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Learning osteology: what resources do undergraduate anatomy students prefer?

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SUMMARY

Several osteology-learning resources are helpful, but using human bones could optimise students' learning experience. Hence, the Department of Basic Medical Sciences, University of the Free State (UFS), South Africa, issues a complete set of unarticulated bones of a human skeleton to registered anatomy students. However, not all students choose to accept this set of bones for additional study. The purpose of this study was to explore anatomy students' utilisation of human bones and to determine their preferences and suggestions for alternative resources to learn osteology. This descriptive observational study entailed an opinion survey regarding resources for learning osteology amongst anatomy students at the UFS in 2014. These students included medical, occupational therapy, physiotherapy and nursing students (n = 425). Results are presented using descriptive statistics. The majority (89.9%) of students across disciplines found using human bones beneficial, irrespective of whether they chose to receive bones. The bones were most frequently used by occupational therapy students and least frequently used by medical students. Students used bones for learning bone names and specific features that included bone markings and muscle attachments. Other preferred and suggested resources included textbooks, atlases, computer software and the anatomy museum. This study reveals that students prefer to use human bones to learn osteology. The results could assist anatomy departments to develop a strategy to provide sufficient opportunities for anatomy students to use human bones to learn osteology. Alternative, suitable resources for the study of osteology could be implemented due to increasing student numbers and difficulty in obtaining human material for teaching purposes.

Key words: Anatomy – Osteology – Osteology learning – Osteology resources – Anatomy education – Health professions education

INTRODUCTION

One of the most important cornerstones of medical education, the study of anatomy, dates back to the 2nd and 3rd centuries BCE, when the Greeks (Hippocrates, Aristotle, and others) and Egyptians (Edwin Smith Papyrus) discovered different structures in the human body (History World, n.d.; Pascoe, n.d.). Anatomy teaching methods have evolved as the undergraduate curriculum has been modernised. Despite these changes, the preferences of anatomy students and anatomy faculties regarding both traditional and technology-based teaching methods and tools are largely unclear. The dissection of cadavers remains one of the most appreciated resources for learning anatomy, providing students with a three-dimensional foundation critical for the development of clinical skills (Marks, 2000; Lempp, 2005; Robbins et al., 2008-2009; Arora and Sharma, 2011; Mitchell et al., 2011; Estai and Bunt, 2016; Ghosh, 2017; Afsharpour et al., 2018; Mitrousias et al., 2018; Preim and Saalfeld, 2018).

However, while the study of osteology forms an integral part of anatomy and forensic anthropology,

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dissection-based teaching using cadavers does not enable students to gain all the osteology knowledge they need. Therefore, anatomy departments worldwide offer students the opportunity to look at and handle human bones and skeletons. Institutions in North America (Carroll and Lawson, 2014; Stanford University, 2016; Florida Gulf Coast University, 2017), the United Kingdom (University of Cambridge, 2015; University of Kent, 2015), Australia (University of Queensland, 2015; University of Sydney, 2018) and locally at universities in South Africa (University of Cape Town, 2018; University of Pretoria, 2018) follow this trend.

Osteology involves learning the names of bones, the classification, articulation, growth and ossification of bones, the neurovascular supply of bones and specific features, e.g., bone markings and muscle attachments on bones. The latter aid to the understanding of functional and evolutionary anatomy and knowledge thereof are especially important for medical and physiotherapy students. Most of this information appears in well-known anatomy textbooks, e.g., *Moore Clinically Oriented Anatomy* (Moore et al., 2014) and *Gray's Anatomy for Students* (Drake et al., 2014). However, to study the specific features of a particular bone in detail, a textbook or even an atlas alone, is not enough, although useful books such as *Drennan's Human Osteology* (Drennan and Coetzee, 1987) and Netter's *Atlas of Human Anatomy* (Netter, 2014) exist. The latest trend in teaching and learning anatomy, towards using 3D computer images of the structure of the human body (Trelease, 1996; Brenton et al., 2007; Trelease and Rosset, 2008; Stull et al., 2009; Kugelmann et al., 2018; Viswasom and Jobby, 2018; Chytas, 2019; Zilverschoon et al., 2019), could assist in learning osteology.

However, students also need so see and touch human bones in order to learn and remember osteology (Giffin et al., 2014). As far as the researchers could establish from literature searches, very few research articles have examined the importance of using human bones and what students use—or prefer—to study osteology. This study emphasises the importance of collecting information about student preferences and evaluating their experiences in learning osteology to optimise the teaching methods used in the undergraduate anatomy curriculum.

To enable their students to study osteology, the Department of Basic Medical Sciences at the University of the Free State (UFS) in South Africa issues a complete set of unarticulated bones of a human skeleton (henceforth referred to as bones) to registered anatomy students for the duration of their course. These students include first- and second-year medical, first- and second-year nursing, and first-year occupational therapy and physiotherapy students.

