A Comparison of Fourth-Year Health Sciences Students' Knowledge of Gross Lower and Upper Limb Anatomy A Cross-Sectional Study

Q1 Juan-Antonio Díaz-Mancha, PT, PhD,[a] José Manuel Castillo-López, PhD,[b] Pedro V. Munuera, PhD,[c] Lourdes María Fernández-Seguín, PhD,[d] Juan Polo-Padillo, PhD,[e] and Alberto Marcos Heredia-Rizo, PhD[d]

Abstract

Objective: The aim of the study was to assess and compare the knowledge of fourth-year medicine, physiotherapy (PT), nursing, and podiatry students in carpal and tarsal bone anatomy.
Methods: A cross-sectional study was carried out. Based on a nonprobability convenience sampling, 177 fourth-year students (117 women and 60 men, mean age of 23.16 ± 3.82 years) from the podiatry (n = 39), nursing (n = 26), PT (n = 73), and medicine (n = 39) schools at a large Spanish university were included. Measurements were taken of their gross anatomy knowledge by means of the carpal and the tarsal bone tests. Students were asked to identify all carpal and tarsal bones in an illustration of the bony skeleton of both regions and were given a maximum of 5 minutes per test.
Results: Of a total of 15 bones to be labeled, the PT (11.07 ± 3.30) and podiatry (9.36 ± 2.93) students had the highest rate of correct answers compared with the medicine (6.13 ± 3.27) and nursing (4.04 ± 3.72) undergraduates. When assessing academic degrees and test scores, significant differences were observed between PT and podiatry participants vs those from the medicine and nursing schools ($P < .001$).
Conclusion: Fourth-year students from the PT and podiatry programs correctly identified a higher number of carpal and tarsal bones than students from the nursing and medicine schools. (J Manipulative Physiol Ther 2016;xx:1-8)
Key Indexing Terms: *Anatomy; Knowledge; Medical Students; Nursing Students; Physical Therapy; Podiatry*

Introduction

Gross anatomy is one of the most relevant basic disciplines of daily clinical activity in health sciences professions.[1,2] A profound knowledge of human anatomy is expected to be a core component of the academic curricula within medical education programs.[3,4] However, in recent years, the total number of teaching hours of gross anatomy has experienced a progressive decrease within the medicine syllabus.[5] For this reason, more gross anatomy courses are becoming part of an integrated curriculum in some medical schools.[6]

Teaching and learning in anatomy have been the focus of study in medical education.[7] However, the knowledge of gross anatomy is equally important in the curricula of other health care disciplines.[8,9] Following the Bologna declaration, profound changes took place in European higher education with a focus on student-centered learning and curricular harmonization to improve student mobility among universities.[10,11]

[a] DO, Assistant Professor, Department of Physical Therapy, Faculty of Nursing, Physiotherapy and Podiatry, University of Sevilla, Sevilla, Spain.
[b] Department of Podiatry, Faculty of Nursing, Physiotherapy and Podiatry, University of Sevilla, Sevilla, Spain.
[c] Faculty of Nursing, Physiotherapy and Podiatry, University of Sevilla, Sevilla, Spain.
[d] Department of Physical Therapy, Faculty of Nursing, Physiotherapy and Podiatry, University of Sevilla, Sevilla, Spain.
[e] Department of Preventive Medicine and Public Health, Faculty of Medicine, University of Seville, Sevilla, Spain.
Submit requests for reprints to: Alberto-Marcos Heredia-Rizo, PT, PhD, Physiotherapist, Assistant Professor, Department of Physical Therapy, Faculty of Nursing, Physiotherapy, and Podiatry, University of Sevilla, C/ Avicena s/n 41009 Sevilla, Spain. (e-mail: *amheredia@us.es*).
Paper submitted March 10, 2015; in revised form April 1, 2016; accepted April 14, 2016.
0161-4754

http://dx.doi.org/10.1016/j.jmpt.2016.05.007

Table 1. *Gross Anatomy Curricula of the Study Sample*

Degree Program	No. of Students (% of the Total)	ECTS Credits in Anatomy	Amount of Theory Lessons (h)	Amount of Practical Lessons (h)	Total Amount of Hours
PT	73 (41.24)	12	95	25	120
Medicine	39 (22.03)	23	182	48	230
Podiatry	39 (22.03)	12	95	25	120
Nursing	26 (14.68)	6	50	10	60

Q3 *ECTS*, European Credit Transfer System; *PT*, physical therapy.

Traditional teaching techniques (student-performed dissection, theoretical lectures, living and surface anatomy, and use of models) are giving way to new, more up-to-date ways of learning, such as virtual anatomy and dissection, or computer-assisted learning in the so-called learning by doing.[12] Understanding of anatomy needs a combination of memorization and visualization.[13] Therefore, teaching anatomy in a clinical context and providing frequent anatomy topics are essential,[14] although methods of instruction such as dissection should be "a rite of passage," at least for medical students.[15]

Strategies to encourage knowledge transmission are as important as educational knowledge testing to ensure the quality standards of the teaching-learning process.[16,17] Gross anatomy knowledge can be assessed by written, practical, or oral tests.[18] There has been a shift in emphasis from practical and oral evaluation toward written methods, even though it has been advised to preserve the practical test as a key element in the evaluation.[17] Written means of assessment are able to highlight important areas of the curriculum, although they may lack face validity.[17]

To such end, several tools have been designed (ie, anatomy spot tests) like the carpal bone test[19] and the tarsal bone test.[20] These tests may help to provide a preliminary assessment of bone anatomy knowledge among health care professionals providing care for upper and lower extremity musculoskeletal conditions.[20] Previous research shows that medical students report a below-average level of confidence in the region-specific clinical examination of the musculoskeletal system[21] and that they exhibit worse retention of carpal bones anatomy than physical therapy students.[22]

The aim of the study was to assess and compare the knowledge of fourth-year medicine, physiotherapy (PT), nursing, and podiatry students in carpal and tarsal bone anatomy using the carpal and the tarsal bone tests.

