A Hybrid Virtual Kinesiology Laboratory Module for Human Anatomy and Physiology

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Abstract

The integration of virtual technology is becoming a common trend in anatomy education at the undergraduate and graduate levels. The incorporation of virtual 3D anatomical models into the classroom is beneficial to students, especially if they do not have access to cadavers. This lesson is a hybrid kinesiology laboratory module that includes virtual anatomical and traditional physiological laboratory components. The module contains procedures that are easy for undergraduate students to follow while also containing advanced content to promote higher order thinking. This lesson provides a brief description of the learning context, time and pace, lesson plan, and teacher and student evaluations. During the learning activities, students will use a virtual dissection Anatomage Table and conduct modified Wingate tests and accumulated oxygen deficit experiments. This module will be useful for anatomy and physiology instructors who want to blend virtual and traditional learning modalities, embrace active learning, and make advanced concepts more accessible to students.

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Supporting Materials: Supporting Files S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test; S2. Hybrid Virtual Kinesiology Lab Module – Pre-Test Key; S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment; S4. Hybrid Virtual Kinesiology Lab Module – Post-Test; S5. Hybrid Virtual Kinesiology Lab Module – Post-Test Key; S6. Hybrid Virtual Kinesiology Lab Module – Anatomage Table Procedures; S7. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Procedures; S8. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions; S9. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions Key; S10. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Lab Procedures; S11. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Data Sheets; and S12. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Results & Conclusions

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Learning Goal(s)

The content of this lesson aligns with the following Learning Goals for Students posted on the Human Anatomy and Physiology Society (HAPS) website.

Content Integration Goals

1. Use appropriate terminology to discuss anatomy and physiology.
2. Use appropriate laboratory tools and techniques to examine anatomical structures or physiological functions.
3. Identify anatomical structures and describe the complex interrelationships between structure and function.
4. Explain how body systems work together to maintain homeostasis.
5. Explain how variability in the human population produces ranges of values considered "normal" for body parameters.
6. Propose evidence-based hypotheses to explain physiological responses or the functions of anatomical structures.
7. Apply knowledge of anatomy and physiology to real-world situations.
8. Recognize and apply patterns that unify, organize, and simplify the abundant detail of anatomy and physiology.

Cognitive Skill Development Goals

9. Interpret and draw appropriate conclusions from graphical and other representations of data.
10. Apply information literacy skills to access and evaluate peer-reviewed resources.
11. Approach and examine anatomy and physiology issues from an evidence-based perspective.
12. Adapt information to effectively communicate with different audiences.
13. Recognize that our individual differences (ethnicity, gender, culture, etc.) shape our understanding of anatomy and physiology.
14. Foster respect for individuals across differences within educational and professional settings.

Learning Objective(s)

Students will be able to:

- distinguish the basic concepts of kinesiology, metabolism, homeostasis, exercise physiology, and biomechanics.
- differentiate between the various forms of homeostasis, cellular respiration, and anaerobic processes, especially in regard to their energy supply and demand.
- identify and describe the functions and fate of lactate.
- discuss the mechanisms of both the lactic acid/Cori cycle, and glycolysis.
- comprehend and perform the Wingate and accumulated oxygen deficit tests.
- define maximal oxygen consumption (VO_2max) and apply the concept to real-life scenarios.
- distinguish the structure, function, and predominant locations of three different muscle fiber types.
- apply virtual dissection techniques to distinguish anatomical features of skeletal muscles of the back and the upper and lower limbs.

INTRODUCTION

Background and Rationale

This laboratory module contains both virtual and physical components that are integrated for an undergraduate anatomy and physiology curriculum. The virtual component, incorporating technology, appeals to the rapidly evolving needs of "Digital Native" students (1,2). The physical component, on the other hand, follows the recommendation of incorporating active learning activities in the classroom and resembles Course-Based Undergraduate Research Experiences (CUREs). CURE Network (CUREnet), which is supported by a National Science Foundation (NSF) grant (3,4,5,6), supports the use of CUREs. This physical component is similar to CUREs in at least four ways because it engages students in use of the scientific method, discovery of potentially ambiguous results requiring creative interpretation, collaboration among students and instructors, and repetitious experimentation that confirms or enhances knowledge acquired from classic studies (6,7). While this module does not meet all of the requirements to be considered a CURE it does include both virtual and physical components, and therefore is more suitably classified as a hybrid course module.

Hybrid course modules such as this one are favored by students over traditional courses, and they have shown to promote student learning gains more than traditional or online courses alone (9). One study found that most students in a health and kinesiology course preferred the combined online and traditional formats as the in-class communications helped supplement the students' learning new technologies (10). Another study described the development of online kinesiology learning modules for both upper and lower level undergraduate students which incorporated advanced kinesiology content through anatomical and physiological components to increase students' critical thinking skills in an anatomy and physiology course (11). Ultimately, critical thinking is more important for anatomy students' learning than content (12,13). For this reason, this module aims to present students with patterns and concepts of muscle anatomy, metabolism, and functions that stress higher order thinking rather than memorization of isolated facts.

The use of virtual three-dimensional (3D) images is a growing trend in anatomical education, especially since some institutions have limited access to cadavers due to financial or ethical concerns (14,15). This fact holds true for undergraduate institutions like Millsaps College, which lacks the funding to support a self-sustaining cadaveric lab. A generous gift to the college has allowed the Department of Biology to purchase an Anatomage Table (Figure 1). This virtual dissection table will now allow students in the human anatomy and physiology courses to explore the human body in a cost-effective and stimulating learning environment. In this way, students have the opportunity to learn the anatomical structures within the human body and their 3D relationships to one another. Simultaneously, students have the opportunity to explore and enjoy the novelty of 3D technology.

A number of studies have discussed in detail the construction of 3D anatomical models and their potential in anatomical sciences education (16,17,18). Several studies have shown the positive impacts of 3D anatomy on students' learning (19,20,21). Similarly, other studies have shown that virtual models are just as effective as cadaveric specimens in engendering student learning of anatomy (22,23). In contrast, other studies have shown that physical models improve students' learning significantly more than virtual models (24,25). These findings demonstrate the importance of using virtual 3D anatomy as a supplement to more traditional forms of anatomy instruction and assert the legitimacy of using virtual 3D anatomical models in the absence of cadaveric material.

Figure 1. A photograph of the Anatomage Table in its vertical orientation, revealing three different layers of the virtual male donor model in virtual dissection.

In addition, combined online and traditional learning has also been shown to be advantageous for students' learning in a physiology course (26,27). Similarly, incorporating technology as a supplementary mode of learning enhances traditional learning in anatomy and physiology (28,29). Therefore, we combine virtual and traditional laboratory learning in this kinesiology hybrid laboratory module developed for an undergraduate anatomy and physiology course. Background information concerning traditional lab components, the Wingate and accumulated oxygen deficit tests as well as the concept of maximal oxygen consumption (VO_2max), can be found in the pre-lab reading assignment document (see Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment). These virtual and traditional components are administered together to provide digital native students with access to technology while also exposing them to advanced exercise physiology concepts to appeal to their critical thinking skills. The virtual anatomy component provides students with an understanding of the structure of skeletal muscles of the back and upper and lower limbs and their three-dimensional relationships to each other. In addition, by studying the muscles in groups, students can understand skeletal muscles by their common functions and locations. Such understanding allows for the discussion of muscle fiber types, which has a direct correlation to homeostasis in regards to ATP synthesis and to lactate metabolism — concepts which are involved in anaerobic and aerobic respiration.

