EDUCATIONAL PRACTICES in Kinesiology

Teaching and Learning Resource

Using the Revised Bloom's Taxonomy for Advanced Graded Exercise Testing in Clinical and Sport Performance-Based Courses

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ABSTRACT

Educational Practices in Kinesiology 4(1): Article 6, 2024. Determining functional capacity (FC) is critical to performance and clinical measures. In this lab, students will propose, complete, and evaluate the success of a graded exercise test (GXT) of their own design. This lab is intended for upper-level students exposed to both maximal and submaximal exercise testing. This is an in-person activity because of the nature of FC testing; however, there may be ways to convert this into an online space as case studies or rely solely on submaximal estimations. Depending on the types of tests being performed, a 50-minute class can complete two tests per metabolic cart available. Lead-in preparation days will make the actual lab day more likely to succeed. These days, students will pilot different procedures and dial in the stepwise staging of the test they are to develop. This activity is designed to engage higher levels of Bloom's taxonomy, with the main benefit of this lab being to have students demonstrate their understanding of the underlying principles of exercise testing remembered from previous courses by applying it to unique situations and designing appropriate testing for the challenge. They will need to defend their design choices after analyzing the material learned from previous coursework as it applies to the current task. Evaluation of the activity begins with distinguishing whether criteria for a successful GXT have been achieved and ends with students critiquing the GXT they have developed after testing.

KEY WORDS: Exercise physiology, testing and measurement, Bloom's taxonomy, graded exercise testing, VO_2

INTRODUCTION

Functional capacity (FC) evaluation is a cornerstone concept for exercise science students. Understanding its application and expected values are critical for properly programming training plans for both athletic and clinical populations (Soer et al., 2009). While fundamental principles and background physiology are commonly taught in lower-level undergraduate courses, application, analysis, and evaluation of appropriateness occurs in higher-level coursework. There are a myriad of FC testing protocols available to choose from that fall under the category of graded exercise test (GXT) based on the needs of the individual (Buttar et al., 2019). This wide selection can be challenging to sort through for the individual due to changes in perspective on appropriate testing, what constitutes criteria for successful testing, and error in measurement (Beltz et al., 2016). This range of options means that instructor choices of course design to meet learning objectives play an important role in bridging the divide between lower and upper-level courses, meeting students where they are, and helping to develop relevant understanding and skills.

Bloom's taxonomy provides a leveled framework by which instructors can align course activities with stages of learning to progress from memorizing the facts from lower-level courses to developing their own uses for these principles in upper-level courses (Zaidi et al., 2017). The original framework proposed in 1956 by Bloom et al. was revised in 2001 by Anderson and colleagues to encapsulate a more dynamic environment of student learning instead of solely evaluating student performance (Anderson et al., 2001). This revised framework has been demonstrated to aid in student understanding in the sciences (Nascimento et al., 2021) by how they interact with the material (Zaidi et al., 2017). However, it is important to remember that activities and lessons need to be structured in a way that integrates the levels of Bloom's taxonomy to be useful in professional settings (Rafai et al., 2016). For exercise science and kinesiology students, professional settings most commonly are in athletic or rehabilitative fields.

Designing engaging activities and assignments that promote synthesis of known topics to address novel situations provides strong opportunities to interact with higher level Bloom domains. Examples that promote application, analysis, evaluation, and creativity have included simulations (Meir, 2022; Nascimento et al., 2021), puzzle-based activities (Stetzik et al., 2015), and concept approaches to pedagogy instead of content-centric (Getha-Eby et al., 2014). This paper aims to outline a laboratory activity for upper-level students that incorporates concepts from lower-level coursework for students to apply to solve novel challenges. Figure 1 identifies the aspects of this lab as they apply to the revised Bloom's taxonomy.

With the common professional settings of these students in mind, this paper will focus on a lab activity that can be adapted to multiple scenarios. Courses that would most likely use this lab activity are upper level and have been preceded by introductory courses such as an introductory exercise physiology, exercise testing and prescription, measurement and evaluation, or physiological assessment course. Familiarity with pre-exercise screening, metabolic cart use, physiologic response to exercise, and criteria for successful GXT will increase the efficiency of this lab. The activity outlined in the current paper is best completed after students have some experience with GXT or submax and symptom-limited exercise testing and specificity of testing.

