Analysis of the use of human remains as teaching materials in higher education: examining differing opinions between population subgroups

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SUMMARY

Human components have been used as teaching resources for centuries. This study aimed to investigate the ethics and practicality surrounding this resource by analysing the opinions of students and professionals with exposure to human remains. Three questions were posed relating to the use of synthetic cadavers, the use of replicated bones, and the overall opinion regarding the ethics of using human material in teaching. These questions were disseminated through a survey aimed at students and professionals working with/studying using human remains in the UK, with 477 respondents. Kruskal-Wallis, Jonckheere Terpstra and Mann-Whitney U tests were used to identify any differences within the participants according to age and gender. Overall, all groups lent towards supporting the use of human remains in teaching. However, significant differences were noted between gender groupings and age categories, in particular between the 21-40 and 61+ age categories regarding the use of cadavers in teaching, and between male and female groups regarding the use of synthetic cadavers and replica bone. Even though multiple differences were noted, there was a consensus that use of human remains in teaching is ethical. The differences related to the degree to which materials should be used across different fields, with medical students and professionals believing that they should have sole access to real materials, whilst both archaeology and heritage professionals and non-professionals believed that all subjects should have access if it will help with students' education.

Key words: Anatomy – Bone – Body Donors – Ethics – Human Remains – Pedagogy

INTRODUCTION

The use of human remains used as a pedagogical aid is not a recent concept, with the earliest documentation dating to 5,000 years ago (Loukas et al., 2011). With human remains once belonging to the living, they hold a clear "significance within all human societies" (Mays, 2010). It has been fur-

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ther stated that "British attitudes to dead bodies are ambivalent, contradictory and volatile" (Parker Pearson, 2003), whereas people are more able to detach themselves from the sight of skeletons, perhaps forgetting they were living people (Swain, 2002; Parker Pearson, 2003). This could lead to skeletal remains being viewed as components rather than an individual's remains, whilst fleshed bodies are easier to regard as human and are less likely to be seen as a series of components, and so, pedagogical aids. This potentially creates a divide in opinion on the use of human remains as learning resources between the public and those who interact with the dead on a daily basis. Even though attitudes vary towards different forms of human remains, their utility in teaching is clear.

While a pedagogical analysis has clear value, ethics must also be considered. In the present day, many countries have legislation for the care and treatment of human remains, including the United States, New Zealand, Australia and the United Kingdom (Gazi, 2014). It is worth noting that, although the United Kingdom still has a large Christian population, it is now a multi-faith environment, and unlike other countries, it is no longer deemed to have a "native" population (Coates, 2021). Whilst other countries have specific laws relating to the handling and display of the remains of native peoples – such as the Native American Graves Protection and Repatriation Act in the United States (White and Folkens, 2005; NAGPRA, 2021) – no such laws exist in the United Kingdom. However, the Honouring the Ancient Dead organisation introduced an initiative to protect remains determined to be from ancient British and non-Christian cultures (HAD, 2021). It also seeks to promote ethical and respectful interaction with human remains of any age. This national, as well as global, move towards more legislative support of ethical practice when handling human remains highlights the need for a review of where ethical opinion lies within the British community of those working with such remains.

The history of human remains as teaching materials

The study of human anatomy was first undertaken in the 3rd century BC in Alexandria, but was only permitted briefly under the Ptolemaic pharaohs (Standring, 2016). It was later, in Renaissance Italy, that the study of human anatomy, and thus dissection, became more widely acceptable (Papa and Vaccarezza, 2013). Legalised in the United Kingdom in the 16th century to continue on the same footing as European counterparts, the Barber-Surgeon Act of 1540 allowed for the bodies of four criminals to be given to medical schools for dissection each year (Thomas, 2006). However, with the introduction of more institutions, there was a greater demand for cadavers; thus, in 1752 the Murder Act was passed, stating that executed murderers could be used for public dissection (Cain, 2017; Tarlow and Battell Lowman, 2018). Again, there was an increased requirement for bodies leading to body-snatchers, or Resurrectionists, removing freshly interred corpses and selling them to anatomy schools (Cain, 2017). One famous case is that of Burke and Hare in Edinburgh, who murdered 16 people in order to profit from the sale of their bodies (Mitchell et al., 2011; Tarlow and Battell Lowman, 2018). This led to the introduction of the Anatomy Act in 1832, which allowed the bodies of unclaimed individuals to be anatomised, thus increasing the number of cadavers received legally by anatomy theatres. Moving into the late 20th century, this practice – although not abolished – was superseded by donation programmes, where individuals can choose to donate their bodies for teaching after death.

During the late 1990s, it was revealed that several hospitals in the United Kingdom had removed and retained tissue without consent (HTA 2021). Known as the Alder Hey Affair (Bauchner and Vinci, 2001), this instance led to the introduction of the Human Tissue Act in 2004, which oversees the regulation and storage of human tissues of individuals who have died within the last century (HTA, 2020), and the subsequent introduction of the Human Tissue Authority in 2005, which regulates the guidelines for the removal, storage and use of human tissue (HTA, 2021). The last public dissection in the United Kingdom succumbed to much scrutiny because of this. In 2002, Dr Gunther von Hagens, the creator of the Body Worlds exhibition, which uses plastinated human remains (von Hagens, 2014; Jones, 2016),

sold tickets for a public dissection undertaken in an abandoned building in London (MacDonald, 2005; Cain, 2017). This dissection, which was also televised, proved extremely controversial as, like his later exhibition, it appeared to be more of a performance piece than an educational event (MacDonald, 2005). This brings to the fore the ethics of both using and storing human remains. The clear progression of both public and professional opinion of the use of human remains in university teaching, and wider educational engagement, highlights the need for a direct analysis of where the opinion of related practitioners lies in regard to teaching with different forms of human remains.

