BIM 228
Skeletal Muscle Mechanics: Form, Function, Adaptability and Implications for Human Movement

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Course Description:

    This course is divided into four parts. The first part covers the structural/functional relationships of skeletal muscle from both the microscopic and macroscopic levels. Various tools used to examine muscle-tendon structure and function are discussed. The influence that structural variations at each of these levels have on muscle mechanics is explored.

    The adaptability of muscle is considered in the second part of this course. The structural changes that occur as a result of the natural aging and maturation processes are explored along with their functional significance. Muscle-tendon responses to exercise and disuse are presented. Also considered is the healing response of muscle after injury.

    Selected topics related to the structural/ functional/ adaptability characteristics of multi-muscle systems are considered in the third part. These include muscle force potentiation during a stretch-shortening cycle, fatigue, and motor control issues.

    In the final section modeling approaches used to describe muscle structure and function are presented.

Course Objectives:

1. To describe the basic structure and function of skeletal muscle.
2. To illustrate the complex interactions that exist between muscle structure, usage, kinematics, and performance.
3. To provide the student with an understanding of the mechanisms involved in muscle adaptation to altered stress states created by such things as overuse, disuse, trauma, aging, etc.
4. To present some of the fundamental approaches currently being used to model muscle and its behavior within the body.

Prerequisites: Graduate standing or consent of instructor. Basic background in biology, physiology, and engineering. Equivalents of EXB 103, and EXB 126 recommended, And/or ENG 35, ENG 45. Eqivalents of MAT21D and NPB 101 recommended.

Grading:

Midterm	=	25	%
Final	=	35	
Paper	=	20	
Home Work	=	10	
Group Projects	=	10	
		100	

Note: Assignments are considered late if received after the end of class on the day the assignment is due. Any assignment turned in late will receive a 10 % penalty if received prior to 5:00 pm. the following day and a 5 % penalty for every additional day thereafter up to 50 %. No work will be accepted after the last day of instruction.

Text: Lieber, R.L. Skeletal Muscle Structure, Function & Plasticity: The Physiological Basis of Rehabilitation. 3rd Edition, Lippincott, Williams and Wilkins, Baltimore, 2009. ISBN 0-7817-75930 (9780781775939).

On-line Text: Hawkins, Skeletal Muscle Mechanics available via Canvas/Pages/Hawkins On-line Textbook.

All students are expected to follow the UC Davis Code of Academic Conduct: Sja.ucdavis.edu/cac.html

Specific Class Objectives

Instructional Objective – At the end of the course students should be able to:	Instructional Material – The following material is provided to assist students in achieving the stated expectations.	Learning Assessment – Students' achievement of the stated expectations will be assessed in the following ways. Students will need to:
Recognize the micro to macro structural organization of skeletal muscle	On-line text (Chps 2-4) Lieber text	Correctly identify the structural organization of skeletal muscle in home work, term paper, mid-term and final examinations.
Describe the structure/function relationships within skeletal muscle	On-line text (Chps 2-6) Lieber text Class Discussions Home work assignments	Accurately describe the structural organization and functional role of neuro-muscle-tendon structures in home work, a term paper and on mid-term and final exams. Correctly answer True/False, fill-in-the blank and short answer questions regarding structure composition and organization.
Recognize and understand common terminology used in muscle mechanics	On-line text (Chp 5) Lieber text Class Discussions Home work assignments	Use correct terminology in home work and term paper. Correctly interpret and answer True/False, fill-in-the blank and short answer questions regarding muscle mechanics terminology.
Clearly describe how skeletal muscle develops and responds to injury, aging and altered environmental stimuli	On-line text (Chps 6-9) Class Discussions Home work assignments	Correctly answer True/False, fill-in-the blank and short answer questions regarding skeletal muscle development and response to injury, aging, altered loading in mid-term and final exams. Provide essay responses to home work problems.
Understand basic mechanisms of muscle fatigue and force potentiation and enhancement	On-line text (Chps 10-11) Class Discussions Home work assignments	Correctly answer True/False, fill-in-the blank and short answer questions regarding skeletal muscle development and response to injury, aging, altered loading in mid-term and final exams. Provide essay responses to home work problems.
Solve mathematical problems pertaining to the force generation potential of skeletal muscle.	On-line text (Chps 5 & 12) Sample questions in text Class Discussions	Correctly answer True/False, fill-in-the blank and short answer questions involving basic mathematical derivations of skeletal muscle. Solve home work problems.

Synthesize information from basic studies of skeletal muscle and theorize as to how muscle might respond to a given change in loading, disease, etc. or what strategies might be most effective to create a desired change in the system	Class Discussions Home work assignments Small Group Case study problem solving	Correctly answer integrative essay questions on mid-term and final. Appropriately synthesize and interpret information provided in home work assignments to answer specific questions.
Conduct a literature search of a clinically relevant Neuro-muscle-tendon topic and write a clear and concise summary explaining the topic and the basic and applied research that has led to our understanding of this topic	Class Discussions Library resources.	Write a clear and concise term paper summarizing the selected topic.