This laboratory activity will have students create and then test a GXT of their own design. Depending on the course, students will be given restrictions and instructions regarding the population tested to fit different learning outcomes. For instance, a clinical exercise physiology course may use symptom-limited testing or submaximal testing and put limitations on the students, such as their participant doesn't have full use of their left arm or leg due to surviving a stroke, which would drive their exercise mode choices. Whereas an advanced exercise physiology course would use principles of specificity to design an appropriate test for an advanced athlete finishing a certain mesocycle of training. A GXT requires surveillance and recording of multiple metrics and settings, which would be difficult for an individual to manage. Student groups should be employed to increase the likelihood of successful GXT operation. In a class of about 20 students,

a team of 3-5 would be appropriate for this activity in a 50-minute class period. The total number of metabolic carts available will dictate the number of students engaged at a given time. In a 50-minute class period, roughly two or three GXT can be performed per metabolic cart.
The primary learning outcomes for this activity are that 1) students will be able to analyze and apply principles of established GXT to identify themes, 2) students will be able to design and conduct a GXT of their own making, 3) students will be able to determine the success of their GXT against accepted criteria for maximal testing, 4) students will be able to modify their GXT, if appropriate, to achieve accurate testing results, and 5) students will be able to justify their choices of design of their GXT. These learning outcomes align with larger program outcomes that relate to assessment of health status and physical fitness and the design, implementation and evaluation of exercise testing and programs for both healthy and clinical populations.