Methods

Design

An observational and cross-sectional study was carried out.

Participants

Based on a nonprobability convenience sampling, 221 fourth-year students from the nursing, podiatry, PT, and medical schools at a large Spanish University were asked to participate as volunteers. Of the total number of eligible participants, 44 of them declined to take part. The study was conducted at the end of May 2014, during the 2013-2014 academic year. The whole sample included 177 students from the podiatry (n = 39), nursing (n = 26), PT (n = 73), and medicine (n = 39) programs. Data collection took place during standard class time, and participants were advised that results from the study were not part of their university assessment.

In Spain, PT, nursing, and podiatry are 4-year degree programs, whereas medical school is a 6-year degree. Therefore, at the time of data collection, PT, nursing, and podiatry participants were about to finish the fourth and last term of their degree and very close to gain licensure, in contrast with students from the medical school. After the 6-year degree program, medical students have to receive residency training for 3 or 4 years before licensure.

All students had passed the gross anatomy examinations in their own degree program. The University of Seville curriculum model, for all assessed disciplines in this study, follows a traditional approach wherein basic science instruction precedes clinical science instruction. The gross anatomy course is taught in the first year of the curriculum for nursing, PT, and podiatry studies, whereas in the medical school anatomy, it is included in the first 2 years. In either case, gross anatomy subject is, therefore, prior to the study of diagnosis, pathology, and treatment methods. The same Anatomy department teaches in these 4 disciplines with similar standards and usually with the same professors. However, the total amount of anatomy teaching hours does differ between disciplines (Table 1). Gross anatomy is divided into theoretical and practical lectures. Anatomy practical lessons take place in dissection rooms. After a brief theoretical introduction, students proceed to the recognition of a number of anatomic samples (ie, sheets, models, previously prepared anatomic material, and corpses). In addition, the medical degree includes a significant amount of further training on anatomic and sectional radiology.

Ethical Approval

The study protocol fully complied with the ethical guidelines established by the institutional review board of the University of Seville, Spain. It was designed and

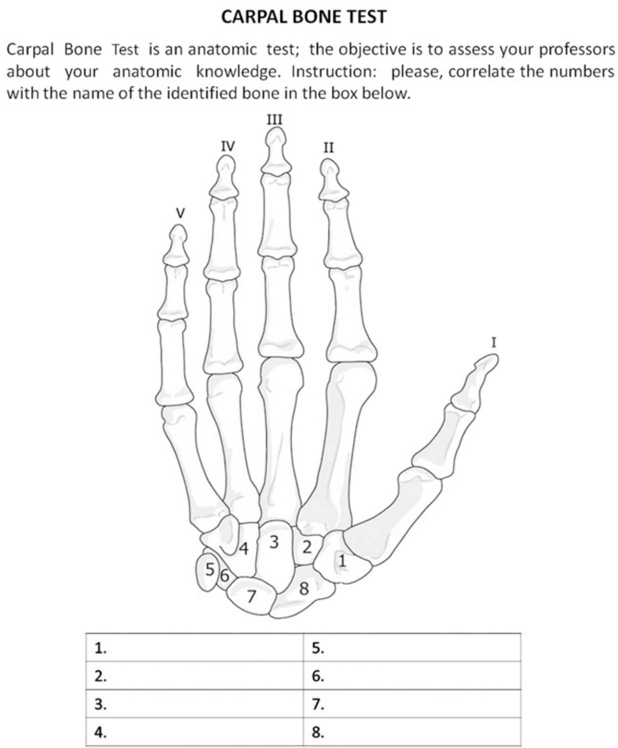

Fig 1. *The carpal bone test. Reprinted with permission from Valenza et al.*[22]

conducted according to the Helsinki Declaration. All subjects signed and submitted an informed consent form prior to their inclusion in the study.

Outcome Measures

Carpal and Tarsal Bone Tests. In the carpal bone test (Fig 1),[22] participants are asked to label hand and wrist bones. The bones of the carpal region can be easily and objectively examined and have clinical relevance in a number of disciplines. This test has been previously used to assess the level of retention of gross anatomy knowledge among students of different health science disciplines.[9,22,23]

The tarsal bone test has been developed and tested on first- and fourth-year podiatric students to establish a goal standard.[20] Similarly to the carpal bone test, this tool requests the student to label each tarsal bone in a drawing of the bones of the foot (Fig 2).[20] Both tests appear to be valid instruments to provide an insight into the level of knowledge of bone anatomy among health care students in different stages of training.[19,20]

Data Collection

The evaluation tools were administered during regular lesson time and without any prior notice to the participants. The researcher briefly explained that each test was to be

