37.39%)	71 (61.74%)	115 (100.00%)	104.09	2.4931E-23	6.88	**0.0087**
Ti10a	25 (22.32%)	33 (29.46%)	54 (48.21%)	112 (100.00%)	577.48	4.007E-126	5.07	**0.0244**

Indet= <0.5 and >-0.5
***bold**=significant bias*

1.4.2 Discussion: Handedness

Handedness probably first arose after the shift to bipedalism when the upper limbs were freed of their locomotor constraints (Auerbach & Ruff 2006).

The distribution of right or left handedness in modern populations has mainly been investigated through studies on hand preference in writing. For instance, a study on an intercontinental sample of 11000 individuals from 17 countries showed that most participants wrote with the right hand (89.6%), 9.5% wrote with left and only 0.9% reported no hand preference (Perelle & Ehrman 1994). Therefore it is not surprising, that the amount of right handed people varies globally between 74-96% (Perelle & Ehrman 1994; Faurie & Raymond 2004; Raymond & Pontier 2004; Uomini 2009; Blackburn 2011; Shaw 2011).

The same pattern holds true for the reconstructed handedness of the people buried in this cemetery. This study has shown that the upper limbs are most indicative when determining handedness, which is due to the fact that manual activities put more mechanical load on the dominant arm, whereas legs are not as much affected as their main use remains in locomotion (Čuk *et al.* 2001). Based on humeral length measurements, ~88% of individuals are right-handed and ~8% left-handed, and ~5% showed no side difference at all. These values lie well in the expected ranges of left-and and right handers, even though they do not reflect the ideal distribution of 90% right-handers, 10% left-handers and ~1% ambidextrous individuals. All humeral measurements show a right-bias, but humeral length shows the highest one. Handedness based on humeral length did not show any differences between the layers, burial locations, age groups or sexes, but a very few of the other measurements did. However, most of these differences can be attributed to the small sample sizes in one of the groups.

1.5 1.4. Cross symmetry

1.5.1 Results: Cross symmetry

Chi-square tests of equivalency were used to test for crossed symmetry between upper and lower limbs. Due to the small group sizes (<50 entries), Pearson's Chi-square tests with Monte Carlo simulation (based on 10000 replicates) were used on the same dataset to detect any differences in crossed symmetry patterns between the sexes, age groups, burial locations, and layers. Values beyond 0.5 and below -0.5 are considered to be symmetrical. 0 stands for a cross symmetry pattern and 2 for a one sided asymmetry, be it left or right-biased. Observed N represents the number of individuals per participating group. In the case of the Chi-square tests of equivalency, the expected N is the number of cases in each group of the hypothetical control population, set at a probability of 50% to 50% for the occurrence of crossed or one-sided asymmetry for each measurement combination. The Chi-square test is significant at $p<0.05$. A significant result means that the pattern with the higher observed N is significantly more prevalent than the other. **Error! Reference source not found.** depicts all the measurement combinations used in this study and significant results are put in bold. A crossed symmetry pattern is abbreviated as CS, same side asymmetry as SA and no pattern as NA. When both groups only diverged by one individual, this was also counted as showing no pattern, otherwise the pattern that was prevalent in most of the individuals was recorded, even when the difference between the groups was not statistically significant, in order to examine any possible tendencies in the sample.

1.5.1.1 Determining the presence of cross symmetry in the whole sample

Hu1 was checked for cross symmetry with Fe1, Hu10 was compared to Fe18, Hu9 to Fe19, Hu4 to Fe21, Hu5 to Fe6, Hu6 to Fe7, Hu7 to Fe8,and finally Ra1 and Ul1 were set against Ti1, Ra5 and Ra4, as well as Ul11 and Ul12 were set against Ti8 and Ti9 respectively. Furthermore, the corresponding measurements were also tested across the same limb. As such, all previously mentioned humeral measurements were set against all radial and ulnar measurements and all femoral measurements were compared to all tibial measurements. Only the humeral and femoral lengths exhibit a significant amount of cross symmetry (CS), whereas the humeral and radial lengths as well as the humeral and ulnar and humeral and radial medio-lateral and antero-posterior diameters display a significant amount of same side asymmetry. With a few exceptions, most comparisons of measurements across the upper and lower limbs display a tendency towards crossed symmetry and those within the upper or lower limbs a tendency towards same side asymmetry. Only the humeral and femoral transverse head diameter, the humeral and femoral distal epiphysis and the ulnar and tibial antero-posterior diameters show some degree of same side asymmetry (SA), and the femoral and tibial antero-posterior and medio-lateral diameters display some slight tendency toward crossed asymmetry. Finally, the humeral and femoral vertical head diameter, as well as the femoral and tibial lengths do not show any tendency to any of both patterns at all.