The Department of Basic Medical Sciences, UFS, is currently experiencing a shortage of bones due to increasing student numbers (student intake into academic programmes doubled in the last few years) and the increasing difficulty of obtaining donated human material (Habicht et al., 2018; Kramer et al., 2018). Thus, since 2014, first-year medical students and nursing students have been given a choice whether or not to receive a set of bones (i.e., obtaining these bones is currently not compulsory). Students who receive the bones pay a small deposit (R300), for which they are reimbursed when they return these resources. This research project did not cover reasons why students chose not to receive a set of bones, but socio-economic factors may play an important role. Students receive their own set of bones, which they may take home or share in study groups.

During a practical class, students work in groups where they use unarticulated bones and articulated skeletons to study osteology. The Department use the dissection hall as a venue for these practical classes. A dissection class only applies to the medical students, as they are the only group that dissects cadavers. However, in the dissection hall and museum, articulated skeletons are always on display and available for learning osteology. Therefore, all students (and not only those who chose to receive sets of bones) get the opportunity to make use of these articulated skeletons and bones. These resources may not leave the respective venues.

Due to reasons mentioned above, The Department of Basic Medical Sciences, UFS, had to reconsider their approach to teaching osteology and find alternatives to the practice of issuing bones to students. The research aimed to explore the use and preferences of anatomy students regarding the utilisation of bones and to determine students' preferences and suggestions for alternative resources to learn osteology.

The objectives of this study included the following regarding learning osteology:

- To explore the use of human bones by undergraduate anatomy students;
- To determine the preferences of students regarding resources for the study of osteology; and
- To compare the usage and suggestions of the different groups of anatomy students regarding resources for learning osteology.

MATERIALS AND METHODS

Study design

Ethical approval was obtained from the Ethics Committee of the Faculty of Health Sciences, UFS (ECUFS No. 201/2014).

This research study entailed a descriptive observational study using an opinion survey amongst undergraduate anatomy students regarding their use of human bones and their preferences and suggestions for alternative resources to learn osteology.

Study population

The study population included all the students in

the Department of Basic Medical Sciences, UFS, registered for anatomy, who were entitled to receive sets of bones to study osteology during 2014 (n = 564), regardless of whether these students accepted bones. The students included first and second-year medical (n = 180 and n = 153 respectively), first and second-year nursing (n = 96 and n = 52 respectively), and first-year occupational therapy and physiotherapy students (n = 42 and n = 41 respectively). All students in these groups were included in the study, irrespective of whether they were repeating anatomy, their language of instruction (as a parallel medium of instruction was followed at the UFS until 2016), age, gender or self-reported ethnicity.

Measuring instrument

A questionnaire was compiled to inquire about the use of skeletons by the anatomy students and to explore their preferences and suggestions for alternative resources to learn osteology. The questionnaire contained items with yes or no answers, lists with one or more options to choose from and open-ended questions which students could answer in their own words.

Demographic information included the particular anatomy module and course for which a student was registered, study year, language of instruction, age, gender and self-reported ethnicity. Students completed the questionnaire in the language of choice (Afrikaans or English).

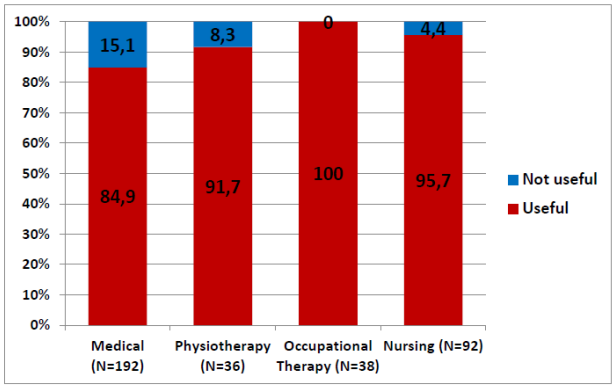

Fig 1. Comparison of students on the different courses who found skeletons useful.