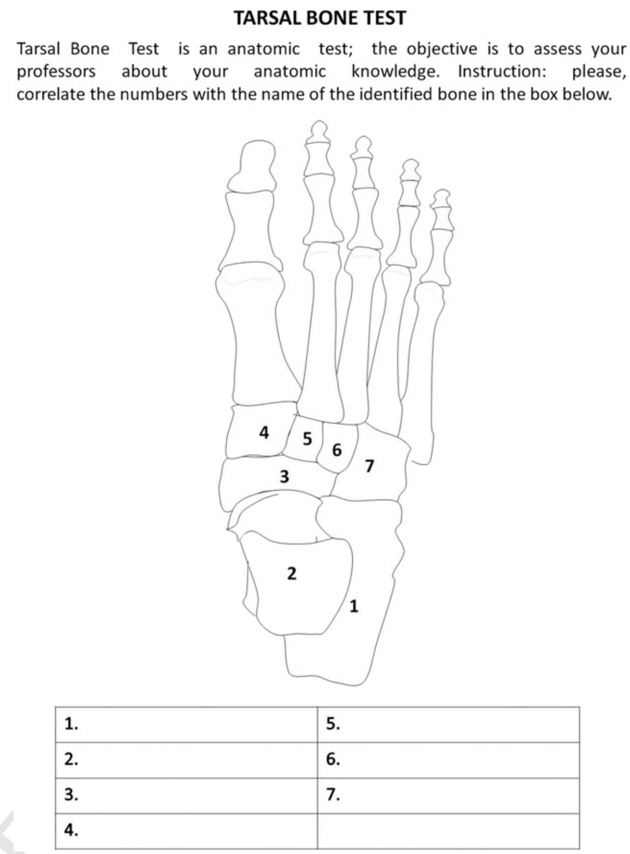

Fig 2. *The tarsal bone test. Reprinted with permission from Castillo-López et al.*[20]

completed in 5 minutes and that the students were not allowed to speak to each other. The carpal bone test was handed in first, and then the students received the tarsal bone test. Participants were also asked to hand in the test as they finished and to remain in silence.

Data Analysis

The data were analyzed with the SPSS statistical software package for Windows (SPSS Science, Chicago, IL). The results are presented using descriptive statistics. Between-group differences in the distribution of the responses were analyzed with the χ^2 test. Standardized residuals larger than 2 (absolute value) were seen as a significant outcome difference. The analysis of variance single-factor variation model was used to identify the group of students with the highest number of right answers, and the Bonferroni correction was used for multiple cross-comparisons. The statistical analysis was conducted at a P value < .05 and a 95% confidence level.

Results

The gross anatomy curricula of the study sample are listed in Table 1, whereas baseline data of the participants

Table 2. *Baseline Characteristics of the Study Sample*

	Total Sample (N = 177)	PT (n = 73)	Podiatry (n = 39)	Nursing (n = 26)	Medicine (n = 39)	*P* Value
Mean age (y)	23.16 ± 3.82	23.28 ± 4.14	23.64 ± 3.30	24.12 ± 5.62	21.85 ± 0.93	.073
Sex						.003
Male (%)	60 (33.89)	21 (28.76)	15 (38.46)	3 (11.53%)	21 (53.84)	
Female (%)	117 (66.10)	52 (71.23)	24 (61.53)	23 (88.46)	18 (46.15)	

Data are reported as mean ± standard deviation or in frequencies (%).

Table 3. *Frequency of Wrongly Labeled Bones or Blank Responses, Classified by Academic Degree*

No.	No. of	Academic Degree (% of the Number of Errors)			
of Errors	Students (% of the Total)	PT	Podiatry	Nursing	Medicine
0	24 (13.6)	18 (75)	5 (20.83)	0 (0)	1 (4.16)
1	7 (4.0)	7 (100)	0 (0)	0 (0)	0 (0)
2	7 (4.0)	4 (57.14)	3 (42.86)	0 (0)	0 (0)
3	7 (4.0)	4 (57.14)	2 (28.57)	1 (14.28)	0 (0)
4	13 (7.3)	8 (61.54)	2 (15.38)	2 (15.38)	1 (7.69)
5	14 (7.9)	6 (42.85)	2 (14.28)	2 (14.28)	4 (28.57)
6	16 (9.0)	9 (56.25)	2 (12.5)	0 (0)	5 (31.25)
7	17 (9.6)	5 (29.41)	7 (41.18)	0 (0)	5 (29.41)
8	22 (12.4)	5 (22.73)	15 (68.18)	1 (4.54)	1 (4.54)
9	7 (4.0)	4 (57.14)	1 (14.29)	0 (0)	2 (28.57)
10	7 (4.0)	0 (0)	0 (0)	1 (14.28)	6 (85.71)
11	10 (5.6)	3 (30)	0 (0)	2 (20)	5 (50)
12	11 (6.2)	0 (0)	0 (0)	7 (63.64)	4 (36.36)
13	6 (3.4)	0 (0)	0 (0)	3 (50)	3 (50)
14	5 (2.8)	0 (0)	0 (0)	4 (80)	1 (20)
15	4 (2.3)	0 (0)	0 (0)	3 (75)	1 (25)
Total	177 (100)	73 (41.24)	39 (22.03)	26 (14.69)	39 (22.03)

Data are reported in absolute values and frequencies (%).

by age, sex, and university degree are included in Table 2. Of the total male participants, only 5% of them (3/60) were from the nursing school, whereas 15.38% of the female subjects (18/117) were studying medicine.