Table 10 Results of the Chi-square tests of equivalency for crossed symmetry

Measurements		Knuedler Total Sample		
	N	Chi^2	$p<0.05$	Pattern
Hu1+Fe1	**42**	**13.7**	**0.0002*** **	**CS**
Hu10+Fe18	30	1.2	0.2733	SA
Hu9+Fe19	21	0.0	0.8273	NA
Hu4+Fe21	22	0.2	0.6689	SA
Hu5+Fe6	69	1.2	0.2786	CS
Hu6+Fe7	67	0.1	0.7140	CS
Hu8+Fe9	45	2.7	0.1011	CS
Ra1+Ti1	21	1.2	0.2752	CS
Ra5+Ti8	62	1.6	0.2041	CS
Ra4+Ti9	53	0.5	0.4922	SA
Ul1+Ti1	15	0.6	0.4386	CS
Ul11+Ti8	66	0.1	0.8055	SA
Ul12+Ti9	64	0.2	0.6171	CS
Hu1+Ra1	**28**	**17.3**	**0.0000*** **	**SA**
Hu1+Ul1	21	5.4	0.5127	SA
Hu5+Ra5	**76**	**11.8**	**0.0006*** **	**SA**
Hu5+Ul11	**82**	**4.9**	**0.0272***	**SA**
Hu6+Ra4	**74**	**6.5**	**0.0105***	**SA**
Hu6+Ul12	**72**	**14.1**	**0.0002*** **	**SA**
FeL+TiL	33	0.0	0.8618	NA
Fe6+Ti8	77	2.9	0.0874	SA
Fe7+Ti9	72	0.2	0.6374	CS
Fe8+Ti10	53	0.5	0.4922	CS

N=number of individuals
p<0.05=Chi square test of equivalences is significant
CS=cross symmetry
SA=same side asymmetry

1.5.1.2 Determining the presence of cross symmetry between the sexes, age groups, layers and burial location

None of the measurements studied, displayed any significant difference in cross symmetry patterns between the sexes, age groups, burial layers and burial location. Therefore, the factors age, sex, layer and burial location did not seem to have an effect on cross symmetry patterns in this population.

1.5.2 Discussion: Crossed symmetry

As already indicated by the Wilcoxon tests, most of the upper-limb measurements are predominantly right-biased whereas most lower-limb measurements are left-biased or show no significant bias at all. The chi-square tests confirmed this tendency and established that there is a pattern of cross symmetry between humeral and femoral lengths, a pattern also noted by Auerbach and Ruff (2006) and Gloux (2007). Furthermore, the majority of the comparisons shows a tendency for crossed symmetry between the upper and lower limbs. This left bias in the femur and to a lesser extent the tibia, seems to contradict behavioural studies that indicate general preferences for the use of the right foot in right-handers (Gentry & Gabbard 1995; Bell & Gabbard 2000). However, the foot which carries out the activity is not necessarily the foot exposed to the most mechanical loading. In fact, the non-preferred foot, acting as stabiliser is most often exposed to the majority of the mechanical stress through postural support (Auerbach & Ruff 2006). As expected, comparisons of measurements within the upper limbs predominantly showed a significant pattern, or at least a tendency towards one-sided, and in this case right-sided asymmetry, however, comparisons within the lower limbs did not show any clear pattern. Furthermore, these patterns stayed the same among the sexes, all age groups, layers and burial locations, suggesting that the pattern of mechanical loading that causes cross-symmetry was similar across all groups.

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