Lecture Schedule

Date	Topic	Reading	HW(due)
Sep	Administrative stuff: Introduction: Historical Perspective of skeletal muscle form and function Muscle Structure - macroscopic to microscopic	L. Chp 1 H. Chp 1,2	
Sep	Specifics of skeletal muscle structure Techniques employed to study muscle-tendon structure	L. Chp 1 H. Appendix	
Sep	Neural aspects of muscle action *Topics due*	L. Chp 1,2 H. Chp 3	#1
Oct	Energy pathways Basic mechanics and muscle behavior	L. Chp 2 H. Chp 4	
Oct	Basic mechanics and muscle behavior	H. Chp 5	#2
Oct	Muscle structural variations and their functional effects	H. Chp 6	
Oct	Muscle structure and function during development: *Literature Review Outline due -* 2nd half of class devoted to Group Project Introduction Hypotheses and Testing Approach for Adaptation Responses	H. Chp 7	#3
Oct	Muscle structure and function during development: Small group meetings	L. Chp 1 H. Chp 8	
Oct	Small group meetings Question/answer time prior to exam	L. Chp 4,5 H. Chp 8	
Oct	**Exam I (small groups can get together after exam)**		
Oct	Review Exam I Time for Group Meetings to plan for presentations	H. Chp 9	
Oct	Group Discussion presented by students (Usain Bolt) Group Discussion presented by students (Endurance Training and Aging) Discussion of Injury & Disease (not covered in Group Topics)	H. Chp 9	
Nov	Group Discussion presented by students (Resistance Training and Maturation) Group Discussion presented by students (Disuse, Aging, Sarcopenia) Summarize response to exercise/disuse/injury/disease	H. Chp 10.	
Nov	Fatigue	H Chp 11	#4
Nov	Muscle Force Enhancement – possible in-class demos		
Nov	Muscle-Tendon Modeling	H. Chp 12	#5
Nov	Muscle-Tendon Modeling		
Nov	Muscle-Tendon Modeling *Paper due*	L. Chp 3	#6
Nov	Multi-muscle systems - implications for human movement Clinical considerations	L. Chp 3 H. Append	
Nov	Example Problems and Solutions		#7
Nov	Example Problems and Solutions *Discussion of papers* Integration, summary & looking forward		
Dec	**Final Exam**		

Literature Review Project

Part of your grade in this class will be based on a Literature Review Project. Some possible topics that may be reviewed are listed on the following page. Other topics are possible, but they must be approved by the instructor. The topics listed below were selected to complement the material presented in lecture.

Literature Review Project due dates:
1. Topic selection - 2nd week of class
2. Literature Review Outline - 4th week of class
3. Written report - 8th week of class
4. Group discussion of papers - last week of class

Summary of Project Expectations
1. Topic should be selected from the list on the following page or approved by the instructor. Some of the topics listed are quite general and can be approached in a variety of ways. Others are more specific and do not provide as much flexibility in your approach. The topic must have an emphasis on skeletal muscle.

2. Your literature review outline should include
   a. A description of the topic and specific focus that you have selected.
   b. A brief outline of what will be reviewed.
   c. A list of at least 10 references that you have found and that you have determined to be relevant to your topic.

3. The written report should be no longer than 8 pages (typed 12 point font and double-spaced). The report should include at least three sections. The first section should be an introduction to the topic. The second section should summarize the information you obtained from the literature. The third section should contain your interpretation of the results cited. You should attempt to explain conflicting reports in the literature and inject your own feelings as to the validity of the various reported findings. Do the results make sense based on your understanding of muscle behavior and your practical experience? The report should also include a comprehensive bibliography.

Grading of Literature Review Project:
1. 5 % of your grade will be assigned for your initial Literature Review Outline (2 % for summary, 1 % for outline, and 2 % for references).
2. Your written report will account for 15 % of your total grade. Of this 15 %, 10 % will be assigned for the completeness of your literature review relative to the topic. The other 5 % will be given for your interpretation of the literature review findings.
3. **Note:** Outlines or written reports turned in late will receive a 10 % penalty for the first day late and 5 % for every day thereafter up to a maximum of 50 %. Reports will not be accepted after the last day of instruction.

