Teaching Musculoskeletal Anatomy: A Technique for Active Learners

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Anatomy laboratory courses have traditionally been taught using a combination of laboratory manuals, anatomy atlases, models and dissections (or prosections). Little variety in the presentation of anatomical information is offered by these conventional media, and few opportunities exist for students to be creative or to question and discuss the relevance of what they are learning. This style of teaching leads students to believe that learning anatomy requires only memorization of anatomical terms, without understanding the relationships between structure and function.

Despite the current biology teaching philosophy that promotes the use of a variety of teaching approaches and cooperative learning activities (e.g. BSCS 1993; NRC 1997; Uno 1997), anatomy instruction seems stuck in the mire of traditionally passive teaching methodology. Anatomy instructors face the challenges of expanding student vocabularies, while, as in any survey course, introducing many new classification systems. With such a vast quantity of information to teach, anatomy instructors often resort to the fastest means of presentation, including lecturing and providing ready-made models and prosected specimens. The assumption of this mode of instruction is that students will be able to walk into the classroom, and in a two-hour lab, see, and to some extent, manipulate the anatomical structures in the region of the body they are required to know. Unfortunately, the ultimate goal, to understand the relationship between structure and function, is often forgotten in the rush to cover the structures.

In this article, we present an exercise that gives students the opportunity to work in groups and be creative, while fostering an appreciation for the relationship between structure and function. The goals of the exercise are to teach macroscopic bone anatomy, muscle anatomy and the creation of movement, and to encourage cooperative learning and inquiry. Simple modifications in the exercise can be made to accommodate the amount of time students spend on the exercise and what level of understanding of bone and muscle anatomy the students achieve.

The Exercise

Purpose

Students create their own string model of bone and muscle anatomy in order to better comprehend the relationship between structure and function in the skeletal and muscular systems.

Materials

Materials needed for groups of 2 to 3 individuals
- Butcher paper (one piece about 5'5" to 6' per group)
- Braided string
- Scotch tape
- Colored tape
- Pencils/pens

Optional Materials
- Articulated skeleton [Instructors may modify the skeleton to include attachment loops (e.g. drill in eyelets or tape on loops) at origin and insertion points for muscles.]
- Tissue paper

Procedures

Students work in groups of two or three. The students tape a piece of butcher paper onto a wall, floor or lab desk. Then they trace or draw the outline of the animal being modeled in its anatomical position on the butcher paper. One half of the trace should represent an anterior or ventral view, while the other half is a posterior or dorsal view.

As a group, students discuss and sketch the bones and bone markings of the skeleton, paying particular attention to properly placing bone markings, since errors here will impact the muscle model. If students are not expected to learn specific bone markings and muscle attachment sites, rough sketches of the skeleton will suffice. The bones should be labeled either off to the side of the butcher paper, along the length of the bone, or in the bone outline. An articulated skeleton can serve as a good visual aid.

Next, students discuss and begin to attach string segments to represent muscles (Figure 1). Multiple or broad origins or insertions can be represented by unbraiding and fanning the string out to attach to numerous sites (Figure 2). The muscle is labeled at mid-belly with colored tape. Tissue paper encircling the unbraided fibers of the same string clarifies the muscle as a unit. Tape identifies the origin(s) and insertion(s) (different colors for origins and insertions may be helpful) and is placed appropriately to hold the string muscles on the skeleton. Clear tape can be used to hold on muscles that have an origin or insertion site that is already labeled.

Getting the Most Out of the Exercise

In using this exercise, we have found that instructions need to be explicit about the purpose of the exercise before the students begin. The amount of detail and accuracy students build into their models will determine how much anatomy they learn from doing...
structures on their models or cadavers will facilitate the transfer of information to other examples. This point is especially relevant for students interested in pursuing careers in medicine or veterinary sciences, because none of their future patients will be exactly like the model or cadaver that they studied in their anatomy course.