Table 3 shows the frequency of carpal and tarsal bones that were mislabeled or left blank. Only 13.56% of subjects (24/177) correctly identified all bones in the carpal and tarsal tests (18 of them from PT, 5 from podiatry, and 1 from medicine) (Table 3). An additional 7 PT students (3.95% from the total) only got 1 single missed or blank answer. The remaining 146 participants (82.48%) were unable to identify 2 or more bones. The percentage of error was especially high among the nursing and medical undergraduates. Over half of them could not label correctly more than half of the bones (eight or more), which means a total of 80.76% for nursing participants (21/26) and 58.97% (23/39) for medical students.

A between-groups comparison observed that students from the PT degree were able to mark the highest number of bones (11.07 ± 3.30), with statistically significant differences ($P < .001$) with nursing (4.04 ± 3.72) and medical undergraduates (6.13 ± 3.27). No statistical significance ($P = .057$) was found between PT and podiatry (mean score of 9.36 ± 2.93). There were also significant differences between podiatry undergraduates and nursing and medical participants ($P < .001$ in both cases). Finally, no significant differences were found between medical and nursing groups ($P = .077$).

Tables 4 and 5 list the data resulting from labeling each tarsal and carpal bone, classified by academic degree. The tables also include the number and percentage of right, wrong, or blank answers and the residual data derived from the contingency table and the χ^2 test. The above parameters showed that PT students observed the highest rate of right answers for the carpal bone test (Table 5) (absolute value of corrected residual being larger than 2), whereas Table 4 shows the same findings for podiatry students in the tarsal bone test.

The bone that received the highest number of right answers was the calcaneus bone (170) followed by the astragalus (162). On the contrary, the trapezoid (127 misses) and lunate (118 misses) bones were the most frequently mislabeled.

Discussion

Anatomy embodies a key role for its influence in daily clinical practice in health sciences disciplines.[2] Even though

Table 4. *Scores in the Tarsal Bone Test by Student Group*

	Academic Degree				
Assessed Bone	PT	Podiatry	Nursing	Medicine	χ^2 (*P*)
Calcaneus					
Yes [% int (correct r.)]	73 [100 (2.3)]	39 [100 (1.4)]	22 [84.6 (−3.2)]	36 [92.3 (−1.4)]	14.98
No [% int (correct r.)]	0 [0 (−2.3)]	0 [0 (−1.4)]	4 [15.4 (3.2)]	3 [7.7 (1.4)]	(.002)
Astragalus					
Yes [% int (correct r.)]	72 [98.6 (2.8)]	39 [100 (2.2)]	17 [65.4 (−5.2)]	34 [87.2 (−1.1)]	32.22
No [% int (correct r.)]	1 [1.4 (−2.8)]	0 [0 (−2.2)]	9 [34.6 (5.2)]	5 [12.8 (1.1)]	(<.001)
Navicular					
Yes [% int (correct r.)]	59 [80.8 (2.9)]	39 [100 (4.7)]	7 [26.9 (−5.0)]	17 [43.6 (−3.9)]	55.51
No [% int (correct r.)]	14 [19.2 (−2.9)]	0 [0 (−4.7)]	19 [73.1 (5.0)]	22 [56.4 (3.9)]	(<.001)
Medial cuineiform					
Yes [% int (correct r.)]	61 [83.6 (3.9)]	39 [100 (4.9)]	6 [23.1 (−5.2)]	13 [33.3 (−5.1)]	71.19
No [% int (correct r.)]	12 [16.4 (−3.9)]	0 [0 (−4.9)]	20 [76.9 (5.2)]	26 [66.7 (5.1)]	(<.001)
Intermed cuneiform					
Yes [% int (correct r.)]	63 [86.3 (4.4)]	39 [100 (4.9)]	6 [23.1 (−5.3)]	12 [30.8 (−5.6)]	78.28
No [% int (correct r.)]	10 [13.7 (−4.4)]	0 [0 (−4.9)]	20 [76.9 (5.3)]	27 [69.2 (5.6)]	(<.001)
Lateral cuneiform					
Yes [% int (correct r.)]	61 [83.6 (4.0)]	39 [100% (5.0)]	5 [19.2 (−5.6)]	13 [33.3 (−5.0)]	74.70
No [% int (correct r.)]	12 [16.4 (−4.0)]	0 [0% (−5.0)]	21 [80.8 (5.6)]	26 [66.7 (5.0)]	(<.001)
Cuboid					
Yes [% int (correct r.)]	54 [74.0 (2.2)]	39 [100 (5.3)]	1 [3.8 (−7.0)]	20 [51.3 (−1.9)]	68.99
No [% int (correct r.)]	19 [26.0 (−2.2)]	0 [0 (−5.3)]	25 [96.2 (7.0)]	19 [48.7 (1.9)]	(<.001)

Percentages are added between brackets in each cell.
Yes = right answer (absolute values); no = wrong answer (absolute values); [% int (correct r.)] = internal percentage (corrected residual).

the specific training in gross anatomy subject takes place over the first years of the curricula, this knowledge should be reinforced over the following curricular stages.[20] All participants were fourth-year students; thus, they were expected to have a fairly consolidated knowledge of gross anatomy.[19] The clinical context has been purported to be useful to learn anatomy and to strengthen previous knowledge.[14] Medical students were the only group who has not been to any clinical placements yet, which may help to explain some of the current findings.