Ethics Policies

Following on from the Human Tissue Act, the Department for Culture, Media and Sport published a generalised set of guidelines for human remains in museum collections within England, Wales, and Northern Ireland (DCMS, 2004) and provided detailed information concerning storage and display. Information is also provided on acquisition, conservation and deaccession should it be necessary (Jenkins, 2008). Within this document, the DCMS also encouraged institutions to think about and compile their own guidelines pertaining to the storage and display of human remains (DCMS, 2004; LaPorte, 2014). This has been undertaken by numerous institutions (i.e. Lohman and Goodnow, 2006; Wellcome Collection, 2018; British Museum, 2021). Even though the DCMS guidelines touch on the "use, access and education" purposes of human remains, the section is rather short, and mainly relates to the prospect of visitors handling remains whilst in a museum (DCMS, 2004). However, teaching institutions – universities and medical schools – tend to have their own ethics policies. In any instance where students have access to human remains, they must first become acquainted with the ethics policies of the institution that they belong to. This highlights the potential need for a more universal stance on ethics and, as a result, ethical policies – this itself requiring research into what is considered ethical by those currently learning from and/or working with human remains.

Dissection

Until recently, dissection was the primary method for studying human anatomy, with the addition of textbooks and photographs (Trelease, 2016). Only in the last thirty years have advances in technology and variations in teaching allowed for a different approach to studying anatomy. Multiple surveys have considered the use of dissection in teaching. Many of these studies broach the subject of whether cadavers, henceforth referred to as donor bodies, are necessary within teaching programmes when there are alternatives available, such as body painting, 3D printing (McMenamin et al., 2018), medical imaging and three-dimensional simulation (Trelease, 2016). In one study, as documented by Papa and Vaccarezza (2013), first- and second-year London medical students were asked whether they believed practical dissection classes aided in their knowledge and understanding of anatomy. Seventy-five percent of the 174 students surveyed stated that dissection was the "single most useful method of learning anatomy". Another study, undertaken over a twelve-month period at the University of Sheffield, interviewed thirteen students as part of a qualitative review, two of which were postgraduates from the Department of Archaeology (Burr et al., 2019). The overall conclusion was that the students gained a "unique and valuable learning experience", which enhanced their understanding of anatomy (Burr et al., 2019).

Although most studies relate to the use of donor bodies purely as teaching materials for medical and biomedical subjects, the consensus is that dissection is the best way for learning human anatomy, but that it should be also accompanied by other methods, including 3D models, software, and atlases (Davis et al., 2013). Students themselves have noted a better anatomical understanding through hands-on learning (Papa and Vaccarezza, 2013); in which case, as long as students are able to have an interactive experience, it could be possible to substitute a real human body for a replica composed of synthetic materials. However, it should be noted that these studies have been universally from within medical or biomedical schools, with a lack of analyses regarding wider fields that commonly teach using human

remains, including bioarchaeology and forensic anthropology.

Human Bones

Unlike complete human bodies, human skeletal remains are widely used outside of medical and biomedical subjects (i.e. archaeology and anthropology), and act as a useful reference for teaching (Hillier and Bell, 2007). Remains held on display and in storage have come up against scrutiny within recent years, due to the Human Tissue Act and the related changes in public opinion. Even though museums have on occasion surveyed the public, since the guidelines from the DCMS were published in 2005 there have been a greater number of surveys focused on human remains. A survey undertaken at the Museum of London in 2007 determined that 53% of respondents expected to see remains on display, and that, in total, 92% of respondents approved of human remains being displayed within collections (Roberts, 2009). Another survey, conducted at the Manchester Museum in 2008, showed that 91% of the 375 respondents were in favour of the display of human remains (Sayer, 2010). Further to this, a study undertaken by the English Heritage in 2009 determined that 87% of respondents felt that the display of human remains helped them to "understand how people have lived in the past" (English Heritage, 2009). These results suggest that the majority of museum goers are happy to view humans remains and for them to be held within collections.

It has been suggested that, instead of displaying human remains, alternative methods could be employed, such as using photographs or replica bones (Levitt, 2016). However, these surveys and alternative ideas relate to storage and display within museum collections (i.e., Bonney, Bekvalac & Phillips 2020; MDU, 2021), not to the use of human bones as a hands-on teaching material. Unlike engagement studies undertaken on dissection as mentioned above, there is less published material for skeletal engagement. In both cases, it is important that opinions be sought not solely from the students or professionals involved in the handling of material, but also by the general public in order to gain a larger picture of what is and is not considered ethical. Also worthy of note is the use of archaeological remains in teaching collections. With a donor system now in place, it could be possible for certain teaching units to replace archaeological skeletal material with donor skeletal material, for which consent has been given. However, this relies on other factors such as whether universities have medical teaching units to gain access to donor bones, and the licensing to hold them.

Aims of this Study

These studies mentioned previously have clear utility for helping develop anatomical education, but suffer from relatively small sample sizes. A larger study, and one which also considers the opinions of graduates now working in the field, alongside those of the public, would further this work. The research presented here thus aims to determine whether there are any differences in opinion regarding the type of remains used for teaching according to the type of remains and conditions of education. Moreover, in review we aim to place in a pedagogical analysis at the forefront of any analyses so that the conclusion may eventually advise on the development of teaching with, and thereby the handling of, human remains within a higher education setting.

MATERIALS AND METHODS

Survey Compilation and Distribution

For this study, a series of questions regarding the use of human remains as teaching materials was compiled into a survey, which was subsequently granted ethical approval by the University of Sheffield ethics board. The survey questions began with individual specific categories, including age, gender, and profession. These questions were necessary to set the demographic parameters of the respondents and had predetermined answer categories: for example, age was set within 20-year stages; <20, 21-40, 41-60 and 61+ to support subsequent statistical analyses. For this study, the responses to four specific questions, one yes/no question, and three graded questions, were analysed.