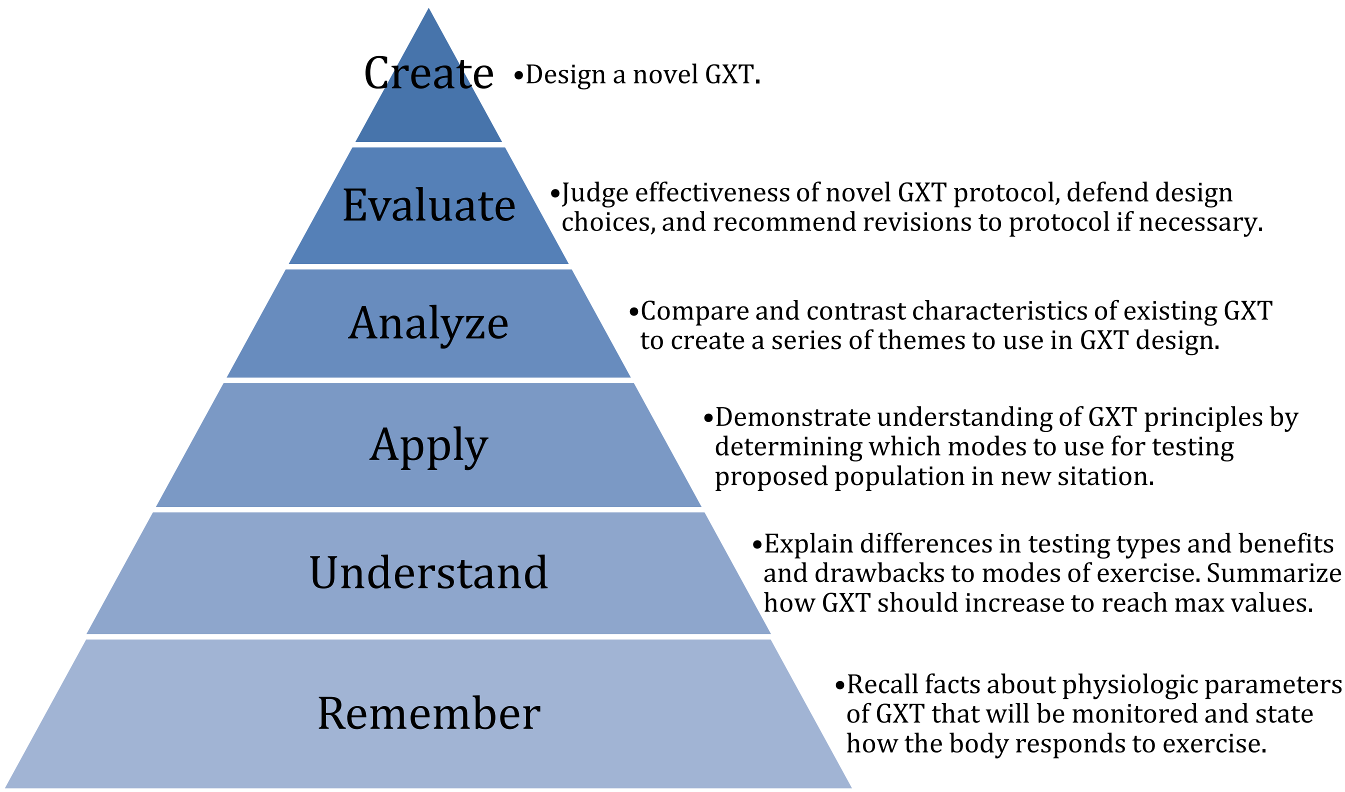

Figure 1. Classifying Lab Activities with Bloom's Taxonomy

METHODS

Classroom Management

Pre-lab preparation days will make this activity more likely to succeed. These days can begin with an in-class or online review of topics from previous courses pertaining to physiologic response to GXT (blood pressure, heart rate, ratings of perceived exertion (RPE), etc.). These days should also ensure that students remember what criteria constitute a successful GXT and understand how they are reached during exertion. Further discussion can be had on the specificity of testing and differences across populations. Quizzes and worksheets can be used here to determine the retention level from previous courses and direct instruction plans.

Instructors have a high degree of freedom to add constraints to the activity before students begin their analysis of established GXT and embark on creating their own. For instance, the instructor may limit the exercise modes to those that only use barbells, dumbbells, or kettlebells. Likewise, they may want to limit aerobic modes to only ones distinct from cycle ergometers and treadmills. A clinical exercise physiology course may provide students with a patient who will be symptom-limited in their testing. In contrast, an advanced exercise physiology course may focus on a case of sport-specific testing or testing that evaluates fitness acquisition over a set mesocycle of training. Instructors may also provide fewer restrictions on student choice to allow for a wider range of innovation. Regardless of the constraints, all students should be asked to justify their choices.

Exercise testing protocols frequently require multiple tasks to be completed simultaneously, be it monitoring physiologic parameters or vital signs, recording stage data, or adjusting workloads. Therefore, student groups are beneficial. With one student performing the novel GXT, three or four additional students would be needed to run the test successfully. For example, one student may be responsible for monitoring metabolic cart readings and calling out time cues, another student may be responsible for collecting RPE and changing settings on the ergometer, another student may be responsible for recording values, and another to serve as the test participant.

Equipment

For GXT, a metabolic cart is desired. This allows for the correct measurement of numerous criteria of a successful test. An RPE poster or sheets can be used. Students may also benefit from practicing blood pressure measurements during the test, although depending on the mode of exercise chosen, this may prove impractical. This lab encourages a variety of exercise modes and the equipment used can vary greatly. Examples of modes that have been used are included in Table 1.

Table 1. Example of GXT selection and populations where they are used.

Example Mode	Population
Back squats/leg press	Athletic
Superset chest press-row machines	Athletic
Jump rope	Athletic
Burpee hop overs	Athletic
Lunges (barbell, dumbbells, or weighted vest)	Athletic
Kettlebell swings	Athletic/Clinical
Rowing ergometer	Athletic/Clinical
Stationary cycling	Athletic/Clinical
Treadmill	Athletic/Clinical
Sandbag carry	Athletic/Clinical
Stair steps	Clinical
Arm ergometer	Clinical
Elliptical	Clinical

Student Instructions

Students are to form small groups of three to five people. The level of constraint the instructor deems appropriate determines how open-ended the directions will be. Three example lab formats are provided in the Resources section that offer various degrees of constraint. Instructors may find them suitable as described or decide to combine or modify them to meet the needs of the course. Generally, a successful format of this lab would have students engage in the following:

1. Students are to examine a list of established GXT (can be instructor-provided, from a book, or up to the students to find). When comparing and contrasting the tests, each group should generate information such as the goal of the test, number of stages, stage length, initial intensity, progression of difficulty, which muscle groups are primarily being worked (and whether smaller muscle fatigue may be an issue), and where an individual would be expected to end the test (may be quantified in metabolic equivalents [METS], or against oxygen consumption [VO_2] norms for different populations).