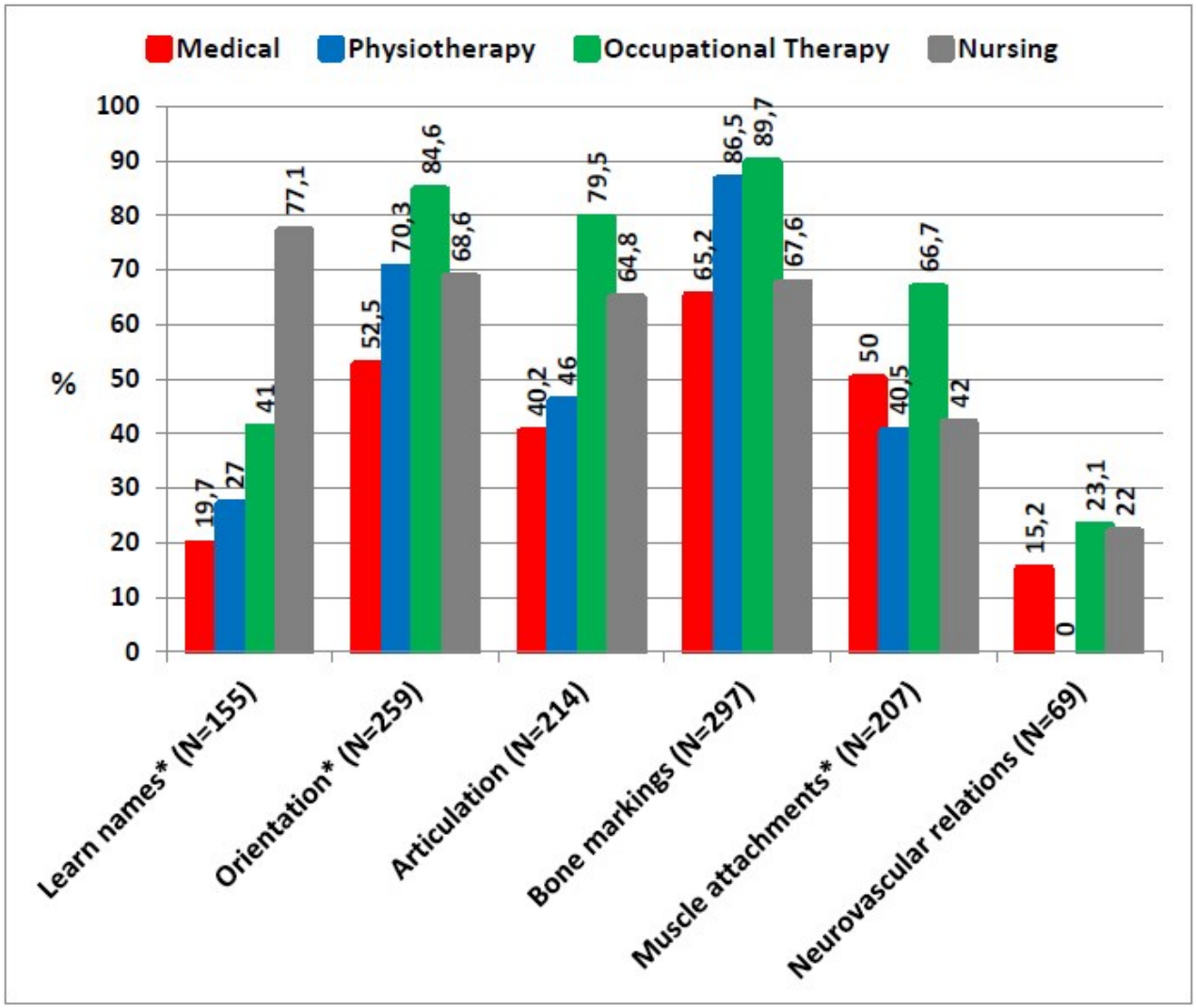

Fig 2. Comparison between the different courses regarding different uses of bones. (*) P<0.0001