The carpal and the tarsal bone tests represent easy-to-use, objective evaluation tools to determine the extent to which participants are able to retain and identify carpal and tarsal bones.[23] However, both instruments can be considered as well as a simplistic way to measure anatomic knowledge.[19,20] Carpal and tarsal bones are important areas in region-specific musculoskeletal medicine. Foot and ankle musculoskeletal problems have been purported to affect around 20% of middle-aged to older people,[24] and it is also estimated that 70% of adults in Western countries experience dysfunction in the upper limb at some point during their life.[25] This issue is a challenge for public health services because of its impact on subjects' quality of life.[26] However, even though health sciences students should be well trained in region-specific musculoskeletal medicine, they have shown low confidence in anatomic physical examination of upper and lower extremities.[21]

This is the first study that assesses and compares the degree of retention of bone anatomy knowledge in undergraduates from 4 different health care disciplines. The present findings observed that participants from PT and podiatry programs scored higher in labeling carpal and tarsal bones than nursing and medical students at the University of Seville. These between-group differences were statistically significant ($P < .001$). Likewise, for all disciplines, the percentage of right answers was higher in the tarsal bone test than in the carpal bone test.

Nursing participants represented the group who identified correctly fewer bones. Nursing was also the discipline with less number of practical tuition hours in gross anatomy (Table 1). However, the optimum quantity of anatomy education remains controversial, and that does not seem to be the only factor involved in students' knowledge.[14] In fact, medical students had received almost 50 hours of practical lessons, and no positive between-group differences were found for them. Nursing students have been purported to have difficulties in using anatomic information into the clinical context[27,28] and seem to be rather apprehensive about attending anatomy sessions in the dissection room.[29]

The format of gross anatomy courses contained in nursing programs has been previously questioned.[30] Interprofessional learning in anatomy between medical and nursing students has been proposed in an early phase of training to promote a learning-together scenario.[31] Nursing undergraduates need knowledge of surface anatomy,[32] but the use of human cadaveric material is also crucial,[33] as it was the case in the present study. Laboratory sessions and hands-on experience have been described for nursing undergraduates to enable them to get and retain knowledge.[34] The present assessment tools cannot explain or compare the general competencies, curricula structure, and/or the clinical knowledge of gross

Table 5. *Scores in the Carpal Bone Test by Student Group*

	Academic Degree				
Assessed Bone	PT	Podiatry	Nursing	Medicine	χ^2 (*P*)
Trapezium					
Yes [% int (correct r.)]	35 [47.9 (2.9)]	10 [25.6 (−1.5)]	6 [23.1 (−1.4)]	12 [30.8 (−0.7)]	8.72
No [% int (correct r.)]	38 [52.1 (−2.9)]	29 [74.4 (1.5)]	20 [76.9 (1.4)]	27 [69.2 (0.7)]	(.033)
Trapezoid					
Yes [% int (correct r.)]	32 [43.8 (3.9)]	9 [23.1 (−0.8)]	0 [0 (−3.5)]	9 [23.1 (−0.8)]	20.02
No [% int (correct r.)]	41 [56.2 (−3.9)]	30 [76.9 (0.8)]	26 [100% (3.5)]	30 [76.9 (0.8)]	(<.001)
Capitate					
Yes [% int (correct r.)]	63 [86.3 (6.8)]	19 [48.7 (−1.0)]	4 [15.4 (−4.5)]	13 [33.3 (−3.2)]	53.56
No [% int (correct r.)]	10 [13.7 (−6.8)]	20 [51.3 (1.0)]	22 [84.6 (4.5)]	26 [66.7 (3.2)]	(<.001)
Hamate					
Yes [% int (correct r.)]	61 [83.6 (5.3)]	16 [41.0 (−2.8)]	7 [26.9 (−3.8)]	23 [59.0 (−0.2)]	34.72
No [% int (correct r.)]	12 [16.4 (−5.3)]	23 [59.0 (2.8)]	19 [73.1 (3.8)]	16 [41.0 (0.2)]	(<.001)
Pisiform					
Yes [% int (correct r.)]	58 [79.5 (6.4)]	11 [28.2 (−3.2)]	6 [23.1 (−3.1)]	15 [38.5 (−1.8)]	42.32
No [% int (correct r.)]	15 [20.5 (−6.4)]	28 [71.8 (3.2)]	20 [76.9 (3.1)]	24 [61.5 (1.8)]	(<.001)
Triquetum					
Yes [% int (correct r.)]	42 [57.5 (5.1)]	14 [35.9 (0.0)]	0 [0 (−4.1)]	7 [17.9 (−2.6)]	34.99
No [% int (correct r.)]	31 [42.5 (−5.1)]	25 [64.1 (0.0)]	26 [100 (4.1)]	32 [82.1 (2.6)]	(<.001)
Lunate					
Yes [% int (correct r.)]	35 [47.9 (3.5)]	13 [33.3 (0.0)]	6 [23.1 (−1.2)]	5 [12.8 (−3.1)]	15.63
No [% int (correct r.)]	38 [52.1 (−3.5)]	26 [66.7 (0.0)]	20 [76.9 (1.2)]	34 [87.2 (3.1)]	(.001)
Scaphoid					
Yes [% int (correct r.)]	39 [53.4 (2.2)]	18 [46.2 (0.4)]	10 [38.5 (−0.6)]	10 [25.6 (−2.5)]	8.38
No [% int (correct r.)]	34 [46.6 (−2.2)]	21 [53.8 (−0.4)]	16 [61.5 (0.6)]	29 [74.4 (2.5)]	(0.039)