These concepts are explored further in the exercise physiology lab activities in which the students perform exercises that

demonstrate the phenomena that occur during exercise periods such as muscle fatigue and recovery during moments of maximal oxygen consumption (VO_2max). These enhanced learning opportunities allow students to make stronger connections between structure (virtual anatomy dissection activity) and function (exercise physiology activities) relationships. The kinesiology lab guided questions (see Supporting File S8. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions), the exercise physiology conclusion questions (see Supporting File S12. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Results & Conclusions), and the pre- (see Supporting File S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test) and post-test questions (see Supporting File S4. Hybrid Virtual Kinesiology Lab Module – Post-Test) are designed to help the students integrate the concepts learned across both the kinesiology and exercise physiology lab activities. Furthermore, these lab activities are cost-effective ways for instructors to incorporate these concepts without expensive exercise physiology equipment or a sustainable cadaveric lab.

Intended Audience

This module was developed for a general anatomy and physiology course at a small liberal arts college, with approximately 20-25 undergraduates. The majority of students taking the course were juniors and seniors on pre-health tracks. Programs such as physical therapy and nursing require the courses as prerequisites for admission into professional school, and other programs recommend, but do not require the course. However, this module is not limited to pre-health students and can be implemented with any variety of upper level undergraduate students. Additionally, this module is not limited to liberal arts colleges as it can be implemented in anatomy and physiology courses at community colleges as well as other colleges and universities with small class sizes.

Required Learning Time

Each semester-long course consists of a lecture component that meets three times a week for an hour and a lab component that meets once a week for three hours. This particular learning module lasts the entire duration of one laboratory session. During this specific lab session on kinesiology, the instructor divides the students into three groups. One group completes the anatomy activities which require the use of the Anatomage Table to facilitate learning muscle anatomy, while the other two groups each complete the exercise physiology components in the institution's fitness center. Upon completion of one activity, each group rotates to the next activity until each group has completed all three activities.

The virtual dissection activity with the Anatomage Table should take approximately 25 to 30 minutes, the Wingate Test experiment should take approximately six to ten minutes, and the accumulated oxygen debt experiments should take approximately 25 to 30 minutes. All time estimates depend on the pace of the students. The group completing the Wingate Test experiment will finish before the other two groups. Thus, the students within this group can work on the calculations on their data sheets (see Supporting File S11. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Data Sheets) and their results and conclusions sheets (see Supporting File S12. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Results & Conclusions) while they wait to start the next activity. Given the approximate timeframes of the other two activities, this time could range to a maximum of at least 20 minutes, thus bringing the total time for activities to approximately one hour and 30 minutes.

Prerequisite Student Knowledge

Students enrolled in anatomy and physiology should have completed four semesters of biology coursework, with at least one course being a 2000-level course or higher. The students should have learned the basic concepts of aerobic and anaerobic respiration in their introductory cell biology course or high school courses. Additionally, a basic understanding of calculations using formulae from high school physical science, algebra, and/or physics courses is expected. Students at lower learning levels (below the junior or senior undergraduate level) might need to have covered the musculoskeletal and cardiovascular systems before engaging in this lab. Instructors can use their own discretion in making this determination, or they could survey the class at the beginning of the semester to gauge students' prior knowledge. Students should also have prior knowledge and experience with operating the Anatomage Table before this laboratory module. Ideally, instructors could organize an introductory lab for use and operation of the table on the first day of lab in the course. Ideally, students should also have covered the muscle groups discussed in the lab activity during the lecture component of the course.

In reality, throughout their educational and occupational careers, students will be confronted with information or tasks that exceed their current knowledge base. As a result, instructors are encouraged to foster twenty-first century skills (30,31) and adult learning strategies (32,33) in their students. Students are encouraged to embark on an exploratory journey to learn about topics and concepts when they confront information that they do not know or understand. Such practices are the hallmarks of lifelong learners.

Before the students begin their laboratory session, they complete a brief, ten-minute pre-test (see Supporting File S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test) to gauge their prior knowledge on the pre-lab assignment's topics. The administration of this assessment can occur during any regular class period prior to the assignment or implementation of any lab module-related activities, but it should be proctored to discourage any dishonest behavior among students. Next they complete a pre-lab reading assignment (see Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment). The completion of this task should take approximately 30 to 45 minutes of time outside the classroom. In lab before the lab activities, the students take a brief ten-minute post-test (see Supporting File S4. Hybrid Virtual Kinesiology Lab Module – Post-Test) to assess their knowledge acquired from the reading. This assessment also encourages the students to complete the pre-lab reading assignment in order to be prepared for the lab activities.

Prerequisite Teacher Knowledge

Instructors teaching this lesson should have an understanding of the anaerobic processes that take place in the human body during physical exercise, the procedures of the Wingate and accumulated oxygen deficit tests, the operation of the Anatomage Table, and the muscles of the back and the upper and lower limbs. Instructors should also complete a run through of the lab themselves before administering the lab to the students in

order to troubleshoot any possible complications. For instance, if certain types of equipment are not present in the institution's exercise facility or in the instructor's lab, the instructor can either drop the activity altogether or modify the procedures for equivalent exercise equipment. In addition, instructors should have a command of facilitator skills they can implement during the lab to encourage student-centered learning.

The reference list at the end of the pre-lab reading assignment (see Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment) provides citations for sources used in the development of this laboratory module. Instructors are encouraged to consult these sources if they seek further reading on concepts such as the Wingate and accumulated oxygen deficit tests. Further reading on the anaerobic processes during exercise can be found in typical biology textbooks for introductory level college biology courses and in any exercise physiology textbook. We suggest the following textbooks on kinesiology (34), exercise physiology (35), and anatomy and physiology (36); however, instructors are encouraged to research textbooks that are most relevant for their courses.

Instructors would need access to an Anatomage Table to complete the anatomical portion of the lab module. Should instructors want to familiarize themselves with the applications on the Anatomage Table, they can always contact a representative from the company for a one-on-one consultation. They also have the option of viewing tutorials online. A number of videos demonstrating the basic functions of the Anatomage Table can be found on YouTube. Recommended resources that are helpful include a video (37) demonstrating these functions as well as those useful for instructors and a series of guides, namely the user's manual (38), accessed through a Google Drive. All of these resources can be found on a webpage (39) of the University of Michigan Taubman Health Sciences Library. The videos can also be accessed through YouTube.

Instructors who are novices in the use of active learning approaches in their classrooms and labs are encouraged to research resources on facilitation skills. There are a number of sources (40,41,42) that instructors can reference to gain an understanding of how to evolve from a predominant "sage on the stage" mentality to more of a "guide on the side" perspective. There are sources that address the incorporation of technology (43,44), highlight best-practice facilitation techniques (45), and emphasize the importance of active learning in developing students' critical thinking and problem-solving skills (46,47,48,49).