The first of these questions was a split-second decision about whether the use of human re-

mains as teaching materials is ethical, answered as yes or no. The graded questions were graded on a five-point Likert scale answering system: 1 – least strongly, 2 – less strongly, 3 – neither agree nor disagree, 4 – strongly, 5 – most strongly. The first graded question was whether it is acceptable for a range of subjects to use dissection as a resource, or if it should only be used by medical and biomedical students. This range of subjects, henceforth referred to as relevant subjects, comprises any discipline which may provide additional teaching regarding human anatomy, for example archaeology and forensics. The second question asked if synthetic bodies, such as those made from plastics and animal components, should be used for all non-medical and biomedical subjects. The third graded question asked whether replicated bones should be used for teaching instead of real human bones. The full list of survey questions can be found in the supplementary material.

The completed questions were uploaded and formatted within Google Forms, chosen because of its security and encryption software, in order to comply with GDPR requirements and ethical standards. The survey was then distributed through various professional platforms, including social media, relevant organisational email listings, and similarly relevant online forums. Distribution was also encouraged by professionals on said platforms to disseminate further, for example by the British Association for Biological Anthropology and Osteological Anthropology, the Sheffield Medical Teaching Unit and the British Archaeological Jobs Resource. Archaeological forums and university emailing lists allowed for a professional and student base, whilst social media was also used to target a non-professional audience. The survey was initially distributed in May 2020 with no official deadline set. Most responses came within the first two weeks, but the link was left live until early July of the same year, when data processing began. A comments section was added to the survey following requests from a number of correspondents on one social media group, which allowed additional participants to provide reasoning(s) as to why they had given some of their answers.

Statistical Analysis

Kruskal-Wallis (with pairwise comparisons) and Jonckheere-Terpstra tests were run to test differences between age groups and trends across ages respectively. Mann-Whitney U tests were conducted to test for differences between male and female groups. Non-parametric tests were selected due to the variation in sample sizes and to strengthen the project's statistical analyses. To limit any errors incurred by running multiple tests, Dunn-Bonferroni corrections were applied to adjust all p-values. Statistical analyses were run using SPSS v.26.

Demographic breakdown of respondents

In total, 477 people took part in the survey. A full breakdown of respondents can be seen in Table 1, outlining profession, gender, and age.

RESULTS

Variation between genders

Table 2 gives the results of the Mann-Whitney U tests between the male and female respondents. The results show a trend regarding the mean values provided for males and females, and also for the questions asked. Female respondents opted for lower scores in the scaled answers on average than males, with the mean value provided in each category for females being consistently lower than that for males (between 0.20 and 0.33 difference across the three questions). Interestingly, the order in which the questions were presented in the survey seems to be their order of importance regarding the scaled answers provided, with the use of donor bodies for all subjects scoring a higher mean value, whilst the use of bone casts instead of real bones has the lowest mean value.

When addressing whether donor bodies should only be used for medical and biomedical students, the Mann-Whitney U test determined that there was no statistical significance between the responses of male and female genders (seen in Table 2). However, statistical significances were noted for the two further questions. A p-value of 0.03 was obtained for the question of whether synthetic bodies should be used for non-medical/

Table 1. Demographic breakdown of respondents, showing gender, age, and profession.

Career			Gender				Total
			Male	Female	Gender Fluid	Prefer not to say	
Student	Age	<20	3	14	2		19
		21-40	18	73	7		98
		41-60	1	14	1		16
		61+	1	1			2
	Total		23	102	10		135
Arch/Heritage Professional	Age	21-40	10	81	2	1	94
		41-60	12	23	1		36
		61+	4	2			6
		Prefer not to say		1			1
	Total		26	107	3	1	137
Med/Bio Professional	Age	21-40	3	12			15
		41-60	1	6			7
		61+	2	3	1		6
	Total		6	21	1		28
Non- professional	Age	21-40	10	40	1		51
		41-60	21	38			59
		61+	26	39		1	66
		Prefer not to say		1			1
	Total		57	118	1	1	177
Total	Age	<20	3	14	2		19
		21-40	41	206	10	1	258
		41-60	35	81	2		118
		61+	33	45	1	1	80
		Prefer not to say		2			2
	Total		112	348	15	2	477

biomedical teaching, determining a difference of opinion between male and female respondents. Similarly, a significant p-value of 0.01 was obtained for the use of real bones versus casts. The mean value obtained for male respondents was 2.42 and 2.16 respectively to the two questions, whilst that for females was 2.14 and 1.83 respectively. These outcomes show a significantly higher score in the male group, but with groups on average giving scores supportive of the use of bone casts and synthetic bodies.

Variation between age groups

Table 3 displays the results of the Kruskal-Wallis and Jonckheere-Terpstra tests undertaken between age categories. Kruskal-Wallis and post-hoc tests were then run to determine if any statistical significances were noted between age categories. Interestingly, they seem to have the opposite result, with a statistical significance noted for the first question (the use of donor bodies for only medical/biomedical teaching), but not for the further two questions. The Kruskal-Wallis determined a p-value of 0.01 for the use of donor bodies for medical/biomedical versus non-medical/biomedical teaching. Associated pairwise analysis showed that specifically the 41-60 and 61+ age categories were significantly different (p=0.04). In addition, the results of the Jonckheere Terpstra test (p=0.01) allude to a significant trend towards increased scores to the use of donor bodies question with age. All mean scores, however, suggested positive responses to the three questions.

Table 2. Results of the Mann-Whitney U test comparing responses between male and female genders. P-values have been adjusted according to Dunn-Bonferroni corrections. Significant results are marked in bold. Note: Gender Fluid data was not included in the statistical analysis due to the differences in sample size compared to male and female groups, but was considered important and is thus reported in the table.