Let students know the models will be graded on detail, accuracy, and relative positioning of the anatomical structures. To encourage them to participate and work together, award points for creativity, but avoid grading aesthetics. It is important that all the students are focused on the anatomy content, rather than on just learning how to build the model (i.e. how to cut appropriate lengths of string or label tape). Encourage student groups to discuss the placement of every structure before putting it on the paper, whether it is a bone marking or a string muscle.

Tailor the exercise to accommodate the time and resources available for the study of bone and muscle anatomy. Depending on student backgrounds and the amount of time available, many alternatives may be explored. For example, students can be given a partial model rather than a blank paper from which to start building their model. Providing paper with the skeleton already drawn requires the students to complete the model by labeling bones and adding bone markings and muscles. Another option to consider is whether to provide information about the anatomical parts being modeled. For guided inquiry, providing lab manuals and other resources (models, articulated skeletons, cadavers) allows students to create their model based on the available resources. To make the activity more open-ended, students may work on their models as a puzzle to be pieced together (i.e. give origin and action or insertion and action of a muscle and have the students come up with the missing attachment point). An articulated skeleton with loops placed at muscle origins and insertions can help students think through their puzzle. By attaching a string from a loop at the origin (or possible origin) to a loop at the insertion (or possible insertion) and pulling on the string, students can create the action of the muscle. When time is limited or considerable detail is desired, it is possible to require only certain areas of the body to be modeled, versus the whole body. For example, having students model only a given subset of muscles or body regions that are not particularly intuitive or visible on the available models or cadavers will reinforce their understanding of structure and function, and be feasible in a short lab period.

Encouraging Additional Activities on Structure & Function

The exercise should be complemented with additional hands-on exercises and thought-provoking questions that groups work on as they make their models. Using an articulated skeleton with loops at possible origins and insertions (described above) helps students understand why the specific location of an attachment site is important. The articulated skeleton can also be used to explore the numerous actions possible when slightly different insertions or origins are used. When students incorrectly identify or question an origin or insertion on their model, we recommend they observe the action created by their attachment sites with the articulated skeleton. The skeleton also can be used to demonstrate how muscles produce single and multiple actions, and how muscles act as synergists and antagonists.

Along with string-muscle models, such exercises can stimulate student inquiry. Having each group list several questions as a result of model building, or providing questions, leads to class discussions. Some possible questions to stimulate student inquiry include:

1. What origin or insertion for a given muscle would make the muscle more efficient at producing power and/or speed?
2. How does changing the origin or insertion influence the action for a given muscle?
3. What impact would the addition or deletion of a given imaginary or real muscle have on the other muscles and the movement about a joint?

Students' Reactions to Model Building

During the fall semester of 1997, students in the Biology 212 (Anatomy & Physiology) course at the University of Montana used the string-muscle model exercise to learn about appendicular and axial skeletal muscles. Drawing the bones and bone markings was a review of previous lab material. Students were instructed to create a model of the appendicular muscles using strings to represent specific muscles and tape to identify the muscle attachment sites and hold the strings.
Table 1. Results of the survey given to students in Anatomy & Physiology at The University of Montana in 1997 (N = 168). When asked, "How useful did you find the following activities?" Students ranked the resources from 1 for the least useful activity and 6 for the most useful activity, using every number only once.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Lecture</th>
<th>Discussing thought-oriented questions</th>
<th>Making models of anatomical structures</th>
<th>Examining ready-made models</th>
<th>Examining cadavers</th>
<th>Examining computer programs and laser disks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.4</td>
<td>2.3</td>
<td>1.8</td>
<td>3.2</td>
<td>4.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Median</td>
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<td>3</td>
<td>2</td>
<td>4</td>
<td>4.5</td>
<td>2</td>
</tr>
<tr>
<td>Mode</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

in place on the paper. Groups created string-muscle models after working with the teaching assistants at the cadavers. Student groups had three two-hour laboratory sessions to work on the models.