SCIENTIFIC TEACHING THEMES

Active Learning

Active learning is an important teaching method to consider when developing laboratory modules and lecture sessions in anatomy and physiology courses. This laboratory module embodies active learning because it incorporates exercises that allow the students to complete work in groups rather than simply acquire knowledge in a traditional, more passive, lecture-based setting (50). Students who engage in active learning are also more likely to obtain critical thinking skills (46). Students are also physically performing the exercises themselves and testing their knowledge of muscle anatomy through the Anatomage Table activities (Figure 2).

Figure 2. Students operating the Anatomage table.

One specific form of active learning incorporates the flipped classroom. This laboratory module also serves as a flipped classroom module because it features a pre-lab reading assignment (see Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment) that students must complete as homework before attending their kinesiology laboratory session. This assignment allows the students to take responsibility for their own learning before coming to the lab. It also frees instructional time for active learning exercises which help foster higher-order thinking skills (51) among the individual students and during their peer-to-peer interactions. More information on the flipped classroom can be found in the literature (52,53). The latter source includes a review of other studies on the flipped classroom and its efficacy (53). Additional studies have explored the development and implementation of a professional development program for high school teachers, enabling them to learn how to use the flipped classroom model (54,55).

In this particular lab module, students had the opportunity to view YouTube and Khan Academy videos included as links in their pre-lab reading assignment (see Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment). For instance, if students desired further clarification regarding the different muscle fiber types, they could view the video associated with the different muscle fiber types. However, if the flipped classroom assignments before class do not elucidate the lesson content as planned, instructors can rely on additional active-learning strategies to help improve their students' understanding of the lesson content. For example, if a student is struggling to grasp the concept of different muscle fiber types and their applications to different types of muscle movements, instructors can use aspects of peer instruction (56) by allowing other students within the student's group to explain the concepts to him/her. The instructor could then invite the students to vocalize their discussion and ask whether the student had a better understanding of the concepts after the discussion. The next critical step would entail the instructor's vocal affirmation of the accuracy of the discussion details and any elaboration or revision to correct the students' understanding, if necessary. Any misunderstandings should also be communicated to the entire class to ensure other students do not make similar mistakes.

If instructors want to ensure further that the student has learned the content, they can request that the student try to teach it to others. This additional active learning strategy known as the protégé effect (57,58) has been shown to improve students'

metacognition (59), use of effective learning strategies (60), motivation to learn (58), sense of competence and autonomy (61), performance (60), motor learning (62), and information processing (63). Instructors can employ aspects of peer instruction and the protégé effect with any other misunderstood or difficult-to-understand concept in the lesson.

Assessment

The instructors assessed the students' learning by administering pre- and post-tests (see Supporting Files S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test and S4. Hybrid Virtual Kinesiology Lab Module – Post-Test, respectively) to the students before and after their learning experiences, respectively, and measuring the change in their performance. The pre- and post-tests (see Supporting Files S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test and S4. Hybrid Virtual Kinesiology Lab Module- Post-Test, respectively) included the same five open-ended questions. Students also completed guided questions during their Anatomage Table investigations (see Supporting File S8. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions). Students completed several self-evaluation components of the lesson on their Results and Conclusions worksheets (see Supporting File S12. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Results & Conclusions). Students were able to evaluate the accuracy of their performance during the lab by calculating the percent error of their power calculations versus the power output from the stationary cycles. Students were also able to assess the reliability of their findings by comparing them to values from peer-reviewed sources. Additionally, students were asked to identify muscles and answer kinesiology questions on the lab exam. Refer to Table 1 to see how these assessments aligned with the lesson learning goals and objectives, as well as the guidelines and learning outcomes for the Human Anatomy and Physiology Society (HAPS).

In this module, several core concepts in physiology are assessed, including homeostasis [Lesson Learning Objective (LLO) 1 and 2; Content Integration Goal (CIG) 4 and 5], energy (LLO 3), and structure-function relationships (LLO 7 and 8; CIG 2, 3, and 6). The core concepts of interdependence, levels or organization, and scientific reasoning are indirectly addressed using different terminology. For instance, the concepts of interdependence and levels of organization are inferred by the discussion of the vital interaction between molecules within muscle fibers (cells), their comprising tissues (i.e., skeletal muscle tissue), and the organs (i.e., skeletal muscles) that they comprise. The concept of scientific reasoning is inferred by the processes students use in conducting their laboratory experiments, communicating their results, and analyzing and reviewing evidence-based research [LLO 5, 6, 7, and 8; CIG 6; Cognitive Skill Development Goal (CSDG) 9, 10, 11, and 12].

These core concepts are a part of a larger body of fifteen Core Concepts in Physiology which were proposed and vetted by approximately seventy physiology faculty respondents through surveys conducted by two other physiologists (64). These core concepts and their subconcepts are discussed further in a text that also provides additional tips for the design of learning resources (65). These tips include maintaining consistency in the use of terminology and relying on logical learning progressions (66) with the introduction of some subconcepts before others (65,67). Instructors can refer to these core concepts and this text should they want to align their lessons and assessments with additional core concepts. A review of this text mentions that while the text encourages the use of multiple-choice questions, it asserts that short-answer questions allow students to demonstrate their reasoning (67) in a way that multiple-choice questions cannot. Such open-ended questions as in the pre- and post-tests (see Supporting Files S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test and S4. Hybrid Virtual Kinesiology Lab Module – Post-Test) can assess students' authentic understanding by more effectively lowering the probability of their answering the questions by guessing alone as many students do with multiple choice questions when they simply do not know the answer. The review by Crowther (67) also mentions an anatomy and physiology textbook (68) whose author has already incorporated many of the suggestions within the *Core Concepts* text. Instructors of anatomy and physiology might also want to consider consulting this text in further understanding how to teach the content of this module.

Inclusive Teaching

This hybrid laboratory module incorporates diversity, equity, and inclusion of students in a variety of ways. This lesson captures the diversity of biological sex by including data from males and females. This lesson also invokes a number of multiple intelligences (69) among a cohort of diverse learners. This lab specifically appeals to students' visual-spatial, bodily-kinesthetic, logical-mathematic, verbal-linguistic, interpersonal, and intrapersonal abilities. For students, such capabilities expressed in the lab can extend beyond the scope of the course and into real-world interactions. The hybrid nature of this lab also appeals to differing student mindsets. This laboratory module is a hybrid virtual module in the sense that it incorporates the use of a virtual dissector table as well as traditional laboratory exercises. In addition, this module embraces the essence of hybrid learning because students can access its pre-lab reading material online via email or an instructional online learning management (OLM) interface such as Canvas or Blackboard. This pre-lab reading assignment also contains embedded YouTube and Khan Academy videos that allow the students to explore web-based, digital content in addition to electronic text.