Possible Literature Review Topics

1. **The role of different exercise modes (isometric, concentric, eccentric) on muscle protein synthesis and architecture.**
   Are there different pathways that cause protein synthesis depending on the mode of exercise?
2. **Muscle trauma**
   What are the types of trauma that occur to muscle and how does a muscle respond? Particular consideration should be given to the time frame of the healing response.
3. **Muscle response to eccentric exercise**
   How does muscle respond to active stretch (injury, response by internal structure, effects on mechanics)
4. **NSAIDS effects on muscle**
   How does muscle respond to acute and chronic use of Non-Steroidal Anti-Inflammatory Drugs?
5. **Muscle-tendon-bone rates of strength gain and/or loss**
   What are the rate variations in the strength gain and/or loss as a result of exercise and/or disuse and/or aging?
6. **Over-training detection methods and their significance**
   What methods are available for detecting over-training based on the muscle's response to such activity?
7. **Limits on muscle strength - physiological basis**
   Based on structural considerations of muscle, what are the physiological limits of muscle strength? Do these limits confirm experimental data?
8. **Muscle force potentiation - factors of influence**
   What factors affect the force potential of a muscle experiencing a stretch shortening cycle?
9. **Potential for gross architectural modifications and its effects on movement**
   Can a muscle-tendon unit be modified architecturally (e.g. through stretching, exercise, surgery, etc.)? What effect can this have on gross limb dynamics?
10. **Fatigue**
    Possible sites of fatigue relative to different movement tasks.
11. **Muscle Regeneration**
    Describe how muscle fibers / nerves regenerate. What are the conditions for successful regeneration or failure.
12. **Diet and muscle gene expression**
    Can nutritional factors affect muscle gene expression and if so how?
13. **Drugs and muscle-tendon-bone function**
    What is the effect of human growth hormone, steroids, etc on muscle, tendon, and bone insertions? What are the long term effects on these tissues? Are these tissue more susceptible to injury after drug use?
14. **Overuse injuries: Can a threshold of injury be identified?**
    What are the contraction conditions most likely to lead to injury of a muscle-tendon complex? That is, can a threshold of injury be defined as a function of the level of force developed, the kinematics, the duty cycle, the duration of activity, etc.?
15. **Muscle mechanics and energetics.** What is the metabolic cost associated with different modes of contraction and is it fiber type dependent?
16. **From isolated muscle testing to intact muscle mechanics**. Compare the basic mechanical behavior of isolated skeletal muscle to muscle behavior in-vivo. Specifically look at force-length and force velocity relationships.
17. **Nitric oxide's role in muscle function/disfunction.** It has been suggested that nitric oxide may play an important role in muscle function and injury. Investigate how nitric oxide could affect muscle function.
18. **Muscle force transmission pathways**. Several studies suggest that skeletal muscle does not transmit force in a simple linear fashion from fiber to connective tissue. Investigate the potential pathways of force transmission.

Group projects

The class will be broken into 3-4 small groups (~2-4 people in each group depending on class enrollment). Each group will be assigned a question. The group is to work together to formulate a clear, concise answer to the question and develop a ~30 minute presentation for the class to describe the question, your original hypothesis, your conclusions and the basis for your conclusions.

Possible questions:
1. Usain Bolt won the 100 and 200 meter Olympics in 2008, 2012, 2016. Describe potential neuro-muscle-tendon-bone features that Mr. Bolt may have that allows him to run so much faster than other elite runners. Consider anatomical and physiological characteristics in your analysis. How do limb inertial properties affect his ability to run fast?

2. Two relatively healthy and moderately active females, one 18 and the other 65, have decided to train for a marathon. How should they train and how will their neuromuscular systems change in response to the training? What are the training objectives? What do you theorize is the best training approach to achieve these objectives? Explain the rationale behind your training program. What precautions need to be taken?

3. Two brothers want to become stronger and decide to start a resistance training program. The two brothers are 12 and 16 years old. Specify a training program or programs that will be appropriate for each boy if the goal is simply to maximize strength gains over 12 weeks. What do you theorize is the best training approach to increase muscle strength in these two boys? Explain the rationale behind your training program. What precautions need to be taken? What magnitude in strength gains can be expected? Explain how the neuromuscular system of these boys will change and the time frame associated with these changes.

4. A 65 year old female recently retired after being the CEO of a large company for many years. She had little time while working to be physically active. Her physician says she has sarcopenia and tells her she needs to start an exercise program. Define sarcopenia and describe how the skeletal muscles in this woman are likely different (structurally and functionally) from those of a woman of the same age who has been physically active (running and lifting weights) throughout her life. Outline a training program that you think would benefit this woman and not hurt her. Describe the time line. Describe how the muscle would adapt to this training and how quickly. Explain the rationale for your recommendations and the time-line associated with any changes that will occur within the muscle.

5. Muscle cramps are commonly experienced by athletes and the elderly. What are the mechanisms responsible for muscle cramps? Can muscle cramps be prevented?

<u>Assignment and Grading:</u>
Each group should formulate a set of hypotheses pertaining to their question(s)/situation. The members should work collectively to develop a plan for approaching the problem. Everyone should agree to a division of labor for acquiring the information needed to address the problem and for summarizing and presenting the findings. Each group member should perform a literature search and identify several articles that might be relevant for answering the question. Each member should be responsible for reading, summarizing and presenting to the group at least one key article. The group should collectively synthesize the information from the various articles and formulate an answer to the posed question. The group should then decide how best to present their findings to the class. The presentation should clearly introduce the question, state the original hypotheses developed by the group, summarize the information obtained from the articles pertaining to their question and hypotheses, and summarize conclusions. Each group should submit a project summary that includes:
1. A project outline indicating the responsibility of each member of the group.
2. A brief summary of your findings, with proper citations supporting your findings.
3. Reference list
In addition each group should organize an approximately 30 minute presentation to be given to the rest of the class. This presentation should clearly describe the question, your original hypothesis, your conclusions and the basis for your conclusions.

Each student will be graded based on evaluations provided by other members of the group as well as the instructor's evaluation of their contribution to the project and presentation.