Students' perceptions on the use of the string-muscle model in comparison to other types of learning tools available are shown in Table 1. The students were asked on a survey to rank the usefulness of the activities offered throughout the semester. While the string-muscle model was ranked below most activities, it was favored more than other two-dimensional activities, such as computer programs (A.D.A.M. standard, version 2.0.1, A.D.A.M. Software, Inc.; Eroshenko's Interactive Histology, Instructors version 1.0, Visible Productions) and laser disk images (Slice of Life VI, University of Utah).

Written comments provided a mix of reactions. For example, some students reported on the merits of the string models, commenting:

Creating our own models was really helpful to me because it made me see the muscles better and the origins and insertions.

I really liked making the model—it was helpful to work in a group and visualize the muscles and their origins/insertions.

I think making the models is really helpful. When you label each muscle it helps with memorizing the name and placing the string helps you remember where the muscle is located and also its origin and insertion.

Other students felt the exercise was less helpful:

I believe that making our own model with paper and string is a waste of time, because it takes a lot of time, especially to learn so many muscles. I believe studying the cadavers is much more efficient.

Unnecessary: Creating your own models and using models, never actually use them on tests.

Unnecessary: I feel that the paper and string model, because we could not see the muscles and it was not exact.

Many negative comments reflected the pressure students feel to memorize hundreds of names (muscles, origins and insertions) and muscle actions in a short period of time; a strategy they...
believe will allow them to do well on a traditional short answer (one to four words) exam. While learning terminology is an important goal for A&P courses, it is equally important for students to “understand” structure and its related function. The importance of this relationship can be emphasized by changing the way in which the students are assessed. Incorporating essay questions in tests and placing importance on activities that emphasize the structure-function relationship, like the model building exercise presented here, remind students why anatomy is important. In addition, biology teaching organizations suggest that student learning can be improved by diversifying teaching and assessment methods to accommodate a variety of learning styles and to reinforce the theme central to the course (BSCS 1993; NRC 1997).

Student comments reiterated the suggestion made by BSCS and NRC to have various types of lab activities. Students reported:

I don’t think any activity was unhelpful. Some activities helped different subjects stick in [my] mind better. Variety helps keep interest while still reviewing the same material.

I think that having a variety for different types of learners is a great way to set up a lab.

People like to learn in different ways and its [sic] nice that there are many options.

Accordingly, we believe that the string-muscle exercise can be a useful activity that adds diversity to lab exercises while reinforcing the link between structure and function.

Discussion

The incorporation of diverse learning activities has been promoted by biology teaching organizations (BSCS 1993; NRC 1997). Here we have presented an inexpensive, hands-on exercise that complements traditional strategies for teaching anatomy. Our students report that constructing a model is preferred over using more expensive two-dimensional resources, such as computer programs and laser disk programs. In addition, building models of anatomical systems gives instructors and students an alternative to conducting dissections, using prospected animals, or examining ready-made models (Balcombe 1997). Thus, building models can be especially useful in high school classrooms, where access to cadavers is rare and resources may be limited to less expensive material, such as atlases, textbooks, and other two-dimensional aides.

Incorporating a string-muscle model into laboratory instruction also encourages group collaboration and discussion. Students practice communication skills, share study methods, and become more comfortable using course resources in a group setting. Furthermore, students in our courses became acquainted with one another in the small groups and were able to pose and discuss questions on structure and function in a more personal and possibly less intimidating setting than they experience during more formal class lectures and discussions.

Finally, students come to appreciate the importance of structure and function as they learn specifics of anatomy, such as muscle attachment sites. Students often have difficulty incorporating origins and insertions as they are examining the cadavers, ready-made models, and even computer programs because these resources rarely permit visualization of most muscle attachment sites. When students understand how a change in the position of an origin or insertion can change muscle performance and, therefore, the importance of the attachment sites, they become more interested in learning muscle attachment sites.

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References