As the promotion of diversity and inclusion within many institutions in the United States has become increasingly paramount, many organizations and social entities are encouraged to adopt standards or policies that celebrate the diversity of their members while also fostering inclusive environments in which all members feel like part of a cohesive team. Such diversity and inclusion standards can be established for professional societies, degree programs, and even anatomy and physiology classes (70). For example, in this particular module, instructors have the opportunity to discuss occupational diversity (70) in the context of an anatomy and physiology course. Students in the course will ultimately decide to pursue different occupations/career paths which in turn can influence the level of interest a student may have in a particular topic covered in the course. The interested students can then help to motivate other students based on their enthusiasm and excitement for the topic. This module should particularly appeal to those students interested in occupational therapy, physical therapy, or exercise science since many of the concepts regarding kinesiology and biomechanics are highly relevant to these fields. Instructors could offer at the beginning of the lesson a quick explanation of why the lab module concepts are pertinent to these particular students and/or fields of study. Even if there are no students in

the course who intend to become occupational or physical therapists, instructors can discuss how the content pertaining to skeletal muscle anatomy would also be revisited in greater detail in medical, dental, nurse anesthesia, physician assistant, or other anatomy-relevant curricula. Moreover, exposure to this content and its career correlations may allow students an opportunity to consider such relevant fields as professional options. Such exposure is especially important for under-represented populations including women, trans or gender non-conforming, or other underrepresented minority students since it might encourage these individuals to help diversify fields in which there is a paucity of members of their respective groups. For instance, physical therapy is a field often predominated by Caucasian men while occupational therapy is a field often predominated by Caucasian women; exposure to fields other than the stereotypical norms can help educate underrepresented students about a more diverse array of options to help them make the best decisions for themselves. On the other hand, some students might not intend to pursue any health-related careers. Nevertheless, instructors could discuss the relevancy of the concepts such as metabolism, homeostasis, maximal oxygen consumption, and anaerobic capacity to an understanding of basic health during physical exercise.

Since students are engaged in physical exercises during the lab module, instructors have the opportunity to emphasize the importance of physical exercise, in general, in people's daily lives. For instructors teaching in states that have higher healthcare disparities than normal, providing statistics from the National Center for Health Statistics (NCHS) regarding the state of health of their citizens (71) can be a powerful learning experience for providing awareness to students. (International readers can refer to their respective health institutions for similar data.) Such awareness can motivate students then to be advocates for healthier lifestyles among their colleagues, friends, families, and community members. This advocacy is also important even in states or regions that are predominated by healthy individuals because there may be some subsets of the population which lack healthy lifestyles due to a number of factors that can include limited access to healthy foods, lower socioeconomic status, reduced health literacy, or other social determinants of health (72,73). By creating an atmosphere of comradery around physical activity as a critical strategy for reducing health disparities and supporting healthy living (74,75), instructors can invite students into a learning community that is inclusive while also diverse. For example, instructors can support an atmosphere of comradery in this lab module by allowing the groups to challenge one another to see which group is the fittest. Alternatively, instructors could display on the walls posters that convey helpful tips for students to incorporate at least thirty minutes of exercise (e.g., walking, jogging, biking, etc.) into their daily routines and could provide encouraging and motivating words to stay healthy. Additionally, instructors could provide opportunities for students to create groups to support healthy lifestyles and hang photos of individuals of diverse backgrounds engaged in physical activities. Instructors can also provide encouraging words and highlight helpful tips during the exercise physiology component of the lab.

Instructors might also teach classes of anatomy and physiology in which students might have disabilities or injuries that prevent them from engaging in the exercise physiology lab activities. Students with disabilities provide another enriching opportunity for incorporating experiential diversity (70,76,77) into the class and creating a more inclusive environment. Instructors can make a number of decisions to accommodate students with disabilities or injuries. Instructors can simply allow such students to abstain from physical activity and work in close proximity with a partner within their lab group or perhaps even serve as the scribe for their lab group if they are able. If the students have the ability to perform alternative exercises (e.g., manually propelling their wheelchairs with their arms), instructors could also provide such students with the option of engaging in the lab activities under modified circumstances. Either way, instructors would consider the freedom of choice and the comfort of the students in this decision. Students who chose to abstain could be placed into a think-pair-share group with their assigned partner within their lab group. In a think-pair-share sequence, the students would have an opportunity to think or write about and discuss the biological concepts being explored in the lab activities (78,79). For instance, in this lab module, if there are students using wheelchairs, crutches, or some other assistive device for mobility, these students can be prompted to explain to their lab group partners how the same concepts of exhaustion and muscle fatigue can apply to situations in which they are rapidly rotating the wheels of their chair or moving their crutches with their arms, perhaps to rush somewhere quickly. In the communication exchange, students without disabilities could gain insights into the experiences of someone who cannot perform tasks that involve physical exertion, like pedaling on the stationary bicycle during the Wingate Test or running on the treadmill during the maximal oxygen consumption experiment, while also sharing their experiences as they perform the Wingate Test and running experiments. In this example, the students with disabilities are provided an equitable opportunity to engage in the lab activities by alternative means since they cannot perform the experiments in the same way that other students can, but they are also included in the conversation and learning experiences with the other students.

Instructors might even choose to adopt a think-pair-share policy for all students in the class to promote further inclusion and equity (79). Dr. Kimberly D. Tanner also provides a self-assessment of equitable teaching strategies in her article on promoting student engagement and cultivating classroom equity (79), so instructors might want to consult this tool when evaluating the inclusive nature of their own classroom. While this article addresses classroom teaching practices as a whole, many of these strategies can be incorporated into this lab module in addition to the think-pair-share technique. Because the students will already be actively participating in groups, instructors might consider ambulating the room and attending to each group periodically to ensure that all students are participating either in the activities or in discussion concerning the activities and that all students are provided fair access to learning, thinking, and teaching.

LESSON PLAN

Required Personnel

The laboratory activities featured in this laboratory module require at least one instructor and one teaching assistant or additional faculty member. The instructor would monitor one area in which the virtual dissector or exercise physiology activities were occurring while the teaching assistant would monitor the other area. If a third individual (instructor or teaching

assistant) is available then the two exercise physiology activities can be monitored individually.

Required Materials

This particular laboratory module requires some specialized equipment as well as access to basic fitness equipment. While there is cost associated with the virtual dissectors they are a more cost-effective alternative for institutions that lack a body donation program for cadaveric dissection. These devices and other required materials provided by the instructor or institution include the following items:

- at least one Anatomage Table
- at least one stationary bicycle
- at least two treadmills
- Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment, distributed electronically
- all of the following printed supporting file documents:
    - Supporting File S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test, assigned before distribution of pre-lab reading assignment
    - Supporting File S4. Hybrid Virtual Kinesiology Lab Module – Post-Test, assigned before the laboratory activities during the lab session
    - Supporting File S6. Hybrid Virtual Kinesiology Lab Module – Anatomage Table Procedures
    - Supporting File S7. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Procedures
    - Supporting File S8. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions
    - Supporting File S10. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Lab Procedures
    - Supporting File S11. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Data Sheets
    - Supporting File S12. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Results & Conclusions
    - Supporting File S4. Hybrid Virtual Kinesiology Lab Module – Post-Test, assigned upon the completion of all laboratory activities

Students must come to the lab on the day of the laboratory session prepared with the following items:

- at least one calculator per student (for making calculations)
- at least one stopwatch, iPhone, tablet, or other mobile device (for timing students on the exercise equipment)
- at least one laptop, tablet, or other device per student (for accessing electronic laboratory documents)
- writing utensils for completing most of the supplementary documents
- appropriate clothing and footwear to engage in the exercises

Instructor Preparation

The instructors and teaching assistants should familiarize themselves with the operation of the Anatomage Table so that they can guide the students' dissections when they have problems with the instrument. They should also test the laboratory activities with a team of faculty and student volunteers that are not enrolled in anatomy, using the supplementary materials in the process to assess the feasibility of the activities. This process also helps allow instructors to make adjustments for differing class sizes.