Percentages are added between brackets in each cell.

anatomy among the study subjects, as they only evaluate the students' retention capacity of tarsal and carpal bones. However, this study raises some questions that need to be answered.

In line with former research,[22] the present results found that medical students were unable to identify the same number of carpal bones as other health care students, with the differences being statistically significant with PT and podiatry groups. Only 4 bones (hamate, calcaneus, astragalus, and cuboid) were correctly marked by at least half of the 39 medical students. For the carpal bone test, the present scores seem to be similar to those described previously.[19,22] In Spielman and Oliver's study,[19] 16% (4/24) of fourth- and fifth-year medical students identified all carpal bones with no mistakes vs only 1 of 39 subjects (2.56%) in our research. Valenza et al[22] recruited 80 medical students, and only 1 of them (1.25%) labeled properly all the carpal bones. The rate of right answers in this former study was between 36.2% and 46.3% for medical students.[22] Those observations are similar to our findings, where the highest percentages of right answers in the carpal bone test were found for the hamate (59%), pisiform (38.5%), and capitate (33.3%) bones. This is the first study undertaken by medical undergraduates including the tarsal bone test; thus, it is not possible to compare with previous research. It is worth mentioning that a single medical student (2.56%) identified correctly all bones in the tarsal test.

Despite the relevance of anatomy in the medical curriculum,[2] medical students' feedback suggests that they lack confidence about their musculoskeletal training and knowledge, which they believe should be better integrated into the clinical setting.[35] Clinical rotations and internships help to reinforce basic knowledge, but medical students from this study had not been to any clinical placements yet. It has been concluded that medical students seem to have a deficient education in the musculoskeletal field[35,36] and that a curricular reform in musculoskeletal medicine may be needed.[37] However, the present findings cannot explain or discuss any of these issues, and future research is needed for this purpose.

The best scores were observed for the PT and podiatry groups. PT is a discipline with a high specificity of musculoskeletal anatomy contents in the curricula.[22] The combination of images and palpation has become a suitable way to teach anatomy to PT undergraduates, and it helps to consolidate the knowledge in later stages of the curricula.[38] This issue could also be a plausible explanation for the good results of podiatry students. Throughout the whole podiatry degree, training focused on image-based diagnosis, physical examination, and clinical practice in foot disorders is at the core of the students' daily routine. Therefore, during their last year, the identification of tarsal bones may not be difficult. Podiatry students of the present study made no mistakes in labeling tarsal bones. This finding is similar to the results of Castillo-López et al[20] who used the tarsal bone test in 254 first- and fourth-year podiatry undergraduates from different Spanish universities. More than 97% of them (247/254) made no mistakes, and only 1 fourth-year student identified incorrectly 1 tarsal bone. On the contrary, the number of mislabeled bones among this group for the carpal bone test was remarkably higher and ranged between 51.3% for the capitate bone and 76.9% for the trapezoid bone (Table 5).

The sensation of palpation in the dissection room in the early stages of training is essential for establishing the grounds for the future health professional.[39] A continuous reinforcement of anatomy knowledge in daily clinical training is also crucial in strengthening the skills to palpate and identify structures.[40] In the PT program, different manual therapy techniques that are taught over the last 2 years of the degree require precise location and mobilization of specific bones, which lead to a constant feedback about gross anatomy. Practical sessions are also a core element of the training in the last years of PT and podiatry programs, and they usually take place in small groups; thus, the teacher-student interaction is permanent. For the PT group, the capitate and hamate bones were the most accurately labeled, which can be due to their singular anatomic size and morphology. The same results were reported by Valenza et al.[22] On the contrary, the trapezium and trapezoid were the most frequently mislabeled bones, in concordance with Valenza et al[22] and Strkalj et al.[9]

Limitations

Only 2 anatomic regions were assessed by the tarsal and carpal bone tests. Although the validity and reliability of these tools have not been established yet, both of them have been previously used in several studies.[19,20,22,23] Because of the lack of validation of the assessment tools and the study methodology, the present findings cannot be generalized. The present project was performed at a single Spanish university. Therefore, it is difficult to know if the results would differ with a larger sample, with other anatomic regions being tested, and with several universities being included. Undergraduates from the podiatry, nursing, and PT schools were all at the end of their academic degree and close to gaining licensure. This was not the case for medical students. Medical studies are a 6-year program, but after that, students receive residency training for 3 or 4 years before licensure. Therefore, this group of participants was at the middle of their academic career. Clinical rotations and internships expose students to review basic sciences principles, and the structure of medical school curricula may, in fact, count on this redundancy. Hence, the possible influence of reinforcing anatomy knowledge into the clinical context was not similar in the study groups. A longitudinal study could help to answer this question. Finally, the use of a purposive sampling instead of a random selection represents a threat to the generalization of the findings. The evaluation tests do not allow any conclusions about overall knowledge of anatomy, clinical skills, and/or competencies between the student groups. Future studies assessing region-specific musculoskeletal knowledge and the level of undergraduates' and graduates' competency and confidence in gross anatomy are needed.