Question	Gender	N	Mean	SD	Mann-Whitney U sig.
Donor bodies for medical/biomedical vs non- medical/ biomedical teaching					.19
	Male	112	2.50	1.36	
	Female	348	2.30	1.33	
	GenderFluid	15	2.40	1.40	
Synthetic bodies for non- medical/biomedical teaching					.03
	Male	112	2.42	1.16	
	Female	348	2.14	1.05	
	GenderFluid	15	2.20	1.26	
Bone casts instead of real bones					.01
	Male	112	2.16	1.18	
	Female	348	1.83	1.01	
	Gender Fluid	15	2.40	1.54	

Table 3. Results of the Kruskal-Wallis test comparing responses between ages, with pairwise analysis between age group and Jonckheere Terpstra tests for significant Kruskal-Wallis tests. P-values have been adjusted according to Dunn-Bonferroni corrections. Significant results are marked in bold. Note: Gender Fluid data was not included in the statistical analysis due to the differences in sample size compared to male and female groups but was considered important and is thus reported in the table.

Question	Age Category	N	Mean	SD	Kruskal- Wallis sig.	21-40	41-60	61+	Jonckheere Terpstra sig.
Donor bodies for medical/ biomedical vs non-medical/biomedical teaching	<20	19	2.73	1.40	.01	.71	1.00	1.00	.01
	21-40	258	2.16	1.24			.55	.04	
	41-60	118	2.48	1.41				1.00	
	61+	80	2.68	1.43					
Synthetic bodies for non-medical/biomedical teaching	<20	19	2.52	1.17	.38				
	21-40	258	2.15	1.08					
	41-60	118	2.24	1.10					
	61+	80	2.30	1.08					
Bone casts instead of real bones	<20	19	2.36	1.01	.11				
	21-40	258	1.86	1.07					
	41-60	118	2.00	1.10					
	61+	80	1.85	1.05					

DISCUSSION

While several statistically significant differences were identified between select groups, there was an overwhelming majority of responses showing participants that believed that the use of teaching with human remains is both practical and ethical. Moreover, these differences at no point alluded to one group being against the use of human remains as pedagogical aids. Instead, the results rather showed that some groups were simply more conservative in terms of which groups should be taught using human remains, but within the context that human remains should be used.

The statistical results were supported and enhanced by the addition of respondents' comments, several of whom provided useful insights into the profession of the individual, and their personal experiences. In some cases, respondents have given reasoning for why specific answers

were chosen and outline their personal thoughts and feelings regarding the subjects of ethics and consent. These provide a valuable context to the more quantitative statistical results.

Is the use of human remains ethical as a teaching material?

Analysis of both the survey data and respondent comments point to a consensus among participants that it is ethical to use human remains as teaching materials, with 89.7% of participants (428/477) giving a "Yes" response. This has been also confirmed by analysis of the Likert scale questions (supplementary material – Tables A, B, and C), which opt for the use of donor bodies in education rather than replications. Even though limited access to donor bodies and replicated materials have been suggested for use outside of the medical and biomedical teaching spheres (discussed in detail later), it seems that the majority of respondents would prefer for everyone to have access to actual human remains in order to obtain a better understanding of anatomy, regardless of specialisation as seen by the mean values documented in Tables 2 and 3.

Overall, the most frequently raised point was of consent (mentioned by 43 individuals). Most respondents appear to approve of the use of donor bodies for teaching, whether for medical and biomedical students or for a broader subject base, because donors consented to give their body as a teaching material. The same, however, cannot be said of archaeological remains. Even though in most cases provenance and a general history of skeletal remains might be known, there is no knowledge of how individuals would have felt knowing their final resting place was no longer so. On this topic, Respondent 306 points out that many skeletons are excavated from funerary contexts, backed up by Respondent 390, who states that people in the past "went to their death with a reasonable expectation of remaining undisturbed". For many individuals in the past, it seems highly unlikely that they could ever imagine themselves being used to educate students. In this context, it is interesting that so many respondents supported the use of archaeological bone to be used in teaching.

As a counter-argument to this, allowing students to handle human remains, in both the form of donor bodies and as skeletal remains, provides them with the opportunity to learn about the ethics of what they are doing and ensures that they understand how to show respect to remains. As stated by Ghosh (2017), "as fellow human beings it is our responsibility to reciprocate the anatomical gift with respect, compassion, care and dignity". This is regardless of how human remains are used, whether they are complete donor bodies, prosections or skeletal material, they were still once living, breathing individuals and so must be treated with the utmost care and respect. Respondent 176 noted that using real bones allowed her to remember that they were once part of a living human – a feeling that might be lost with the use of casts. The best way to promote the respect of people who lived before us is to use them and learn from them, in as ethical and respectful a way as possible.

Use of cadavers for only medical and biomedical teaching

The results of the statistical analyses show no statistical significance between male and female groups; however, differences have been noted between certain age categories. In particular, significant differences were noted between 21-40 and 61+ age categories, along with increases in mean response scores with the increasing age groups analysed. This highlights a differing opinion between ages on the usage of donor bodies for the purposes of medical and biomedical versus non-medical and biomedical teaching.

Alongside the statistical significances, it is of value to note that over half the data – 57.4% – lies in categories 1 (least strongly – all relevant subjects should have access to cadavers) and 2 (less strongly), whilst only 21.8% of the data lies in categories 4 (strongly) and 5 (most strongly – donor bodies should only be used to teach medical and biomedical students). This can be seen broken down by gender in a crosstabulation in the supplementary material (Table A). The answers given by respondents could stem from the issue of consent, with 19 respondents agreeing that, if individuals have consented to dissection after death, it is ethical

Supplementary Material

Table A. A breakdown of scaled answers for the use of cadavers for biomedical vs non-biomedical teaching against gender.