If the exercise equipment is located in a facility not affiliated with the instructor's department, the instructor should reserve the space containing the exercise equipment at least one month before the lab activities occur. Instructors should also call the manufacturer of the stationary bicycles to confirm the mass associated with the resistance settings to standardize student calculations.

Instructors should also remain aware of the timeline of components associated with the laboratory module to distribute or administer certain components on time. For instance, instructors should administer the pre-test (see Supporting File S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test) sometime before allowing students online access to the pre-lab reading assignment (see Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment). Instructors should allow students access to the pre-lab reading assignment at least one week before the date of the scheduled laboratory activities.

Moreover, instructors should print an appropriate number of copies of all supplementary documents that are provided to the students as hard copies at least a few days before the date of the lab activities. This preparatory measure accounts for any issues that may occur with the departmental copier or printer. Furthermore, the instructors and teaching assistants should read and review all of the supplementary documents before facilitating the laboratory activities. This process allows the activity facilitators to have a better understanding of the types of questions students might ask during the laboratory session.

Lesson Description

This hybrid virtual kinesiology laboratory lesson is designed for a first-semester anatomy and physiology course including up to 30 students. Overall, the lesson includes three main components: a pre-lab component, a laboratory component, and a post-lab component. The pre-lab component consists of a pre-lab reading assignment (see Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment) and a pre-test (see Supporting File S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test). The laboratory component consists of three parts: an anatomy activity requiring an Anatomage Table and two exercise physiology activities requiring basic fitness equipment. The post-lab component consists of a post-test (see Supporting File S4. Hybrid Virtual Kinesiology Lab Module – Post-Test), and an optional review of class average data. Figure 1 depicts a photograph of the Anatomage Table in its vertical orientation, revealing three different layers of the virtual male donor model in virtual dissection. Figure 2 depicts a photograph of students operating the table. Figure 3 depicts a photograph of the virtual donor model being rotated with a full view of the dissected muscular anatomy. Figure 4 depicts a photograph of the right tibia having been selected to display its labeled name. Figure 5 depicts a photograph of the right tibia having been omitted using the Dissection tool feature. Table 2 provides a schedule of these components and their respective assignments and assessments.

The pre-lab reading assignment (see Supporting File S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment) discusses the purpose, rationale, and objectives of the laboratory module. In addition, it provides the etymology of key terms and the background of the fields of kinesiology and two of its subdisciplines: exercise physiology and biomechanics. It also provides the students with basic information concerning

the topics of homeostasis, metabolism, the procedures used in the lab, muscle fiber types, and virtual 3D imaging. The pre-test (see Supporting File S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test) consists of five short-answer questions which are identical to the questions on the two post-tests (see Supporting File S4. Hybrid Virtual Kinesiology Lab Module – Post-Test), but in different orders. These two post-tests are designed to measure students' learning gains after the pre-lab reading assignment and after the laboratory session, respectively.

The laboratory activities include the virtual dissection using the Anatomage Table along with the Anatomage Table Procedures guide (see Supporting File S6. Hybrid Virtual Kinesiology Lab Module – Anatomage Table Procedures) and the Kinesiology Lab Procedures (see Supporting File S7. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Procedures). The former document aids the students with basic operational functions of the table while the latter document aids the students in conducting the virtual dissection activity. In addition, the Kinesiology Lab Guided Questions document (see Supporting File S8. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions) consists of a series of questions that facilitate the students' learning as they complete their virtual dissection.

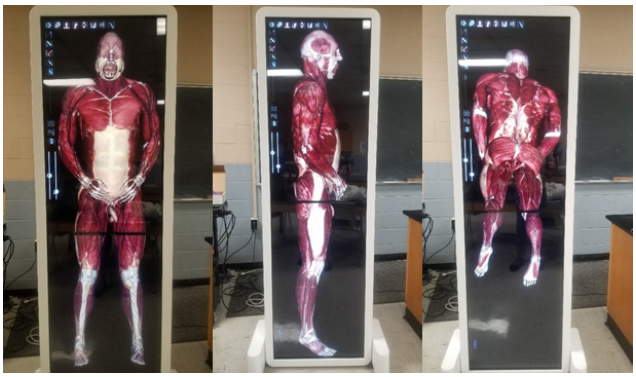

Figure 3. Photograph of the virtual donor model being rotated with a full view of the dissected muscular anatomy.

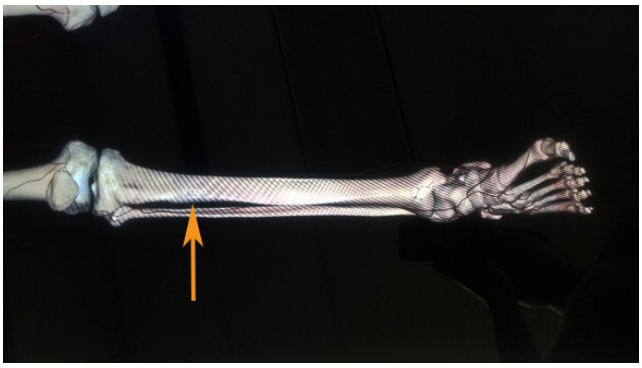

Figure 4. Photograph of the right tibia having been selected to display its labeled name.

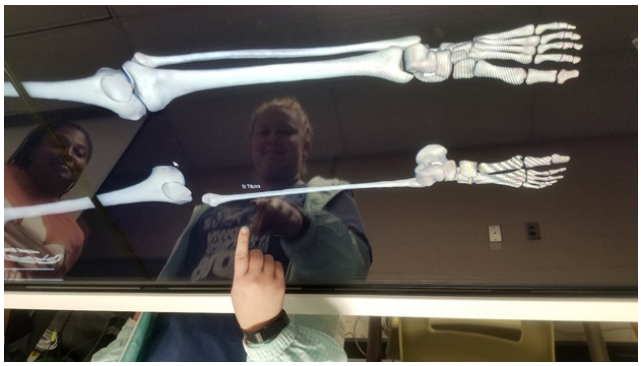

Figure 5. Photograph of the right tibia having been omitted using the Dissection tool feature.

The laboratory activities also include the exercise physiology experiments. These experiments include the Wingate Test and walking and running experiments for measuring accumulated oxygen debt and maximal oxygen consumption. The Exercise Physiology Lab Procedures (see Supporting File S10. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Lab Procedures) document guides students through these experiments. The additional documents, including the Exercise Physiology Data Sheets (see Supporting File S11. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Data Sheets) and the Exercise Physiology Results & Conclusions (see Supporting File S12. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Results & Conclusions) provide a way for students to record data, make calculations, and draw conclusions from their results.