    A. Students should create an outline of these shared themes to help them develop their test. This might look like:
        i. Stepwise, linear progression of intensity, starting with walking speed (~3.5 mph) up a small incline (~2%).
        ii. Stage length should be 2-3 minutes, and the total test should not exceed 15 minutes.
        iii. Expect the test to end >10 METS.
        iv. High incline on the treadmill may cause undue calf fatigue.

2. Students will be given a case/scenario of an individual for which to design a GXT. These will vary depending on the course or content being covered at the time. Some examples include a person who has diabetes with peripheral neuropathy resulting in foot pain while walking, a midfield lacrosse player wrapping up off-season training, a person whose legs are paralyzed but has full use of their arms and no autonomic complications, or a practitioner of Brazilian Jiu-Jitsu getting ready for no time limit submission only tournament training.

3. Students are to identify the needs and capabilities of their individual, which will inform choices for the specificity of testing. Using the themes students categorized earlier, they will draft a GXT protocol that they think will best evaluate that individual.

4. Students are to perform the GXT they have created. Students will be assigned various responsibilities to ensure the testing is completed smoothly. The instructor should give data collection sheets for the GXT or outline values to obtain during the test so that each group can complete the post-lab write-up.

5. Following the test, students must evaluate whether they achieved maximal oxygen consumption (VO_{2max}).
    A. Student groups are to determine their test's strengths and weaknesses after reflecting on their results.
    B. If the student did not achieve the criteria for a successful test, they are to propose improvements to their protocol and justify why they believe these would result in better outcomes.
    C. Students are to compile their work using a lab write-up outline provided by the instructor for submission.

Assessment

Instructors have multiple opportunities to assess student work throughout the project. Pre-activity quizzing was suggested under classroom management, but real-time evaluation is also present. For instance, the instructor may curate a list of GXT that students will evaluate and then lead a discussion regarding the student groups' findings to ensure that the correct themes are identified. An instructor may also have students look at original research that provides validity and reliability data on GXT protocols and use in-person or online quizzing to demonstrate understanding. Many of these choices in the assessment are directly related to the amount of freedom the class is given to complete the project and how the instructor chooses to tie this activity to other course material or to course material that was encountered earlier in the curriculum as well as the time available to provide oversight. An instructor may give latitude in the initial GXT investigation but then meet with groups individually to discuss their plans or ask for drafts of protocols and provide feedback, directing the students towards a more successful or appropriate plan.

An example of a pitfall that could be avoided with a more involved assessment may be ensuring students make the test challenging enough. As many GXT start with several lower intensity stages, without direction and assessment, students might take the wrong notion from this and overprescribe less challenging work while neglecting higher intensities. When using foreign exercise, a student may not be familiar with how difficult a given work rate is or how fatigue will accumulate. This opens opportunities for piloting their protocol or investigating additional resources to prevent a situation where the student performing the GXT can complete all the stages laid out in the protocol but has not achieved the criteria for a successful test. The instructor may direct students to "work backward" when designing their tests such that their top stage should be slightly out of reach for most people in their target population and then adjust to the first stage in a stepwise fashion. While this oversight may be necessary for undergraduates, a graduate-level course may specifically avoid this type of direction to assess the capability and ingenuity of their students. Regardless of the number of assessment points along the analysis and design phases of the activity, all groups (or individuals) would be expected to submit an assessment of their protocol after the test was run and judge whether it was successful and what changes would be necessary if it was not.

Post-Activity

A short post-activity debriefing can be beneficial. For instance, it may be necessary to split GXT tests across days due to limited equipment, or the attendance of the entire roster may overcrowd lab space. However, allowing students to observe tests being performed can be a powerful tool for students to see shortcomings and work through their solutions, and be tied to activity assessment. To this end, it may be worthwhile to assign students to observe other groups and write a synopsis of the strengths and weaknesses of the observed protocol.

It may be best for the instructor to bring the entire class together and talk through some generalities and specifics of positives and negatives that came out of the testing. If student groups were split across days when performing the GXT, all students may not have been able to see the other tests performed. The instructor can discuss the results of each group - or specific groups that serve as teachable examples - to give the rest of the class ideas on how to proceed with their post-lab write-up and assessment of their procedures.