		Use of cadavers for only medical and biomedical teaching					Total
		1.00	2.00	3.00	4.00	5.00	
Sex	Male	39	17	29	15	12	112
	Female	139	66	69	45	29	348
	Gender Fluid	3	9	0	0	3	15
	Prefer not to say	1	0	1	0	0	2
Total		182	92	99	60	44	477

Table B. A breakdown of scaled answers for the use of synthetic cadavers for non-biomedical teaching against gender.

		Use of synthetic cadavers for non-medical or biomedical teaching					Total
		1.00	2.00	3.00	4.00	5.00	
Sex	Male	32	23	40	11	6	112
	Female	134	62	125	21	6	348
	Gender Fluid	5	6	1	2	1	15
	Prefer not to say	0	0	2	0	0	2
Total		171	91	168	34	13	477

Table C. A breakdown of scaled answers for the use of replica human bones instead of real ones against gender.

		Use of replica bone instead of real human bones					Total
		1.00	2.00	3.00	4.00	5.00	
Sex	Male	47	19	31	11	4	112
	Female	186	57	84	18	3	348
	Gender Fluid	5	6	0	1	3	15
	Prefer not to say	2	0	0	0	0	2
Total		240	82	115	30	10	477

for any relevant subject to use them. Yet this is not an overall opinion, and alongside the statistical results two respondents specifically commented that donor bodies should only be used by medical and biomedical students. Respondent 152 believed that it is primarily medical and biomedical students who should have access to donor bodies, although within the context of their use in different subjects, they would not "be against their use if it adds value to the course". This was seconded by Respondent 291, who believed that donor bodies should be "prioritised for medical teaching", but had access through their own archaeological course and said that it had aided in their education and understanding.

Overall, with a mean value of 2.35 for the combined dataset, there is a general acceptance for all relevant subjects having access to dissection as a resource, rather than solely medical and biomedical subjects. There are a few counter-arguments, stating that donor bodies should be prioritised, but, on the whole, the respondents of this study appear to be of agreement that any relevant subject which would benefit from the use of dissection should have access to the resource.

Synthetic bodies for non-medical and biomedical teaching

The results of the statistical analyses revealed that the male group to have significantly higher mean response scores than the female group, but with no additional significances discovered between age categories. Again, the majority of data collected – 54.9% – was held in categories 1 (least strongly – all relevant subjects should have access to real donor bodies) and 2 (less strongly), whilst only 9.8% of the data was allocated as categories 4 (strongly) and 5 (most strongly – anyone not studying medical or biomedical subjects should use synthetic bodies). The mean score for male respondents was calculated at 2.42, for gender fluid at 2.20 and for females 2.14. The results of the statistical analysis show that, although males agree that access should be provided to real donor bodies, female respondents were more inclined towards this. Further information can be seen broken down by gender in a crosstabulation in the supplementary material (Table B).

There were also notable comments on this question from respondents. For example, Respondent 85 suggested that synthetic bodies would be highly useful for teaching if there was no access to real donor bodies, whilst Respondent 83 said they should be considered as an option, but if people had chosen to donate their bodies for teaching, their wishes should be adhered to. Perhaps this could suggest a compromise: if institutions have sufficient access to donor bodies for a variety of subjects, then this facility should be used, but if not, there is now an alternative. This can be seen in a study undertaken in 2019 using a SynDaver model (Richardson et al., 2021), which introduced a synthetic body into an anatomy module. Even though this experiment did not test whether students learnt more from a synthetic body than a real one, it concluded that students who had access to a synthetic body gained more skills than those who had no access, showing this as an invaluable teaching resource. This in part concurs with the results of this project and respondent comments, most notably the potential for using synthetic resources where donor bodies are unavailable.

However, all individuals are anatomically different and so may present different traits during dissection, including blood vessels in irregular places and additional growths (Mazhar et al., 2014): traits such as these could be easily missed if using a standard synthetic body. Also, the textures and densities of real human remains cannot be fully replicated in synthetic models. A study undertaken at a university in Poland asked students if they would prefer to use real donor bodies, synthetic bodies, or a combination of both. Over 70% of students opted for real donor bodies due to variance and degradation of the living body, seeing how it changes over time, whilst only 21.8% would rather have a replication in order to see how anatomy should look if it was without flaw (Wilk et al., 2020).

Although not asked to participants, there is a clear issue with the synthetic body relating to purchasing cost. The starting price of SynDaver organs is reasonable: for example, a synthetic spleen costs $139 (SynDaver, 2021), but a high-end, full body can cost around $350,000 (Hansman, 2015). However, synthetic bodies like these conversely have a relatively low upkeep, in both a physical and monetary sense. They do not have to be stored in the same environment as real donor bodies, allowing for easier and cheaper storage facilities and, most importantly, they can be used multiple times (Richardson et al., 2021). Whilst a real donor body can be classed as a "single use" material which can be dissected only once (although it can be used further in the form of prosections, etc), a synthetic body can be used over consecutive seasons with multiple groups, because it can be reassembled after each use. Potentially, this could link in with the findings from the previous question: medical and biomedical students should have priority over real donor bodies, but other relevant subjects could use synthetic bodies as a useful study aid if access to a donor body is not possible. However, this relies on non-medical and biomedical fields having the funds available to purchase a synthetic body.

Another issue, raised by five respondents, was the use of animal components in the creation of semi synthetic bodies, which use animal organs inside a synthetic structure. The recurring comment was that human individuals had consented to be used for educational purposes after death,

whilst animals had not. For example, respondent 195 commented that the use of animal components in semi synthetic bodies is "morally wrong". Unlike humans, other animals, both living and dead, are classed as a "tradeable commodity" (Kaw et al., 2016), and in the case of semi synthetic bodies it could be fairly argued that a student is dissecting an animal merely housed inside a different shell.