The optional component of the lab module was not implemented in this course, but should instructors choose to incorporate it, they can follow a few basic instructions. Instructors can encourage their students to share the average data from their lab experiments reported on their Average Data Sheets (see Supporting File S11. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Data Sheets, page 3). Each lab group can nominate a reporter to share their findings with the rest of the class while another student from the group enters the lab values in an Excel spreadsheet that is simultaneously projected on a screen during class or lab time. Once all data has been entered and presented, instructors can determine overall class averages for the associated data and encourage students to consider how the average values compare to normative values reported in the literature. The students are required to perform a similar task within the results and conclusions component of the lab module (see Supporting File S12. Hybrid Virtual Kinesiology Lab Module – Results & Conclusions). If there is enough time during the allotted time for the lab module, instructors can implement the optional activity at the end of all other lab activities. If there is not enough time, instructors can choose another time in class or lab to implement the activity. Furthermore, if there are students who are too timid or embarrassed to share their own data, instructors can encourage them to use the normative data they find in their research. If students have trouble finding normative data during their research, instructors can consult two articles in particular providing normative data for men and women at various age ranges, one for anaerobic capacity (80) and one for maximal oxygen consumption (81).

TEACHING DISCUSSION

Instructor and Student Evaluations

This lesson was implemented in Biology 3440 (Anatomy and Physiology I) with 18 students in the Fall of 2017 and 20 students in the Fall of 2018. Two components of this kinesiology module, exercise physiology activities and virtual anatomical dissection activities, were successfully integrated in alignment with the module purpose, rationale, and learning objectives.

Overall, the students responded positively to the laboratory activities. In the Fall of 2017, the Biology 3440 students had trouble recording the distance measurements from the stationary bicycles during the Wingate Test. In the Fall of 2018, this issue was fixed by increasing the time intervals for recording from 5 to 10 seconds. The instructor team (course instructor, teaching assistant, and first author), conducted a run through of the laboratory activities to trouble shoot and address any additional issues.

During the virtual dissection exercise in conjunction with the guided questions, students learned authentic information rather than simply memorizing isolated facts about origins and insertions of individual muscles. For example, rather than simply making lists of muscles and writing their origins, insertions, and actions, the students were asked a series of guided questions (see Supporting File S8. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions) that asked them to consider collective functions of muscle groups. In addition, students were given application-based prompts, such as using their knowledge of the rotator cuff muscles to describe the actions of someone pitching a baseball.

This method of dissection is also a cost-effective alternative for students at undergraduate institutions with limited funding, especially since some undergraduate medical institutions have replaced cadavers with virtual models (12). Future directions will include implementing additional laboratory modules in the anatomy and physiology courses.

After the module was revised and implemented for the Fall of 2018 cohort, the students' performances on the pre- and post-test assessments were compared using a paired two-sample t-test. This analysis showed that students performed significantly better on the post-tests than the pre-tests. Figure 6 displays these results.

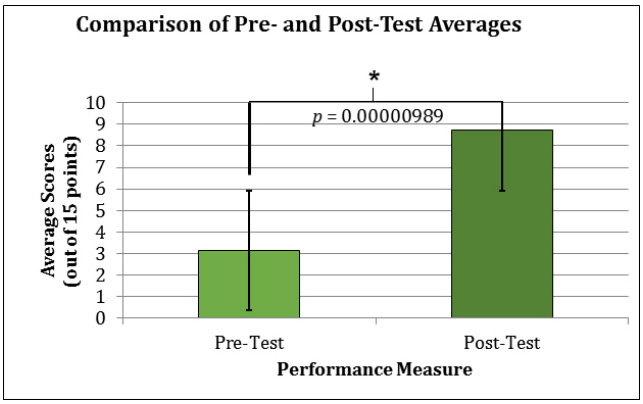

Figure 6. Fall of 2018 students' performances on the pre- and post-test assessments, compared using a paired two-sample t-test. This analysis showed that students performed significantly better on the post-tests than the pre-tests.

Overall, the students also performed significantly better on questions 1, 2, 4, and 5 of the post-test than on the same questions of the pre-test. Although the scores on question 3 of the post-test were higher than those of the pre-test, there was no significant difference between the scores. This finding might have been due to the fact that question 3 was not clearly articulated in a way that informed the students what specific concepts they need to apply to provide a complete and thorough response. This question has been modified accordingly to provide students with a more specific prompt to apply and explain these concepts. Figure 7 displays these results. Only two students performed better on the pre-test than the post-test. However, these point differences were only by one point and a half of a point, respectively. Figure 8 displays these results.

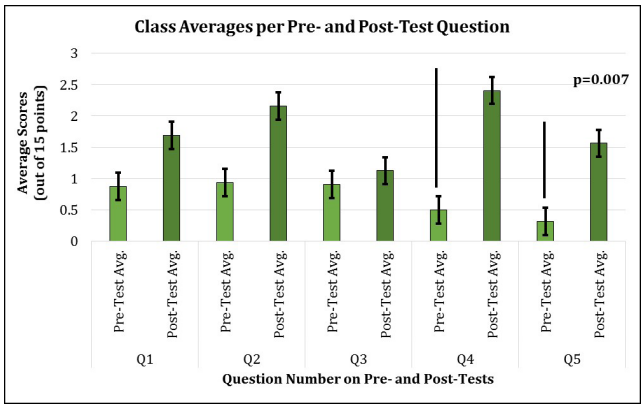

Figure 7. Class averages of student performance on pre- and post-test questions. Students performed significantly better on questions 1, 2, 4, and 5 of the post-test than on the same questions of the pre-test.

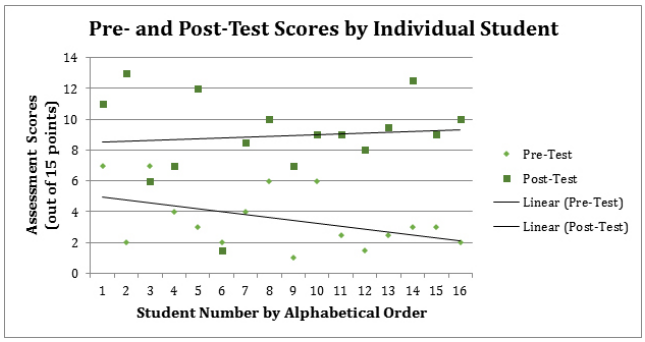

Figure 8. Pre- and Post-test scores by individual student.

Possible Adjustments and Adaptations

This lab module is written for courses that utilize an Anatomage Table; however, similar procedures can be adapted to apply to the use of other virtual dissection tables, like the Sectra Table manufactured by ToLTech, or even other virtual anatomy platforms, such as Complete Anatomy by 3D4 Medical or the Human Body Atlas by Visible Body. All platforms have similar features that allow users to remove structures such as muscles and reapply them back to the model. If institutions, instructors, or individual students do not have access to any virtual anatomy models or devices, then instructors could adapt procedures for actual cadaveric labs, either with real dissections or prosections if their institutions have cadavers, or for plastinated specimens if their institutions use those. These adaptations would not adversely affect the learning objectives, but they might not be considered by some technologically adept students as fun or exciting as the virtual models.