During these debriefings, the instructor may give examples that may or may not have occurred in the lab. For instance, posing scenarios for discussion as to why a test resulted in a high respiratory quotient but never reached a VO_2 plateau, or a VO_2 plateau but observing a minute ventilation of 60 L/min for a large statured person, or meeting RPE criteria but not seeing a VO_2 within the expected range. The instructor would then drive discourse seeking conjecture on how these scenarios were achieved and what could be improved to reach a more predictable result. These scenarios could also be used as additional write-up questions or as follow-up exam questions on this material.

DISCUSSION

This is the first instance of a paper applying the revised Bloom's taxonomy to design upper level GXT coursework for kinesiology and exercise science students. Students must retain and utilize knowledge and concepts from previous coursework and apply it to a new scenario where they develop their own GXT and critique its effectiveness in measuring VO2 max. It provides a flexible framework for instructors to achieve varied outcomes while requiring a higher level of engagement from students. The flexibility of this activity means it can be utilized in both clinical and sport-centric courses.

This activity presents challenges. Primarily a lack of exposure, understanding, or recall of previous coursework regarding GXT will mean some remediation is required before being able to perform the lab. However, this may serve as a benefit as the instructor can review the pertinent material and couch it in terms of the current course to best direct student efforts in creating their own GXT. Along with this challenge is the organization of performing the actual lab. Substantive time loss may occur if students lack familiarity or confidence when completing any part of a GXT. An explicit understanding of who has which job and how to perform it before entering the lab is important to prevent this. To combat this, pre-activity quizzing can help the instructor understand the student's current knowledge, skills, and abilities required for success and then apply constraints that will move students toward the desired outcomes. In 2022, Meir wrote that constraints offer a trade-off where greater restrictions and increased instructor direction reduce cognitive load on students, which can free up engagement for creativity and understanding. However, this may make the activity less engaging for advanced students who would thrive in a more open-ended activity (Meir, 2002). In our case, an example of a slight constraint would be removing the time taken to learn how to navigate the menus of a metabolic cart interface, which might make the activity less frustrating (by instructor-provided step-by-step directions) and therefore, more exciting as time can be spent investigating and designing a novel GXT.

A large constraint that might be appropriate for intermediate students or those with a weak grasp on underlying material would be severely limiting the number or range of GXT to analyze and ultimately providing common themes from those GXT followed by minimal exercise mode selection and detailed GXT criteria. For instance, students without much exposure to GXT might only be shown a few treadmill tests that follow easily identifiable patterns and be asked to create a treadmill-based GXT (a pared-down version of Example lab 2 in the Resource section). In contrast, more advanced students may analyze tests that use many different modes of exercise and ramping protocols and be asked to create a wholly new GXT (similar to Example lab 3 in the Resources section). The variability in constraint choice demonstrates how powerful of a tool this is which allows the activity to be adapted to different courses and able to meet varied learning outcomes.

An advantage activity-based labs have within exercise science and kinesiology is that the student population tends to have athletic backgrounds or a general interest in fitness. To that end, the novelty of exercise modes students might pick presents an engaging challenge that fitness and competitively minded students may find appealing. Indeed, in sections where this lab has been deployed, seeing a fellow student group determine how to progress a back squat, walking lunge, kettlebell swing, or sandbag carry in a way that achieves a VO_{2max} excites the others in the class and sparks infectious creativity. However, clinical courses would not have this level of competition given the subject matter. Inspirational videos of individuals with acute or chronic illness overcoming or maintaining an active lifestyle can also promote engagement. As many exercise science and kinesiology students will have careers in the helping and rehabilitation professions of allied health, assisting someone in obtaining the physical abilities to live independently and engage in activities they desire can be highly appealing and motivating.

A positive aspect of the complexity within GXT is that multiple students need to be involved in a variety of tasks, and as such, students with disability or accessibility considerations can remain involved in some critical capacity. If acceptable by the student, they might serve as the "case" for their group GXT or be able to offer valuable insight on adaptive equipment or complications of testing and training. However, this would best be discussed with the student outside of the classroom beforehand by the instructor, so they do not feel compelled to agree due to peer pressure within a live classroom.

Group-based projects are not without challenges. As with all groups, interpersonal dynamics lead to varying levels of engagement and workloads. While it was discussed that more athletic students might be excited about performing a unique physical challenge, it has also been the author's experience that students who would otherwise be less engaged often volunteer to be the test participants as they see it as a way not to have to contribute to the mentally demanding protocol development because they're going to do the physically demanding part later. However, it's often the case that these students will give qualitative and quantitative information about their physical abilities as feedback to the group during protocol design so that the desired outcome can be reached. Through this exchange, the student serves a more central role in the planning process than they would have otherwise.