Alongside the ethical issues of using donor bodies in teaching, there are also practical issues, including transportation, chemical preservation, and storage (Brenner et al., 2003; Brenner, 2014). Additionally, substances hazardous to the health of living individuals (Brenner, 2014; Wilk et al., 2020) must be used to preserve donor bodies, thus requiring a specific environment for their processing, storage, and dissection. For example, an open and well-ventilated area is essential when dissecting a donor body due to the overpowering odour omitted by cutting into the preserved flesh (Bhat et al., 2019). Fully synthetic bodies such as the SynDaver (SynDaver, 2021), comprised of plant and polymer fibres, produced without the use of hazardous or toxic material, could be a counter to this.

Overall, the results presented here, as well as in literature, suggest that professionals and students working with human remains see value in the use of synthetic and semi synthetic bodies for the purposes of teaching. However, there are obvious ethical and educational issues with using semi synthetic alternatives. This suggests that whilst there are financial and variational limitations to using synthetic bodies, they may present a viable and more ethical alternative to semi synthetic versions and, in some cases, real donor bodies, according to the resources available in each case. That being considered, as the response seen by the majority of respondents still suggests that if there is access to a real donor body, then this should be used.

Replacement of human bones with replicas

The final question provided similar results to the previous, with a significant difference between the responses of the male and female groups, but with no significant variation between age categories. The difference noted between gender categories saw a mean score for males of 1.18, females of 1.01, and for gender fluid of 1.54. Even within the context of significant variation between male and female response, the consensus is that real human bones should be used for teaching, rather than replicated material with the majority of data – 67.5% – held in categories 1 (least strongly – skills would be lost by only using casts) and 2 (Less strongly) whilst only 8.3% was held in categories 4 (Strongly) and 5 (Most strongly – casts should be used instead of real bones).

This has also been noted in the additional comments. In total, 47 comments referred to the importance of using real bones over replicas for study, with 38 made by students and archaeology or heritage professionals who have experience of handling human bone. However, within these comments there was a further consensus that replica bone should be used initially to build an understanding of skeletal anatomy (i.e., identifying bones and their features). This applies mainly at a non-specialised, undergraduate level. However, with more advanced students, studying towards a specialisation, respondent comments suggested that casts are not always appropriate. Unfortunately, this could mean that some archaeologists without post-graduate qualifications could have little to no experience of handling real human bones before they first begin fieldwork, suggesting that real bones should still play a part to some degree within undergraduate study.

One of the repeated comments was of taphonomic damage – the alteration of bone over time depending on both environmental and human-based factors (Sorg, 2019). For example, Respondent 337 believed that students should become accustomed to studying real bones in order to understand any fragmentation and/or degradation that they may experience. The bones of an individual can alter dramatically depending on the environment of internment and any post-depositional interaction. This should be considered in teaching, and cannot be reflected effectively through replicas. Similarly, Respondent 62 believed that it was essential to have experience of handling human bones before beginning any fieldwork as an archaeologist in order to understand types of damage. Respondent 70 concurred,

believing that students need to handle human bones in order to be able to distinguish them from animal bones and to understand their fragility during excavation – something noted in past literature (Johnson, 1994).

Eighteen respondents also commented on the variation of human bones, which are specific to each individual. There are numerous metric and, more importantly in this instance, non-metric or discrete traits, seen in some individuals as singular or multiple characteristics (White and Folkens, 2005; Mays, 2010). The worries projected by these respondents were unanimous; when replacing real bones with polyresin copies, instances of individual variation could be lost. In particular, Respondent 313 focused on paleopathology (bone disease), and stated that real bones should be used for teaching, so students can understand normal variation before attempting to "identify pathological or atypical changes". It is vital to understand whether a characteristic is a non-metric trait, taphonomic damage or evidence of pathology as this is a core component of biological profiling across all anatomical, archaeological, and forensic fields (e.g. Roberts and Manchester, 1995; Mays, 2010).

Interestingly, Respondent 321 believed that replicated bones should be substituted for real ones within a public display setting; but, for teaching individuals who want to specialise in human remains, they should have access to real bones. This respondent also pointed out that the use of real human bone as a teaching material can help strengthen the protocols of ethical practice by thoroughly informing students about the material with which they are working. In fact, several institutions have begun to replace human skeletal material with replica bones. For example, when the remains of Richard III were uncovered in 2012, it was always the intention to re-inter them. However, his bones were scanned using CT equipment and then 3D printed, allowing for a copy to be put on display whilst his actual remains were interred in Leicester cathedral (Levitt, 2016). Technology has now advanced to the point that it is possible to 3D print bone to act as a graft in a living person (Xilloc, 2021). Given that this type of printing has to be precise in order to serve a living individual, it seems the use of 3D printed bones for the purposes of teaching could provide more than just a basic understanding of skeletal anatomy.

Replicated bones are now more readily available, with numerous online outlets selling them, from low quality plastic items to high quality 3D printed replicas. High end replications, such as those created by Bone Clones (2021) are much more detailed, encompassing a range of individual and pathological features. These are created using real human bones and are cast with enough precision to preserve fine details such as muscle attachment sites and nutrient foramina (Bone Clones, 2021). Created from polyurethane resin and hand stained to appear more realistic, these replicas have been cast from a number of individuals in order to demonstrate differing non-metric traits and pathologies. In fact, the page dedicated to replica skulls showcases multiple types or trauma from human impact as well as various diseases and ailments. One survey respondent liked the idea of casts to show trauma: Respondent 188 focussed heavily on different types of traumas which might not be readily available within skeletal collections, but which could be substituted with the use of casts. The most economic set-back of highly detailed items such as Bone Clones is the cost. Whilst institutions may obtain human remains from excavation work or from other such facilities, replicated bones must be purchased.