Since this module can also be implemented in anatomy and physiology courses at community colleges as well as other small colleges and universities, instructors might consider reducing the number of concepts covered or activities assessed during the laboratory module. For instance, instructors can reduce the number of muscles required for identification during the virtual anatomy component of the lab (e.g., focusing either on upper

or lower limb muscles). They could also remove some of the more complex procedures and analysis questions such as those pertaining to maximal oxygen consumption and accumulated oxygen debt from the exercise physiology component of the lab. Such a reduction in complexity might be especially appropriate for community college students who have not been exposed to the same level of content as junior and senior students at four-year institutions. Another option instructors have is simply waiting to implement this lab module until after they have covered both the musculoskeletal and cardiovascular systems. In this way, instructors can have more assurance that students in lower-division courses have the necessary prior knowledge to complete the lab activities successfully. Moreover, if instructors are concerned that their students might be overwhelmed by the content and activities within the lab, they could potentially split the lab into two separate labs, a kinesiology lab and an exercise physiology lab.

Depending on the class sizes at other undergraduate institutions, anatomy and physiology instructors can adjust group sizes as necessary to accommodate larger numbers. For instance, instructors can reserve more stationary bicycles and treadmills so that multiple groups can conduct the same activities at the same time and rotate with other groups conducting different activities at the same time. If the exercise devices at other institutions are different brands and models with different operational functions, instructors can modify the procedural protocols as necessary to allow the students to use the equipment successfully. Students with health conditions that prevent them from participating in the exercise experiments can serve as scribes for their respective groups if they are able. Instructors can also refer back to the section on "Inclusive Teaching" for additional ideas regarding lab activity accommodations for students with disabilities.

Instructors who prefer their students not to have access to mobile devices may limit them to using only calculators to perform their calculations. On the other hand, if instructors prefer to go paperless, they can provide all documents electronically. In addition, for large class sizes, if instructors choose to adopt the optional activity, they can plan to use more time during class for more student group presentations.

Summary

Overall, this lab module is not meant to overwhelm the students but rather to challenge them to discuss concepts and engage in activities that enrich their understanding and application of muscular anatomy, kinesiology, and exercise physiology. Instructors are certainly encouraged to use their best judgement in adopting or modifying this hybrid lab module to best meet the needs of their students and the goals of their course. Students having participated in this hybrid virtual lab module showed significant improvement between their pre- and post-test performances. This module is recommended for additional small anatomy and physiology courses at the undergraduate level.

SUPPORTING MATERIALS

- S1. Hybrid Virtual Kinesiology Lab Module – Pre-Test
- S2. Hybrid Virtual Kinesiology Lab Module – Pre-Test Key
- S3. Hybrid Virtual Kinesiology Lab Module – Pre-Lab Reading Assignment
- S4. Hybrid Virtual Kinesiology Lab Module – Post-Test
- S5. Hybrid Virtual Kinesiology Lab Module – Post-Test Key
- S6. Hybrid Virtual Kinesiology Lab Module – Anatomage Table Procedures
- S7. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Procedures
- S8. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions
- S9. Hybrid Virtual Kinesiology Lab Module – Kinesiology Lab Guided Questions Key
- S10. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Lab Procedures
- S11. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Data Sheets
- S12. Hybrid Virtual Kinesiology Lab Module – Exercise Physiology Results & Conclusions

For questions, please feel free to contact the corresponding authors Edgar R. Meyer at ermeyer@uams.edu and Yvette Langdon at langdyg@millsaps.edu as students could easily gain access to these documents online.

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Table 1. Alignment of Lesson Assessments to Lesson Learning Objectives and to the Learning Goals and Outcomes of the Human Anatomy and Physiology Society (HAPS).

HAPS Learning Outcome(s)	Bloom's Taxonomy Concept Level(s)	Targeted HAPS Learning Goal(s)	Lesson Learning Objectives	Lesson Assessments
Module A: Body Plan & Organization				
Topic 5. Basic Terminology				
2. Give specific examples to show the interrelationship between anatomy and physiology.	Application Analysis & Evaluation	1,3,6-8 1,3,6-9,11,14	1 1,8	Pre- and Post-Test Q. 1 Kinesiology Lab Guided Questions
3. Describe the location of structures of the body, using basic regional and systemic terminology.	Comprehension Analysis & Evaluation	1,2 1,2,9,11,14	8 8	Pre- and Post-Test Q. 1,5 Kinesiology Lab Guided Questions
Module B: Homeostasis				
Topic 1. Definition				
1. Define homeostasis.	Knowledge	1	1,2	Pre- and Post-Test Q. 1 Exercise Physiology Results & Conclusions
Module C: Chemistry & Cell Biology Review				
Topic 5. Energy transfer using ATP				
1. Explain the role of ATP in the cell.	Comprehension Analysis & Evaluation	1,4 1,4,9-14	2,4,5,6 2,4,5,6	Pre- and Post-Test Q. 1-4 Exercise Physiology Results & Conclusions
2. Describe the generalizable reversible reaction for the release for ATP synthesis and the release of energy from ATP.	Comprehension Analysis & Evaluation	1,2,4 1,2,4,9-14	2,4,5,6 2,4,5,6	Pre- and Post-Test Q. 1-4 Exercise Physiology Results & Conclusions
Topic 12. Cellular respiration (introduction)				
1. Definte the term cellular respiration.	Knowledge Analysis & Evaluation	1 1,9-14	1,2 1,2	Pre- and Post-Test Q. 1-4 Exercise Physiology Results & Conclusions
2. Explain the process by which glucose is converted through metabolic pathways to carbon dioxide and water (e.g., glycolysis, citric acid [Krebs or tricarboxylic acid] cycle, electron transport chain).	Analysis Analysis & Evaluation	1,2 1,2,3,9-14	1,2,4,5,6 1,2,4,5,6	Pre- and Post-Test Q. 1-4 Exercise Physiology Results & Conclusions
Module D: Histology				
Topic 4. Microscopic anatomy, location, and functional roles of muscular tissues				
1. Describe the structural characteristics common to all types of muscle tissue	Comprehension & Application	1,2,11	7,8	Pre- and Post-Test Q. 1,5 Kinesiology Lab Guided Questions
2. Classify different types of muscle tissue based on structural characteristics	Comprehension & Application	1,2,11	7,8	Pre- and Post-Test Q. 1,5 Kinesiology Lab Guided Questions
Module G: Muscular System				
Topic 5. Skeletal muscle metabolism				
1. Describe the sources of ATP (e.g., glycolysis, oxidative phosphorylation, creatine phosphate) that muscle fibers use for skeletal muscle contraction.	Comprehension Analysis & Evaluation	1-3 1-3,9-14	2,4-6 2,4-6	Pre- and Post-Test Q. 1-4 Exercise Physiology Results & Conclusions