Conclusions

A group of fourth-year PT and podiatry undergraduates was able to correctly identify a higher number of tarsal and carpal bones in gross anatomy tests in comparison with students from the nursing and medicine programs.

Funding Sources and Potential Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): J.A.D.M.
Design (planned the methods to generate the results): J.A.D.M., J.M.C.L., P.V.M., L.M.F.S., J.P.P., A.M.H.R.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): J.A.D.M., J.M.C.L., P.V.M., L.M.F.S., J.P.P., A.M.H.R.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): J.A.D.M., J.M.C.L., P.V.M., L.M.F.S.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): J.P.P., P.V.M.
Literature search (performed the literature search): J.A.D.M., J.M.C.L., P.V.M., L.M.F.S., A.M.H.R.
Writing (responsible for writing a substantive part of the manuscript): P.V.M., L.M.F.S., A.M.H.R.
Critical review (revised manuscript for intellectual content; this does not relate to spelling and grammar checking): J.A.D.M., J.M.C.L., P.V.M., L.M.F.S., J.P.P., A.M.H.R.

Practical Applications

- The current study showed that PT and podiatry students were able to correctly label a higher number of carpal and tarsal bones when compared with nursing and medical undergraduates.
- General competencies and knowledge about gross anatomy are not comparable between health professions (nursing, podiatry, medicine, and PT) using 2 simplistic tests like the tarsal and carpal bone tests.
- Future longitudinal studies among health care students to assess the adequacy of region-specific musculoskeletal knowledge and the level of competency and confidence in gross anatomy knowledge are needed.