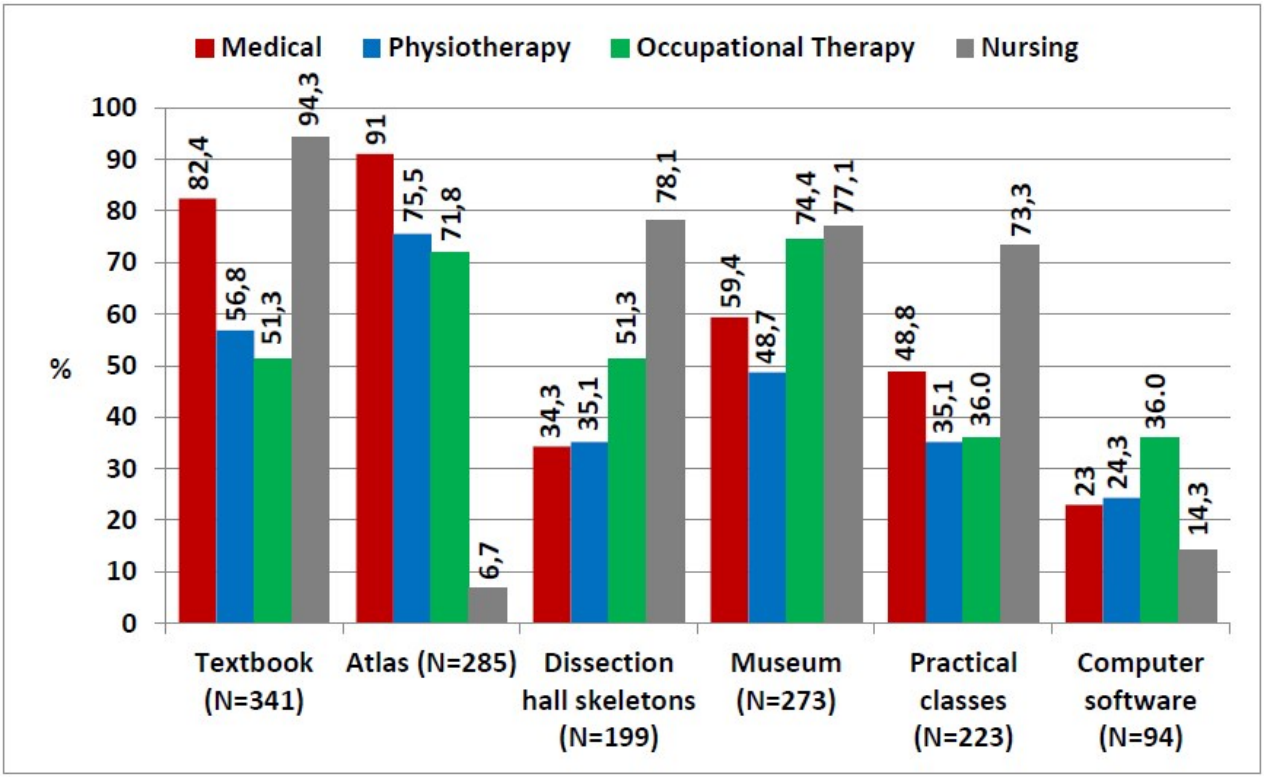

Fig 3. Comparison of osteology resources used by students on the different courses

A pilot study included five students in the Afrikaans class and five students in the English class of the second-year medical student group of 2014 (chosen randomly). Minor changes were made to the questionnaires according to responses of the pilot study; the results from the pilot study were not included in the main study.

All students who were part of the study population were approached at the start of a scheduled contact session towards the end of their particular anatomy module. The purpose of the study was explained to the students and they were invited to participate in the study. Every student received an information leaflet beforehand (in either Afrikaans or English) explaining the aim of the study. Participation was voluntary and the questionnaires were completed anonymously to ensure that students' identities remained protected.

Data analysis

The responses to the questionnaires were transferred to a data capturing form using Microsoft Excel by one of the researchers. The Department of Biostatistics, Faculty of Health Sciences, UFS did the data analysis. Mainly descriptive statistics were calculated (e.g., frequencies, modes and means), although cross-tabulation or correlations were drawn between different responses, where appropriate. The statistical significance of some of the findings was calculated using chi-square tests. Data were analysed using SAS®/STAT® software, version 12.3 of the SAS® System for Windows®. Similar responses to the open-ended questions were grouped to identify the main ideas, preferences and suggestions of students regarding resources for studying osteology.

RESULTS

Demographic information

In total, 425 students completed questionnaires (response rate of 76.7% after exclusion of the ten pilot study participants). The participants included 244 first and second year medical (57.4%), 37 physiotherapy (8.7%), 39 occupational therapy (9.2%) and 105 nursing students (24.7%). Of the students who indicated their gender, 29.4% were male and 70.6% were female (n = 418). The average age was 20.3 years, ranging from 18 to 36 years. The self- reported ethnicity of the students (n = 417) were White (71.5%), African (18.9%), Indian (4.6%), Coloured (3.4%) and Asian (1.4%).

Responses regarding the use of bones

The majority of students (n = 269, 63.3%) received a complete set of human bones for the duration of their anatomy course. Of the students who made use of bones to study osteology, regardless of whether they had been issued bones or not, 89.9% (n = 358) found the use of bones valuable (the students who did not receive bones used the bones available in the Department). This proportion was relatively constant across study courses as at least 85% of students' responses in the different courses were affirmative (Fig. 1). Many of the students used the bones only before tests and exams (n = 141, 39.4%), while more than a quarter used them at least once a week (n = 93, 26.0%).

Students on the various courses used the bones for different purposes (Fig. 2). Questions on the