HAPS Learning Outcome(s)	Bloom's Taxonomy Concept Level(s)	Targeted HAPS Learning Goal(s)	Lesson Learning Objectives	Lesson Assessments
2. Explain the factors that are believed to contribute to skeletal muscle fatigue.	Comprehension Analysis & Evaluation	1,2,5,6 1,2,5,6,9-14	3-6 3-6	Pre- and Post-Test Q. 1-4 Exercise Physiology Results & Conclusions
3. Describe the events that occur during the recovery period from skeletal muscle activity.	Comprehension Analysis & Evaluation	1,2,5,6 1,2,5,6,9-14	3-6 3-6	Pre- and Post-Test Q. 1-4 Exercise Physiology Results & Conclusions
5. Compare and contrast the anatomical and metabolic characteristics of slow oxidative (Type I), fast oxidative (Type IIa, intermediate, or fast twitch oxidative glycolytic), and fast glycolytic (Type IIb/IIx or fast twitch anaerobic) skeletal muscle fibers.	Analysis Analysis & Evaluation	1,2,5,7,8 1,2,5,7-14	7,8 7,8	Pre- and Post-Test Q. 1,5 Exercise Physiology Results & Conclusions
Topic 7. Nomenclature of skeletal muscles				
Explain how the name of a muscle can help identify its action, appearance, or location.	Comprehension	1,3	8	Kinesiology Lab Guided Questions
Topic 8. Location, general attachments and actions of major skeletal muscles				
1. Identify the location, general attachments, and actions of the major skeletal muscles.	Knowledge Analysis & Evaluation	1,2 1,2,9,11,14	8 8	Pre- and Post-Test Q. 1,5 Kinesiology Lab Guided Questions
2. Describe similar actions (functional groupings) of muscles in a particular compartment (e.g., anterior arm) or region (e.g., deep back).	Comprehension Analysis & Evaluation	1-3,6-8 1-3,6-9,11,14	7,8 7,8	Pre- and Post-Test Q. 1,5 Kinesiology Lab Guided Questions
**Topic 12. Appliction of homeostatic mechanisms*				
1. Provide specific examples to demonstrate how the muscular system responds to maintain homeostasis in the body.	Application Analysis & Evaluation	1-6 1-6,9-14	1-8 1-6	Pre- and Post-Test Q. 1-5 Exercise Physiology Results & Conclusions
2. Explain how the muscular system relates to other body systems to maintain homeostasis.	Analysis Analysis & Evaluation	1-6 1-6,9-14	1-8 1-8	Pre- and Post-Test Q. 1-5 Exercise Physiology Results & Conclusions
Topic 13. Predictions related to disruption of homeostasis				
1. Given a factor or situation (e.g., muscular dystrophy), predict the changes that could occur in the muscular system and the consequences of those changes (i.e., given a cause, state a possible effect).	Synthesis Analysis & Evaluation	1-8 1-14	1-8 1-8	Pre- and Post-Test Q. 1-5 Exercise Physiology Results & Conclusions
2. Given a disruption in the structure or function of the muscular system (e.g., skeletal muscle atrophy), predict the possible factors or situations that might have caused that disruption (i.e., given an effect, predict possible causes).	Synthesis Analysis & Evaluation	1-8 1-14	1-8 1-8	Pre- and Post-Test Q. 1-5 Exercise Physiology Results & Conclusions

*Note: The HAPS Learning Outcomes listed under topic 12 of Module G are from the 2010 Learning Outcomes, because these two objectives are better aligned with the activities in this lab module.

Table 2. Schedule of the Hybrid Virtual Kinesiology Laboratory Lesson

Activity	Description	Estimated Time	Notes
Preparation for Class			
Instructor Lab Run Through	Practice completing the lab to troubleshoot any potential complications.	2-3 hours	Record experimental measurements and make calculations to note additional instructions helpful to provide to students.
Make copies of Supporting Materials	Print 1 copy of each document for each individual student.	30 minutes	Handouts are provided in the Supporting Files.
Pre-Lab			
Pre-Test	Assessment of students' prior knowledge with 5 open-ended questions.	10 minutes	1. The Pre-Test and key should not be distributed to non-students. Pre-Test provided in Supporting File S1. 2. Administer Pre-Test during a separate class period before the pre-lab reading is assigned.
Pre-Lab Reading Assignment	Background information pertaining to lab concepts.	15-20 minutes	1. Pre-Lab Reading Assignment provided in Supporting File S3. 2. Assign the reading for homework before lab.
Post-Test	Assessment of students' learning with five open-ended questions	10 minutes	1. The Post-Test and key should not be distributed to non-students. 2. Administer Post-Test during class immediately before the lab session.
Laboratory Activities			
Anatomage Virtual Dissection	1. Operate the dissector table using the Anatomage Table Procedures. 2. Complete the dissection by following the Kinesiology Lab Procedures. 3. Answer the Kinesiology Lab Guided Questions throughout the dissection.	25-30 minutes*	1. Anatomage Table Procedures provided in Supporting File S4. 2. Kinesiology Lab Procedures provided in Supporting File S5. 3. Kinesiology Lab Guided Questions provided in Supporting File S6.
Wingate Test Experiment	1. Complete the experiment by following the Exercise Physiology Lab Procedures. 2. Record measurements on Exercise Physiology Data Sheets. 3. Make calculations, interpret data, and draw conclusions on Results and Conclusions sheet.	6-10 minutes* 20-24 minutes	1. Exercise Physiology Lab Procedures provided in Supporting File S8. 2. Exercise Physiology Data Sheets provided in Supporting File S9. 3. Results and Conclusions sheets provided in Supporting File S10.
Accumulated Oxygen Debt Experiment	1. Complete the experiment by following the Exercise Physiology Lab Procedures. 2. Record measurements on Exercise Physiology Data Sheets. 3. Make calculations, interpret data, and draw conclusions on Results and Conclusions sheet.	25-30 minutes* ~30-40 minutes	1. Exercise Physiology Lab Procedures provided in Supporting File S8. 2. Exercise Physiology Data Sheets provided in Supporting File S9. 3. Results and Conclusions sheets provided in Supporting File S10.

Activity	Description	Estimated Time	Notes
Post-Lab			
Post-Test	Assessment of students' learning with 5 open-ended questions	10 minutes	1. The Post-Test and key should not be distributed to non-students. Post-Test provided in Supporting File S4. 2. Administer Post-Test during class immediately after the lab session and the completion of all assignment sheets.
****Optional Activity:** Review of Class Average Data	1. Each group tabulates its average data. 2. The mean of all group means are calculated to predict trends.	~30 minutes ~15 minutes	1. Students tabulate on Average Data Sheet on p. 3 of Supporting File S9. 2. Encourage students to share their results with their classmates.

This table outlines the main components of the laboratory lesson and specific times during which the instructors should administer their respective assignments and assessments. It also includes the duration of time for each assignment and assessment. The laboratory activities and both post-tests can be conducted during one four-hour lab period as the implementation of this hybrid lab module was completed within the allotted four-hour timeframe. Instructors at institutions with no or shorter lab periods can spread this lab module's activities over the course of several class sessions. The pre-lab reading assignment is designed to be provided to students as a flipped classroom assignment so that they can read it and the linked videos before coming to lab. The pre- and post-tests though should be administered during class or lab time to ensure that students do not look up the answers or engage in any other dishonest behaviors.

***Note**: The students rotate between these three activities during their laboratory sessions. The time allotted to each of these activities does not include the time taken for students to rotate between activities, so instructors should allow students 10 minutes of travel time between stations.

****Note:** The Review of Class Average Data is listed as an optional activity because only the first step was conducted during the lab session when the students recorded the average data for their group onto their Average Data Sheet on page 3 of Supporting File S9. The second step was not conducted during this lab module.