Many Exercise Science and Kinesiology programs must make accommodations to the curriculum for transfer students, students taking courses out of sequence or co-enrollment, or any number of scheduling adjustments made for individuals. As such, students may be enrolled in an advanced course before it would typically be desired. While these students may feel ill-equipped to attempt this assignment or participate in their group, the instructor may find ways to encourage their participation. For instance, while student groups work, the instructor should survey the classroom, walk from group to group, discuss plans, and make suggestions. If the instructor knows of one such student, the instructor can engage the group, ask directed questions, and then ask the student to look something up on their computer to help answer or ask the student about their background with athletics and comment about how that sport-specific conditioning may be useful here. Generally, once the instructor can give that student a smaller way to contribute, it can improve their confidence and encourage them to continue adding to the group effort.

The final challenge that most commonly presents can also be a means for creativity. As the instructor applies more constraints, the chances that two or more groups design similar protocols may increase. The instructor should decide how appropriate this is for their learning outcomes. Using example lab format 2 from the Resource section, most groups might develop a similar protocol, which could be fine if a major goal is to have students independently gather how ramping protocols have a similar approach but can be different in application. However, if this is not the goal, then the list of conditions to choose from that example lab format 2 includes will need to be curated ahead of time such that there will be less overlap among groups. An instructor may want groups to develop roughly similar protocols to demonstrate how successful GXT can be obtained by following a set of overarching themes or to develop vastly different protocols by assigning each group a unique case that constrains their mode of exercise or population. This variability is a challenge for the instructor but a strength of the assignment. Overall, this lab provides a flexible activity model that requires students to engage in analysis, creativity, and evaluation while reinforcing content across a curriculum.

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RESOURCES

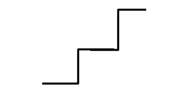
I. Example Student Worksheets for Analyzing and Creating GXT

Example Lab Format 1

Problem: You don't have working treadmills or bikes and can't use a standardized GXT procedure.

Your task: Create a graded exercise test and write it in the space below. It must be:

1. Equal stage lengths.
2. Stepwise progression.



3. The stage where the person is likely to achieve VO_{2max} should end before the 15-minute mark.

Example Lab Format 2

Review the following list of GXT: Bruce, modified Bruce, Balke-Ware, modified Balke-Ware, Ellestad, Gerkin, and Taylor.

Describe similarities between protocols. Contrast protocols for appropriate populations for each test. Explain why you think a protocol would be useful to test a population.

Use the similarities you identify to construct a GXT of your own design for one of the populations listed by the instructor (the instructor will have a list of possibilities).

Example Lab Format 3

Read the following articles:
Brown, G. A., Krueger, R. D., Cook, C. M., Heelan, K. A., Shaw, B. S., & Shaw, I. (2013). A prediction equation for the estimation of cardiorespiratory fitness using an elliptical motion trainer. *The West Indian Medical Journal*, *62*(2), 114–117.

Farrar, R. E., Mayhew, J. L., & Koch, A. J. (2010). Oxygen cost of kettlebell swings. *Journal of Strength and Conditioning Research*, *24*(4), 1034–1036. https://doi.org/10.1519/JSC.0b013e3181d15516

Penichet-Tomas, A., Jimenez-Olmedo, J. M., Pueo, B., & Olaya-Cuartero, J. (2023). Physiological and mechanical responses to a graded exercise test in traditional rowing. *International Journal of Environmental Research and Public Health*, *20*(4), Article 3664. https://doi.org/10.3390/ijerph20043664

Create a list of themes deduced from similarities in the approach to GXT across the papers. Compare these to the themes generated from the in-class discussion about Bruce, Balke, and Astrand-Rhyming GXT. Elaborate on distinguishing characteristics of all these tests in a way that provides guidance for creating a novel GXT. Use these guidelines to develop a new GXT for either an athletic or clinical population from the list on the board (developed from class discussion earlier).

II. Example Post Activity Write-Up Prompt

1. Write the GXT protocol you constructed for this activity.
    A. Discuss your thought process for selecting the exercise mode, stage length, and intensity. Include justifications for these choices.