Limitations

Several limitations have been noted within this study. One of the methods of distribution was a female-led social media group, accounting for a greater number of female respondents. Also, the survey was sent out through several professional email lists and social media groups, but also distributed through a personal social media account. This accounts for the greater number of professional respondents as opposed to public. Were this study to be undertaken again, having greater access to the public could allow for a more even split in the data.

CONCLUSION

Despite some variations between groups, the results of the survey and subsequent statistical

analysis show a clear opinion that the use of human remains as a teaching resource is ethical. Whether in the form of a donor body or skeletal material, there is the overwhelming opinion that it is ethical to use real human remains to enhance the education of students, with the majority of respondents feeling more at ease with the use of real material as opposed to synthetic, and especially semi synthetic in regard to created material. However, while these seemed to be a general ethical consensus there was some contention regarding the issue of consent. Moreover, it must be remembered that the analysis conducted here focussed on the British population. The findings presented here may thus not apply within different cultures and societal groups. Future research would thus be well served conducting similar surveys amongst different groups, considering different factors such as nationality, ethnic background, and religion.

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Notes on Contributors

Georgina Goodison - contributed to all aspects of the manuscript including writing, reviewing, data analysis, and conception, as well as being the main writer on the first draft. Christopher Aris - contributed to all aspects of the manuscript including writing, reviewing, data analysis, and conception.

Ethical Compliance Statement

Before beginning research, ethical approval was sought and granted by the University of Sheffield in order to gather data from professionals and the general public.

REFERENCES

BAUCHNER H, VINCI RJ (2001) What have we learnt from the Alder Hey affair? *BMJ: Brit Med J,* 322: 309-310.

BHAT D, CHITTOOR H, MURUGESH P, BASAVANNA PN, DODDAIAH S (2019) Estimation of occupational formaldehyde exposure in cadaver dissection laboratory and its implications. *Anat Cell Biol,* 52(4): 419-425.

BONE CLONES (2021) Only Mother Nature does it better. *Bone Clones Inc*. URL: https://boneclones.com/ [accessed 14th August 2021].

BONNEY H, BEKVALAC J, PHILLIPS C (2020) Human remains in museum collections in the United Kingdom. In: Squires K, Errickson D, Márquez-Grant N (eds). *Ethical Approaches to Human Remains: A Global Challenge in Bioarchaeology and Forensic Anthropology*. Switzerland: Springer International Publishing, pp 211-237.

BRENNER E, MAURER H, MORIGGL B, POMAROLI A (2003) The human cadaver as an educational tool – classification and comparison with other educational tools. *Ann Anat,* 185(3): 229-230.

BRENNER E (2014) Human body preservation – old and new techniques. *J Anat,* 224(3): 316-344.

BURR JA, WINTER RC, HEYERDAHL-KING I, WARREN MA, REDMAN AK, NICHOLLS O (2019) A qualitative study of how students learn from human cadavers. *Eur J Anat,* 23(6): 447-452.

CAIN T (2017) Getting under the skin. *Wellcome Collection.* URL: https://wellcomecollection.org/articles/WXXZUyoAAJpKfPOq [accessed 20th July 2021].

COATES S (2021) Population estimates by ethnic group and religion, England and Wales: 2019. *Office for National Statistics.* URL: file:///C:/Users/wiggl/Downloads/Population%20estimates%20by%20ethnic%20group%20and%20religion,%20England%20and%20Wales%202019.pdf [accessed 25th July 2021].

DAVIS CR, BATES AS, ELLIS H, ROBERTS AM (2013) Human Anatomy: Let the students tell us how to teach. *Anat Sci Educ,* 7(4): 262-272.

DCMS (2004) Guidance for the Care of Human Remains in Museums. *Department for Culture, Media and Sport.* URL: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/906601/GuidanceHumanRemains11Oct.pdf [accessed 25th July 2021].

ENGLISH HERITAGE (2009) Research into Issues Surrounding Human Bones in Museums. *English Heritage.* URL: https://historicengland.org.uk/content/docs/research/opinion-survey-results-pdf/ [accessed 10th August 2021].

FLETCHER A, ANTIONE D, HILL JD (2014) *Regarding the Dead: Human Remains in the British Museum.* London: British Museum Press.

GAZI A (2014) Exhibition Ethics – An overview of major issues. *J Conservation Museum Studies*. URL: https://www.jcms-journal.com/articles/10.5334/jcms.1021213/ [accessed 14th August 2021].

GHOSH SK (2017) Paying respect to human cadavers: We owe this to the first teacher in anatomy. *Ann Anat,* 211: 129-134.

HAD (2021) Statement of Intent. *Honouring the Ancient Dead.* URL: https://www.honour.org.uk/statement-of-intent/ [accessed 14th August 2021].

HANSMAN H (2015) Med school students can play "operation" with these synthetic cadavers. *Smithsonian Magazine.* URL: https://www.smithsonianmag.com/innovation/med-school-students-can-play-operation-with-these-synthetic-cadavers-180957328/ [accessed 10th September 2021].

HILLIER ML, BELL LS (2007) Differentiating human bone from animal bone: a review of histological methods. *J Forensic Sci,* 52(2): 249-263.

HTA (2020) Human Tissue Act 2004. *Human Tissue Authority.* URL: https://www.hta.gov.uk/guidance-professionals/hta-legislation/human-tissue-act-2004 [accessed 20th April 2021].

HTA (2021) About the HTA. *Human Tissue Authority.* URL: https://www.hta.gov.uk/about-hta [accessed 20th April 2021].

JENKINS T (2008) Dead bodies: The changing treatment of human remains in British museum collections and the challenge to the traditional model of the museum. *Mort*, 13(2): 105-118.