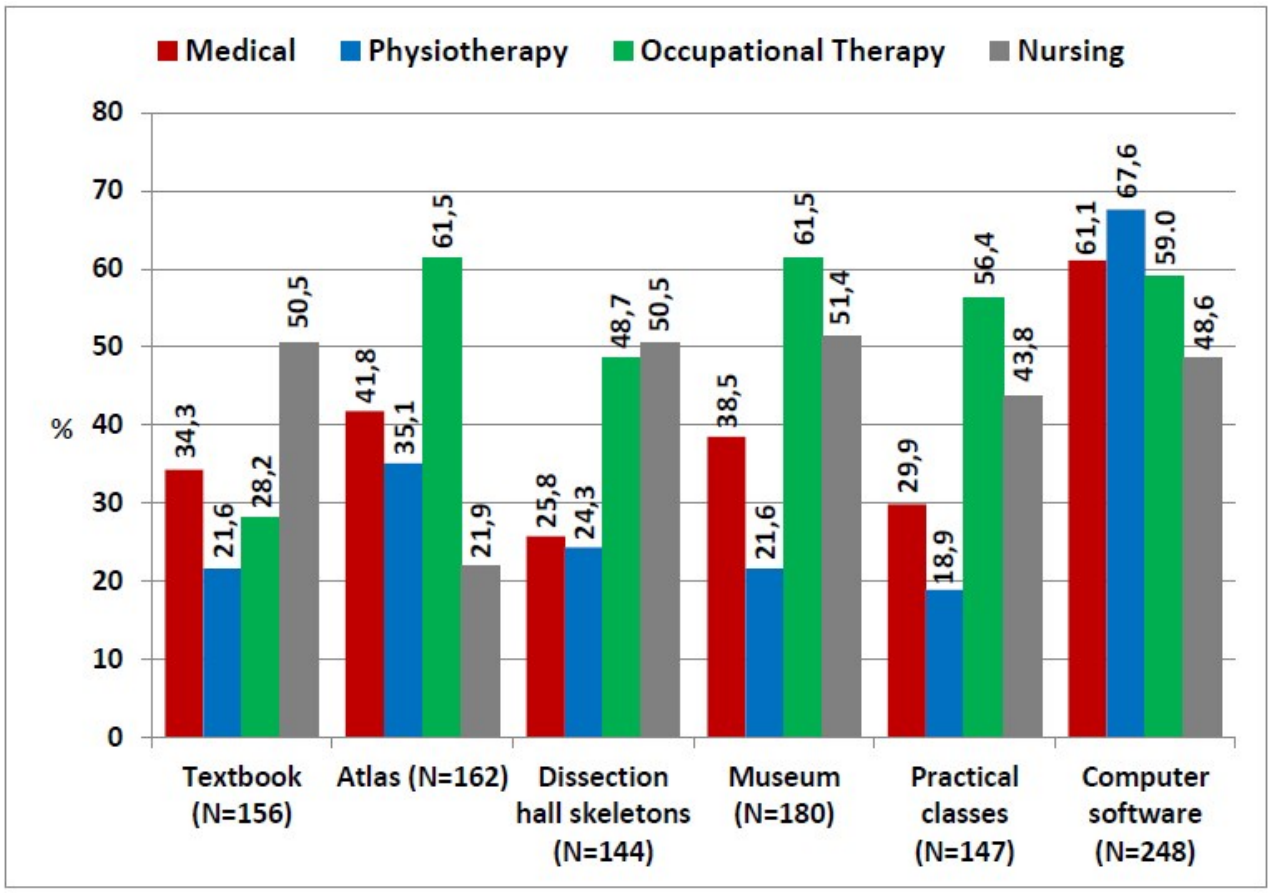

Fig 4. Comparison of osteology resources suggested by students on the different courses

specific features of a bone included separate questions on the use to learn bone markings and the use to study muscle attachments, as for some students (e.g., medical and physiotherapy students) knowledge of muscle attachments is more important than for students on other courses. From Fig. 2, it is clear that the bones were most frequently used by occupational therapy students and least often used by medical students. The overall chi- square analysis between the four courses was statistically significant for using bones to learn their names, to orientate bones and to learn muscle attachments on bones ($p < 0.0001$).

Students also used various other resources to learn osteology. Fig. 3 illustrates results for each course separately. Nursing (94.3%) and medical students (82.4%) mainly used textbooks, while 91.0% medical, 75.5% physiotherapy, 71.8% occupational therapy students and 6.7% nursing students used atlases. Nursing and occupational therapy students, in particular used the anatomy museum. Many nursing students also made use of the articulated skeletons in the dissection hall (78.1%) and the bones displayed during practical classes (73.3%). In general, students used computer software the least, ranging from 14.3% (nursing students) to 36.0% (occupational therapy students). Overall comparisons for all resources used were statistically significant ($p < 0.0001$), except for the use of the museum and computer software.

Students also had the opportunity to suggest the various osteology resources they use to learn osteology (Fig. 4). Approximately half the occupational therapy and nursing students suggested the use of articulated skeletons in the dissection hall and museum and the bones displayed during practical classes, whereas closer to a quarter of the medical and physiotherapy students did so (except for the museum, which 38.5% medical students suggested). Occupational therapy students (61.5%) emphasised the use of an atlas, specifically. However, as can be seen in Fig. 4, the majority of students suggested computer software as a resource for learning osteology (61.1% of medical students, 67.6% of physiotherapy students, 59.0% of occupational therapy students and 48.6% of nursing students). Comparisons for resources suggested were all statistically significant ($p < 0.0001$), except for textbooks, the museum and computer software.

Fig. 5 illustrates a comparison of the resources used by students who received bones versus those who did not receive bones (Yes vs. No on the questionnaire). In this figure, it is important to note that the students who did not receive bones, made considerably more use of the skeletons and bones available in the museum (74.4% vs. 58.4%), during practical classes (69.2% vs. 42.8%) and in the dissection hall (62.2% vs. 37.9%). More students who did not receive bones also used the