2. Include the GXT data collection sheet with this assignment. Use Excel to graph the changes to heart rate, VO_2, respiratory quotient, and minute ventilation across stages of the test. Include best-fit lines and correlations for each metric.

3. What would an expected VO_{2max} be for this population? What value was reached during your test?

4. Were you able to achieve the criteria for a successful GXT? If not, which values were not met?
    A. Why do you think the values were not met?
    B. How would you change your protocol to better achieve successful peak values?

5. Was the group that you were assigned to evaluate able to achieve the criteria for a successful GXT? If not, which values were not met?
    A. Why do you think the values were not met?
    B. How would you change the protocol to better achieve successful peak values?

III. Example GXT Data Collection Sheet

Data Collection Sheet for Graded Exercise Tests

Participant identifier: ______________ Age: ____________

Height: _____________ Weight: ____________

Resting BP: _______________

Stage 1: ____

HR: _______ VE: ________

VO2: _______ RPE: ________

RER: _______ BP: __________

Stage 2: ____

HR: _______ VE: ________

VO2: _______ RPE: ________

RER: _______ BP: __________

Stage 3: ____

HR: _______ VE: ________

VO2: _______ RPE: ________

RER: _______ BP: __________

Stage 4: ____

HR: ______ VE: _______

VO2: ______ RPE: _______

RER: ______ BP: _________

Stage 5: ____

HR: ______ VE: _______

VO2: ______ RPE: _______

RER: ______ BP: _________

Stage 6: ____

HR: ______ VE: _______

VO2: ______ RPE: _______

RER: ______ BP: _________

Stage 7: ____

HR: ______ VE: _______

VO2: ______ RPE: _______

RER: ______ BP: _________

Stage 8: ____

HR: ______ VE: _______

VO2: ______ RPE: _______

RER: ______ BP: _________

Stage 9: ____

HR: ______ VE: _______

VO2: ______ RPE: _______

RER: ______ BP: _________

Stage 10: ____

HR: ______ VE: _______

VO2: ______ RPE: _______

RER: ______ BP: _________

IV. Example Quiz and Answers

1. A GXT begins by ramping speed on the first few stages to an individual's maximum cruising (walking, jogging, or running) speed before increasing incline slightly each stage thereafter. For which population might this be appropriate?

   Possible Answers:
   - A track athlete would mainly engage in flat ground running; therefore, the specificity of testing matches the specificity of training well.
   - An individual with calf pain from peripheral artery disease might find success with this test if cycling or other modes aren't available. Walking speed and distance are outcomes of interest to this population.
   - A midfield soccer player might do well with this test as they are running on a flat surface during practice and games. Therefore, adding incline after reaching a difficult pace would likely result in an exhaustive test.

2. List three objective and one subjective criteria for achieving VO_{2max}.

   Possible Answers:
   - VO_2 plateau < 2.1 ml/kg/min with an increase in difficulty
   - Respiratory quotient > 1.1
   - Heart rate plateau within 10 bpm of age-predicted max
   - Blood lactate > 8 mmol
   - RPE > 17

3. Explain one positive and one negative implication of high incline treadmill protocols.

   Possible Answers:
   - Positive: can get to max at slower speeds.
   - Negative: localized fatigue may cause premature termination of test.

4. Describe differences in max heart rate between 220-age and 208-0.7*age. Why would one be used over another?

   Possible Answer:
   - 220-age may underpredict max heart rate, especially in those over 40 years old. However, it is a simpler equation for non-practitioners to remember and thus may be used more readily. 207-0.7*age has less of an error range but still introduces some error in max heart rate estimation (7-11bpm).

5. How would peak VO_2 levels achieved in arm ergometry differ from cycling ergometry or treadmill running?

Possible Answer:

- Smaller muscle group usage generally results in lower obtained VO_2 values. Further, it may introduce localized fatigue that prematurely causes volitional fatigue.

6. Contrast different stage lengths and their strengths and weaknesses.

Possible Answer:

- Shorter stage lengths below 2 minutes are not likely to allow for a steady state; however, they can quickly and smoothly increase difficulty in a short period of time. Stage lengths longer than 3-4 minutes will spend time without advancing the challenge of the test and may result in early fatigue; however, longer stages may reveal symptoms of an individual that might require early termination without reaching dangerous intensity levels.