JOHNSON JS (1994) Consolidation of archaeological bone: a conservation perspective. *J Field Archaeol,* 21(2): 221-233.

JONES DG (2016) The public display of plastinates as a challenge to the integrity of anatomy. *Clin Anat,* 29(1): 46-54.

KAW A JONES, DG, ZHANG M (2016) The use of animal tissues alongside human tissue: Cultural and ethical considerations. *Clin Anat,* 29(1): 19-24.

LAPORTE C (2014) Ethics of displaying human remains in museums. *Institute for Cultural Practices – The University of Manchester.* URL: https://culturalpractice.wordpress.com/2014/11/26/ethics-of-displaying-human-remains-in-museums-by-caitlin-laporte/ [accessed 25th July 2021].

LEVITT S (2016) Displaying replica bones and skeletons. *Honouring the Ancient Dead.* URL: https://www.honour.org.uk/displaying-replica-bones-and-skeletons/ [accessed 14th August 2021].

LOHMAN J, GOODNOW K (2006) *Human Remains and Museum Practice.* London: UNESCO.

LOUKAS M, HANNA M, ALSAIEGH N, SHOJA MM, TUBBS RS (2011) Clinical anatomy as practiced by ancient Egyptians. *Clin Anat,* 24(4): 409-415.

MACDONALD H (2005) Human Remains: *Dissection and its Histories.* London: Yale University Press.

MAYS S (2010) *The archaeology of human bones.* (2nd ed). Oxford: Routledge.

MAZHAR MA, QAZI S, KHERALLAH S, ALDALATI A, ALTINAWI B, AZOUZ H, AHMAD JH, GANGULY P (2014) Identifying rare human anomalies through students directed dissection at Alfaisal University: Case Report. *Austin J Anat,* 1(4): 1018.

MCMENAMIN PG, MCLACHLAN J, WILSON A, MCBRIDE JM, PICKERING J, EVANS DJR, WINKELMANN A (2018) Do we really need cadavers anymore to learn anatomy in undergraduate medicine? *Med Teach,* 40(10): 1020-1029.

MDU (2021) Storing and disposing of human skeletons and material. *The MDU.* URL: https://www.themdu.com/guidance-and-advice/guides/storing-and-disposing-of-human-skeletons-and-material [accessed 14th August 2021].

MITCHELL PD, BOSTON C, CHAMBERLAIN AT, CHAPLIN S, CHAUHAN V, EVANS J, FOWLER L, POWERS N, WALKER D, WEBB H, WITKIN A (2011) The study of anatomy in England from 1700 to the early 20th century. *J Anat,* 219(2): 91-99.

NAGPRA (2021) Facilitating Respectful Return. *NAGPRA – Native American Graves Protection and Repatriation Act.* URL: https://www.nps.gov/subjects/nagpra/index.htm [accessed 10th August 2021].

PAPA V, VACCAREZZA M (2013) Teaching Anatomy in the XXI Century: new aspects and pitfalls. *Scientific World,* 2013: 310348-5.

PARKER PEARSON M (2003) *The archaeology of death and burial.* Sutton Publishing Limited, Gloucestershire.

RICHARDSON NS, ZWAMBERG D, MCFALL K, ANDREWS DM, GREGORY D (2021) Exploring the utility and student perceptions of synthetic cadavers in an undergraduate human anatomy course. *Anat Sci Educ,* 14(5): 605-614.

ROBERTS CA, MANCHESTER K (1995) *The Archaeology of Disease.* 3rd ed. Cornell University Press, New York.

ROBERTS CA (2009) *Human remains in archaeology: a handbook*. Oxford: Information Press.

SAYER D (2010) *Ethics and Burial Archaeology.* Gerald Duckworth & Co Ltd., London.

SORG MH (2019) Differentiating trauma from taphonomic alterations. *Forensic Sci Int,* 302: 109893.

STANDRING S (2016) A brief history of topographical anatomy. *J Anat*, 229: 32-62.

SWAIN H (2002) The ethics of displaying human remains from British archaeological sites. *Public Archaeology,* 2(2): 95-100.

SYNDAVER (2020) Our History. *SynDaver: Beyond Human.* URL: https://syndaver.com/history/ [accessed 20th August 2021].

TARLOW S, BATTELL LOWMAN E (2018) *Harnessing the Power of the Criminal Corpse.* Cham: Palgrave Macmillan.

THE BRITISH MUSEUM (2021) Human Remains. *The British Museum.* [Viewed 25th July 2021]. URL: https://www.britishmuseum.org/our-work/departments/human-remains.

THOMAS DP (2006) Thomas Vicary, barber-surgeon. *J Med Biogr,* 14(2): 84-89.

TRELEASE RB (2016) From chalkboard, slides, and paper to e-learning: How computing technologies have transformed anatomical sciences education. *Anat Sci Educ,* 9(6): 583-602.

VON HAGENS G (2014) *Body Worlds: the original exhibition.* Heidelberg: Arts and Sciences Exhibitions and Publishing GmbH.

WELLCOME COLLECTION (2018) Full policy on care of human remains in museums and galleries. *Wellcome Collection.* URL: https://wellcomecollection.org/pages/WyjY_SgAACoALCmH [accessed 25th July 2021].

WHITE TD, FOLKENS PA (2005) *The Human Bone Manual.* Elsevier Academic Press, London.

WILK R, LIKUS W, HUDECKI H, SYGULA M, RÓŻYCKA-NECHORITIS A, NECHORITIS K (2020) What would you like to print? Students' opinions on the use of 3D printing technology in medicine. *PloS One,* 15(4): e0230851.

XILLOC (2021) CT-bone: real bone from the 3D printer. *Xilloc.* URL: https://www.xilloc.com/ct-bone/ [accessed 14th August 2021].