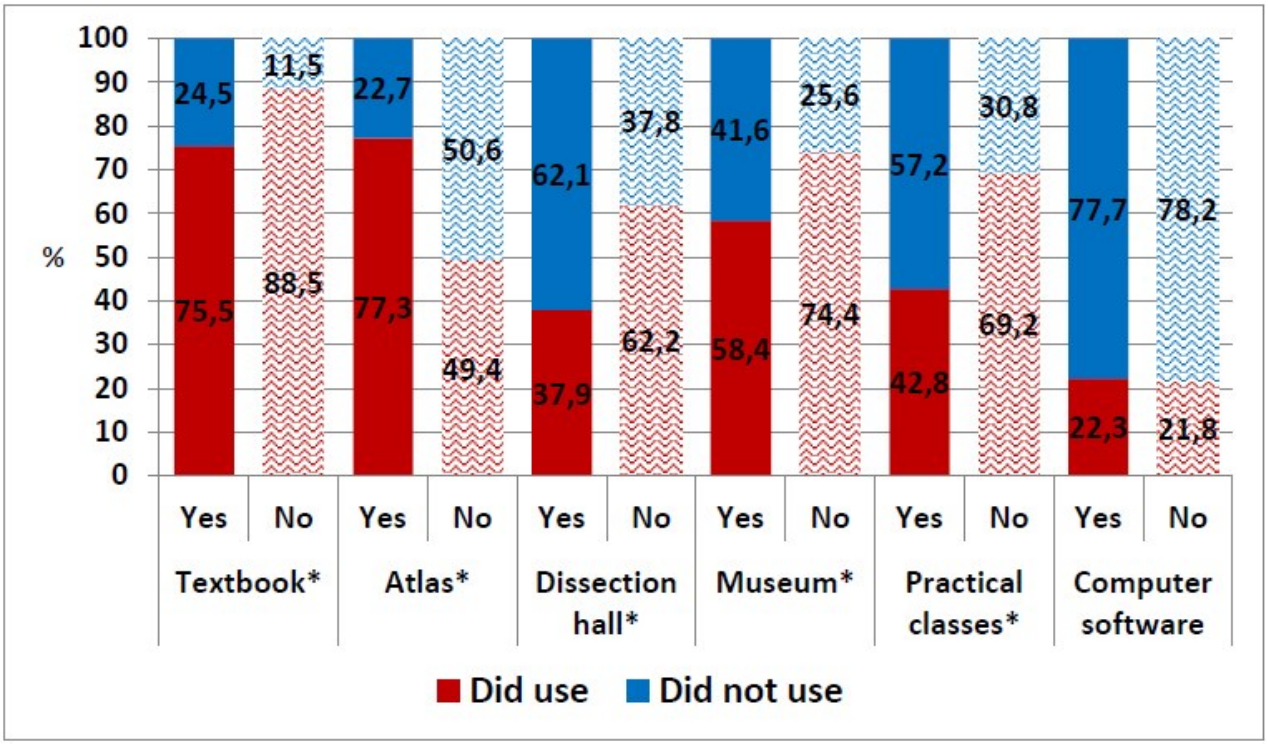

Fig 5. Comparison of resources used by students who did (yes) and did not (no) receive bones. (*) P<0.001

prescribed textbook than those who received bones (88.5% vs. 75.5%); although it is interesting that fewer students without bones used an atlas, compared to those who had bones in their possession (49.4% vs. 77.3%). All the comparisons illustrated in Fig. 5 were statistically significant ($p < 0.001$), except for using computer software.

The question about the usage of the different bones by students on the different courses (Fig. 6) indicated that the skull bones were most frequently used by more than 80% of students from the different courses, except medical students (68.0%). The sternum and ribs were used the least (especially the medical students, of whom only 4.9% and 9.4% used these bones respectively). The bones of the appendicular skeleton were used somewhat more often, especially those from the upper limb. Interestingly, the foot skeleton was used more frequently than the other lower limb bones by occupational and physiotherapy students (84.6% and 70.3% respectively). The occupational therapy students used all the different bones of the skeleton most frequently, while medical students used all the different bones least frequently, except the os coxa (used by only 21.0% of nursing students). All comparisons were statistically significant ($p < 0.0001$), except for the skull.

Responses to open-ended questions

Open-ended questions included questions about resources that students preferred or wished to suggest for learning osteology. Students also had the opportunity to make any other comments or suggestions that could support and enhance the learning of osteology.

These questions revealed that the most commonly used additional resources were the PowerPoint slides used in classes (n = 9), as well as videos shown during practical classes or video tutorials (n = 9). Many students indicated that they preferred more visual aids to learn osteology (n = 36). These 36 suggestions included printed photos, diagrams, flashcards or posters (n = 26), photo atlases or colouring books (n = 5), X-rays (n = 2), plastic bones (n = 2) and 3D models of bones (n = 1). Some students also noted their need for anatomy videos (n = 30), especially the videos shown during the practical classes (n = 25). Eleven students indicated that they preferred to use computer software programs or the internet; nine students desired more interactive practical classes and seven students expressed their need for printed material, such as class notes or handouts of the practical classes. Open-ended questions on computer software programmes used or suggested by students revealed that most students preferred YouTube videos; 18 students indicated that they used these, and 26 students suggested them for use (10.4% of all the participants).

