Simple manipulative of gross organization of skeletal muscle: enhancing learning among students offline and online

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Abstract

Understanding the gross organization of skeletal muscle is critical to understanding the mechanism of action of muscle physiology. Due to coronavirus disease-19 (COVID-19), many colleges have had to discontinue or curtail teaching and laboratory activities. Whether students are in the classroom or learning online, it is important for them to understand the basics of skeletal muscle organization that allows for movement. Manipulatives have been shown to enhance student learning and understanding in many fields, including physiology. This gives instructors an easy-to-follow tool for making a manipulative that allows students to see the organization of the skeletal muscle. Students can make this manipulative themselves from supplies commonly found in the home or office.

fasciculus; gross organization; myofibrils; sarcolemma; skeletal muscle

INTRODUCTION

“Lecture” as a method for undergraduate teaching often emerges as a passive learning process, resulting in rote memorization (1). The way a subject like physiology is taught can affect the process of meaningful understanding of the learners. Active participation in the process of learning leads to productive learning (1, 2). One method of incorporating active learning is through use of manipulatives; this method improves conceptual learning and can also be handled by the students (1, 3). Manipulatives can be any software, three-dimensional (3-D) models, models made of clay, or illustrations (4). In this paper, we present a simplified method of teaching the gross organization of skeletal muscle using manipulatives in the form of a 3-D model made from materials used in day-to-day life. Using the model to visualize the gross organization could reduce rote memorization while enhancing conceptual understanding.

Manipulatives provide a platform to explain a concept in their own terms. Students can also construct the manipulatives, incorporating the terminologies learned from the textbooks (1). Manipulatives also cater to the learning styles categories of visual (V), auditory (A), and kinesthetic (K) (1, 5), especially the “K” learning preference, which involves physically touching or manipulating materials or objects (6). The manipulative activity should also motivate students to construct or replicate a conceptual model to understand and apply the newly gained knowledge (1). Manipulatives and models have been utilized at various undergraduate institutions demonstrating success due to their hands-on-nature (7). The examples include Kronitiris-Litowiz (1) using manipulatives to demonstrate membrane movement; Rios and Bonfim (8) explaining sarcomere contraction using model building; and Motz et al. (7) demonstrating hands-on-activity on a soda bottle nephron model.

Many times due to several factors, the discipline itself, how it is taught, and how the students approach learning, the students do not acquire specific knowledge in a meaningful way (9), for example, the gross organization of skeletal muscle. In a lecture on “functional organization of skeletal muscle,” as per the specific learning objectives, the learners had to be taught gross organization followed by arrangement at the molecular level. A PowerPoint was used as a teaching media with descriptive illustrations. The following terms were introduced:

1) Skeletal muscle;
2) Epimysium;
3) Fascicles,
4) Perimysium;
5) Muscle fiber;
6) Endomysium;
7) Sarcolemma; and
8) Myofibrils with A and I bands and Z lines.

In one of the subsequent class, to make sure that students understood the basic concepts, a 3-D model was prepared and the students were asked to label the parts and explain the concepts as they related to the structure. The students, as per their rote memorization, named the terms but could not translate to the 3-D manipulative nor explain the concepts. These concerns and priorities changed in the wake of...
the World Health Organization declaring COVID-19 pandemic in 2020. The large group lecture method shifted to online mode of teaching that became the “new” normal. Taking this into account, we prepared the gross muscle manipulative with the objectives incorporating the revised Bloom’s taxonomy.

**OBJECTIVES**

The students will do the following:

1) Apply the theoretical knowledge learned in classes to the 3-D manipulative (offline or online mode of teaching); and

2) Create/construct a 3-D manipulative of gross organization of muscle model using inexpensive, readily available materials.

**MATERIALS AND METHODS**

To construct the gross organization of skeletal muscle, the following materials are required:

1) Discarded or scrap papers;

2) Straws;

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**Figure 1.** Basic requirements for the 3-dimensional manipulative.

**Figure 2.** Side view of the 3-dimensional model of gross organization of skeletal muscle.

**Figure 3.** Front view of the 3-dimensional model of gross organization of skeletal muscle.
GROSS ORGANIZATION OF SKELETAL MUSCLE MODEL

3) Brown and black markers or paint; and
4) Stapler.

TIME REQUIRED
It will take the students ~10 min to construct the 3-D manipulative.

OVERVIEW
The gross organization is composed of the skeletal muscle belly. The connective tissue layer around the skeletal muscle belly is the epimysium. The cross section of the muscle belly depicts many muscle bundles or fascicles. The connective tissue layer around each muscle fasciculus is called the perimysium. Each fasciculus consists of large number of muscle fibers, parallel to each other. The sarcolemma is the plasma membrane of a muscle fiber (cell). The endomysium is a connective tissue that wraps around the individual muscle fiber. Each muscle fiber consists of densely packed myofibrils. Myofibrils show Z lines and A and I bands (10, 11).

POINTS OF CONCEPT BUILDING AND APPLICATION OF THEORETICAL KNOWLEDGE AS A FORMATIVE ASSESSMENT
The students should do the following:
1) Label or point out the structures and layers of skeletal muscle; and
2) Explain the concept of importance of muscle fiber and the functional aspects of sarcolemma and myofibrils.

The students should assemble/construct the 3-D manipulative as follows:
a) Take, for example, one piece of an A4-sized paper, as shown in Fig. 1 as “1.” Roll from the ends with arrows to form a hollow cylinder. This will form the muscle belly. Label the outer layer as epimysium.
b) Cut the A4 paper in two halves. One half is shown in Fig. 1 as “2.” Take three such halves. Roll from the ends with arrows to form hollow cylinders. This will form the fasciculi. Make three such fasciculi. Label the outer layer of fasciculus as perimysium.
c) Cut the no. “2” paper into three parts as shown in Fig. 1 as “3.” Take three such pieces. Roll from the ends with arrows to form hollow cylinders. This will form the muscle fiber. Make three such fibers. Label the fiber and outer layers as endomysium/sarcolemma.
d) Take the straws and draw Z lines, A band, and I band to make it look like myofibril.
e) Then, insert three fasciculi inside the muscle belly. Insert the three fibers into any one of the fasciculi. Insert the straws into any one of the fibers.
f) The whole unit can be colored using shades of black and brown color (optional).
g) The layers can slide upon each other, and when all the layers are inside, the manipulative can be stored in a box for future use (the “sliding” is simply for purposes of illustrating the organization and is not the shortening of a muscle) (Figs. 2 and 3).

DISCUSSION AND CONCLUSION
This 3-D manipulative of gross organization of skeletal muscle is easy to construct and could also be used in online class modes. The manipulative can be easily constructed using the assembly instructions, and students can show and describe the parts in online mode.

Due to the COVID-19 pandemic, this model was shown and explained in an online mode. The details of the model were explained online, and the list of the supplies required were shared online so that the students could recreate the model at their homes. Although formal feedback was not gathered, the students appreciated the model through personal interactions. Such skeletal muscle manipulatives could overcome the excessive dependency on rote memorization and translate the learned matter into better understanding by visualizing and manipulating the muscle model. Such 3-D constructed models give a hands-on learning experience to the students, thus also enhancing the method of teaching for better retention among the students.

DISCLOSURES
No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS
A.J., A.G. and N.G. conceived and designed research; A.J., A.G. and N.G. drafted manuscript; A.J., A.G. and N.G. edited and revised manuscript; A.J. approved final version of manuscript.

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