References

1. Pabst R. Anatomy curriculum for medical students: what can be learned for future curricula from evaluations and questionnaires completed by students, anatomists and clinicians in different countries? Ann Anat 2009;191:541-6.
2. Arráez-Aybar LA, Sánchez-Montesinos I, Mirapeix RM, Mompeo-Corredera B, Sañudo-Tejero JR. Relevance of human anatomy in clinical practice. Ann Anat 2010;192: 341-8.
3. Rizzolo LJ, Stewart WB. Should we continue teaching anatomy by dissection when…? New Anat 2006;289B:215-8.
4. Badenhorst E, Mamede S, Hartman N, Schmidt HG. Exploring lecturers' views of first-year health science students' misconceptions in biomedical domains. Adv Health Sci Educ Theory Pract 2014 [in press].
5. Drake RL, McBride JM, Lachman N, Pawlina W. Medical education in the anatomical sciences: the winds of change continue to blow. Anat Sci Educ 2009;2:253-9.
6. Drake RL, McBride JM, Pawlina W. An update on the status of anatomical sciences education in United States medical schools. Anat Sci Educ 2014;7:321-5.
7. Wilhelmsson N, Dahlgren LO, Hult H, Scheja M, Lonka K, Josephson A. The anatomy of learning anatomy. Adv Health Sci Educ 2010;15:153-65.
8. McCuskey RS, Carmichael SW, Kirch DG. The importance of anatomy in health professions education and the shortage of qualified educators. Acad Med 2005;80:349-51.
9. Strkalj G, Schroder T, Pather N, Solyali V. A preliminary assessment of the fifth-year chiropractic students' knowledge of anatomy. J Altern Complement Med 2011;17:63-6.
10. Michaud PA. Reforms of the pre-graduate curriculum for medical students: the Bologna process and beyond. Swiss Med Wkly 2012;142.
11. Martens K, Knodel P, Windzio M, Ed. Internationalization of education policy. A new constellation of statehood in education? London: Palgrave Macmillan; 2014:43-4.
12. Chirculescu ARM, Chirculescu M, Morris JF. Anatomical teaching for medical students from the perspective of European Union enlargement. Anat 2007;11:63-5.
13. Pandey P, Zimitat C. Medical students' learning of anatomy: memorisation, understanding and visualisation. Med Educ 2007;41:7-14.
14. Bergman EM, Prince KJ, Drukker J, van der Vleuten CP, Scherpbier AJ. How much anatomy is enough? Anat Sci Educ 2008;1:184-8.
15. Farey JE, Sandeford JC, Evans-McKendry GD. Medical students call for national standards in anatomical education. Surg 2014;84:813-5.
16. Larsen DP, Butler AC, Roediger HL. Test-enhanced learning in medical education. Med Educ 2008;42:959-66.
17. Rowland S, Ahmed K, Davies DC, et al. Assessment of anatomical knowledge for clinical practice: perceptions of clinicians and students. Surg Radiol Anat 2011;33:263-9.
18. Lukic IK, Gluncic V, Katavic V, Petanjek Z, Jalsovec D, Marusic A. Weekly quizzes in extended-matching format as a means of monitoring students' progress in gross anatomy. Ann Anat 2001;183:575-9.
19. Spielmann PM, Oliver CW. The carpal bones: a basic test of medical students' and junior doctors' knowledge of anatomy. Surgeon 2005;1:257-9.
20. Castillo-López JM, Díaz-Mancha JA, Heredia-Rizo AM, Fernández-Seguín LM, Polo-Padillo J, Domínguez-Maldonado G, et al. The tarsal bone test: a basic test of health sciences students' knowledge of lower limb anatomy. Biomed Res Int 2014;939163.
21. Day CS, Yeh AC. Evidence of educational inadequacies in region-specific musculoskeletal medicine. Clin Orthop Relat Res 2008;466:2542-7.
22. Valenza MC, Castro-Martín E, Valenza G, Guirao-Piñeiro M, De-la-Llave-Rincón AI, Fernández-de-las-Peñas C. Comparison of third-year medical and physical therapy students' knowledge of anatomy using the carpal bone test. J Manipulative Physiol Ther 2012;35:121-6.
23. Meyer AJ, Armson A, Losco CD, Losco B, Walker BF. Factors influencing student performance on the carpal bone test as a preliminary evaluation of anatomical knowledge retention. Anat Sci Educ 2015;8:133-9.
24. Thomas MJ, Roddy E, Zhang W, Menz HB, Hannan MT, Peat GM. The population prevalence of foot and ankle pain in middle and old age: a systematic review. Pain 2011;152: 2870-80.
25. Huisstede BM, Bierma-Zeinstra SM, Koes BW, Verhaar JA. Incidence and prevalence of upper-extremity musculoskeletal disorders. A systematic appraisal of the literature. BMC Musculoskelet Disord 2006;7:7.
26. Rao S, Riskowski JL, Hannan MT. Musculoskeletal conditions of the foot and ankle: assessments and treatment options. Best Pract Res Clin Rheumatol 2012;26:345-68.
27. McVicar A, Clancy J. Education. The Biosciences and fitness for practice. A time for review? Nurs 2011;10:1415-20.
28. Tanner CA. Science and nursing education. J Nurs Educ 2003; 42:3-4.
29. Meskell M, O'Connor JE. Nursing students' perceptions on the use of anatomical prosections as an educational tool. Anat 2007;11:73-7.
30. Diekelmann NL. Guest editorial. Creating an inclusive science for nursing education. Nurs Educ Perspect 2005;26:64-5.
31. Herrmann G, Woermann U, Schlegel C. Interprofessional education in anatomy: learning together in medical and nursing training. Anat Sci Educ 2015;8:324-30.
32. McLachlan JC. New path for teaching anatomy: living anatomy and medical imaging vs. dissection. New Anat 2004;281:4-5.
33. Johnston AN. Anatomy for nurses: providing students with the best learning experience. Nurse Educ Pract 2010;10:222-6.
34. Johnston AN, McAllister M. Back to the future with hands-on science: students' perceptions of learning anatomy and physiology. J Nurs Educ 2008;47:417-21.
35. Day CS, Yeh AC, Franko O, Ramirez M, Krupat E. Musculoskeletal medicine: an assessment of the attitudes and knowledge of medical students at Harvard Medical School. Acad Med 2007;82:452-7.
36. Bernstein J, Alonso DR, DiCaprio M, Friedlaender GE, Heckman JD, Ludmerer KM. Curricular reform in musculoskeletal medicine: needs, opportunities, and solutions. Clin Orthop Relat Res 2003;415:302-8.
37. DiCaprio MR, Covey A, Bernstein J. Curricular requirements for musculoskeletal medicine in American medical schools. J Bone Joint Surg Am 2003;85:565-7.
38. Gabard DL, Lowe DL, Chang JW. Current and future instructional methods and influencing factors in anatomy instruction in physical therapy and medical schools in the U.S. J Allied Health 2012;41:53-62.
39. Moore NA. To dissect or not to dissect? Anat Record 1998;253:8-9.
40. Nicoll L, Butler M. The study of biology as a cause of anxiety in student nurses undertaking the common foundation programme. J Adv Nurs 1996;24:615-24.

AUTHOR QUERY FORM

ELSEVIER	Journal: YMMT Article Number: 1481	Please e-mail your responses and any corrections to: E-mail: Corrections.ESSD@elsevier.spitech.com

Dear Author,

Please check your proof carefully and mark all corrections at the appropriate place in the proof (e.g., by using on-screen annotation in the PDF file) or compile them in a separate list. Note: if you opt to annotate the file with software other than Adobe Reader then please also highlight the appropriate place in the PDF file. To ensure fast publication of your paper please return your corrections within 48 hours.

For correction or revision of any artwork, please consult http://www.elsevier.com/artworkinstructions.

We were unable to process your file(s) fully electronically and have proceeded by

☐ Scanning (parts of) your article ☐ Rekeying (parts of) your article ☐ Scanning the artwork

Any queries or remarks that have arisen during the processing of your manuscript are listed below and highlighted by flags in the proof. Click on the 'Q' link to go to the location in the proof.

Location in article	Query / Remark: click on the Q link to go Please insert your reply or correction at the corresponding line in the proof
Q1	The author names have been tagged as given names and surnames (surnames are highlighted in teal color). Please confirm if they have been identified correctly.
Q2	Please provide an update for reference '4'.
Q3	Please verify that abbreviations have been added correctly.
Q4	For Reference 20, please verify authors are listed correctly.

Please check this box if you have no corrections to make to the PDF file. ☐

Thank you for your assistance.