DISCUSSION

From the results, it is clear that most anatomy students at the UFS prefer the use of human bones for studying osteology. Almost 90% of students on the different courses found the use of bones beneficial, while almost 20% of the students indicated that bones remain the most useful resource for learning osteology. The students who chose not to receive a set of bones, made much greater use of the bones and skeletons available in

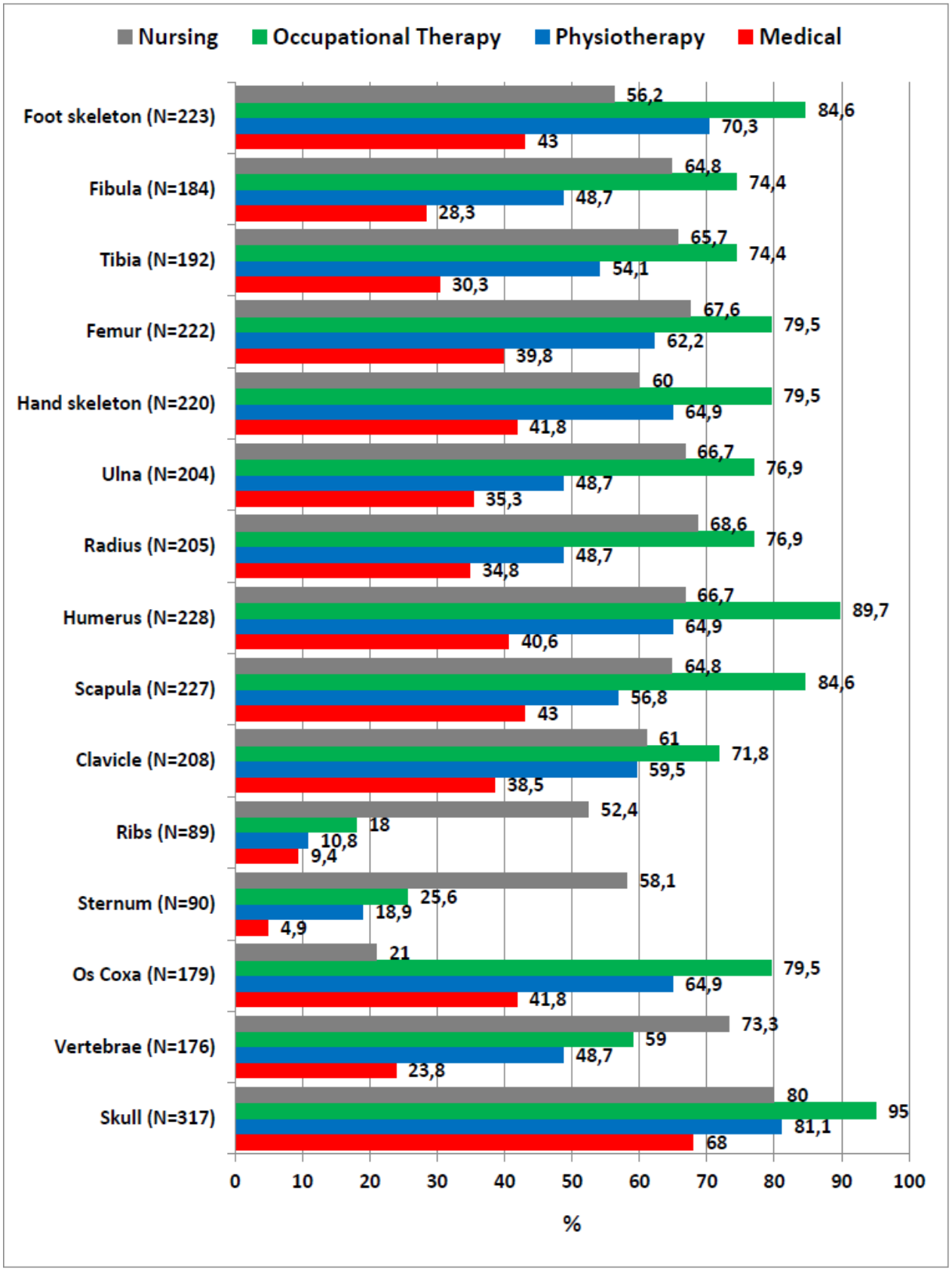

Fig 6. Usage of the different bones by students on the various courses.

the Department than those who received a set with bones. At least half the students on the different courses made use of the skeletons and bones in the museum (especially nursing and occupational therapy students). About three quarters of the nursing students used the skeletons in the dissec-

tion hall and the bones displayed during practical classes.

The majority of students used the bones to learn the orientation and bone markings. However, most of the students did not appreciate using bones to learn neurovascular relationships with bones, which is a pity, due to important neurovascular injuries that could occur with bone fractures. Many students did not use the bones to learn their names or articulations (except for the nursing students, of whom 77.1% used bones for this purpose), though this is most likely because most students already knew the bones' names from school. However, it is somewhat worrying that it appears that students learn the bone markings, but do not appreciate the value of bones to learn muscle attachment sites, as only about half of all the students on the different courses, on average, used the bones for this purpose. A possible explanation for this finding is the workload, level of difficulty and detail involved in learning bone markings and muscle attachments.

Analysis of the usages of the different bones of the skeleton shows that the skull was used most frequently by students from the different courses (81.0% on average), whereas the other bones of the axial skeleton were not used as often (especially the ribs and sternum). The skull is probably used more frequently due to its complexity and because it features in both the neuroanatomy, as well as the head and neck regions of anatomy courses. A matter of concern is the finding that medical students used the bones less frequently compared to students on other courses, especially the occupational therapy students. A possible explanation for this finding is that only medical students at the UFS dissect cadavers. Medical students also had a marked use of textbooks and atlases compared to occupational therapy students (82.4% vs. 51.3% and 91.0% vs 71.8% respectively).

Anatomy students also have a certain preference for visual aids when learning osteology, as seen by their comments on other resources used or suggested. These visual aids include pictures or X-rays, flashcards, textbooks and atlases, as well as videos and digital resources. In the literature, it is clear that students, and even anatomy instructors worldwide, prefer and benefit from a visual approach (Clavert et al., 2012; Mavridis, 2013; Pokhrel and Bhatnagar, 2013; Kugelmann et al., 2018; Chytas, 2019).

The majority of students on the different courses (59.1%, on average) suggested using computer software or digital resources to learn osteology versus the 24.4% of students who already used digital resources. The fact that the Department of Basic Medical Sciences, UFS, does not currently use digital resources on a large scale may explain the results. This study and several research studies (Jaffar, 2012; Barry et al., 2016; Zilverschoon, 2019; Chytas, 2019) demonstrate the popularity of YouTube videos amongst this so-called "YouTube Generation" or "Generation Connected".

Many Open Source programs for anatomy students and instructors are available, such as 3D Slicer and ParaView, and several Web-based digital atlases (Trelease and Rosset, 2008).

Other computer programs include the A.D.A.M. Interactive Anatomy, Dynamic Human, 3D-DOCTOR, Anatomy.t and Anatomy Explorer (Rehman et al., 2012). Cornwall and Pollard (2012) suggest some useful applications, such as free gross anatomy i-applications on portable pocket-sized and handheld devices. Anatomy departments could also develop their own "virtual reality learning objects" (VRLOs) from clinical images, such as CT scans or MRIs (Trelease and Rosset, 2008). Other research studies show that, although computer- assisted learning of anatomy is a favourite way of learning anatomy among students, the majority still prefer actual dissection (Tam et al., 2009; Hasan et al., 2011; Rehman et al., 2012) and consider it as "a very useful addition to the anatomy course" (Kugelmann et al., 2018). Once again, the same could apply to using human bones to learn osteology.

Other suggestions made by the students in this research study could be considered to improve their learning experience e.g., involving the students more in their learning, spending more time on osteology and having more frequent assessments in osteology. Any project or assignment on bones that encourages students to handle and look at bones, but which would not necessarily take up precious academic contact time, could be of value. Student projects involving painting bone markings and building bones or joints in groups could also assist students to learn osteology using a hands-on experience (Williams, 2006; Polizzotto and Ortiz, 2008). Even board games could enhance students' interest in and knowledge of anatomy and osteology (Anyanwu, 2014). Irrespective of the approach, students should be given the opportunity to learn anatomy and osteology through visual exposure and experience. The principle of supported student-directed learning has proven to enhance students' understanding of anatomy and their retention of knowledge (Cowan et al., 2010; Findlater et al., 2012).

CONCLUSION

The debate continues about how to teach osteology most effectively. Students can have a virtual reality tour on YouTube (where digital skeletons and cadavers replace human material), or they can physically handle human bones and cadavers in the dissection hall or practical laboratory. The latter could also promote empathy and respect for the deceased patients. There is no irrefutable proof that virtual imaging can replace human body material in osteology teaching (Visvasom and Jobby, 2017). Therefore, using human bones to study osteology still remains the gold standard.

The findings of this survey contributes to the understanding of how students perceive the utilisation of human bones and other resources for facili-

tating ease of learning of osteology. The outcome indicated that the majority of students still use and prefer human bones to study osteology. However, most of the students proposed that the use of supplemental digital resources was beneficial to the learning of osteology.

Value of study and recommendations

Although the study provides valuable insight into the preferences of anatomy students at the UFS, the institutional contexts and specific anatomy curricula at other institutions might pose other problems or no problems at all. Other institutions might not be in the privileged position of having human bones in their possession for students to use. Irrespective of the situation at any particular anatomy department, it remains true that the new generation of students are visual learners who live in a digital era.

The increasing difficulty to obtain donated human material for teaching purposes, the increasing student numbers and the changing preferences of the current digital orientated students challenge anatomy lecturers to be creative and innovative in their approach to teach osteology. The researchers recommend that the Department of Basic Medical Sciences, UFS, and other anatomy departments should prescribe or suggest internet resources and digital software with selected accuracy and usefulness regarding course outcomes (Azer, 2012; Jaffar, 2012) to accommodate the rapidly expanding digital platform and social-media addicted "Generation Connected".

Anatomy departments should be flexible, and consider the preferred learning methods of students on different courses. Suggestions and findings of this study could be useful in designing a student-directed strategy for teaching and learning osteology.

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