ILLUMINATIONS

The 2-hour marathon: what do students think?

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Overview

This educational activity is designed to enhance teaching and learning of physiology by connecting the limits of human physiology to one of the most coveted barriers in athletic performance: the 2-h marathon. Moreover, investigation into the possibility of achieving this athletic feat promotes critical thinking and an understanding of how science works.

2-h Marathon

For over 100 yr, athletes, coaches, and scientists have endeavored to improve running performance. For example, former Olympian and academic physician, Sir Roger Bannister, broke the 4-min barrier in the mile, while at the same time publishing a series of experiments in the Journal of Physiology (2–5) investigating the limits to athletic performance. Bannister would later write (1) that “Athletic performance depends upon the understanding of the physiological limiting factors when man runs at different speeds.” One of today’s running barriers is the 2-h marathon. The current official men’s marathon world record is 2:02:57 (Berlin Marathon; Berlin, Germany, 2014), requiring a 2.4% improvement to achieve the first sub-2-h marathon. Joyner (16) originally modeled marathon running performance using maximal oxygen consumption ($V\dot{O}_{2\text{max}}$), lactate threshold, and running economy that might predict that an elite runner could theoretically run a 1:57:58 marathon. Twenty years later, Joyner and colleagues (18) revisited this work by formally posing the question, “The two-hour marathon: who and when?” to the scientific community. This question sparked interest and enthusiasm as over 75 physiologists and applied sport scientists from around the world provided detailed follow-up commentary (22) and identified additional secondary and tertiary factors that warrant consideration for achieving this daunting task. Most recently, a multinational shoe manufacture (Nike) led an initiative (“Breaking2”) utilizing strategic engineering, sport science, and planning, along with the top male marathon runners, to achieve the first sub-2-h marathon (7). This initiative enabled an elite male runner to complete a marathon with a new best time of 2:00:05 (closed course at the Autodromo Nazionale Monza; Monza, Italy, 2017). While this fastest marathon time to date has not been ratified as an official world record by the International Association of Athletics Federations, it suggests that the sub-2-h marathon goal is within reach. Given the widespread interest (12, 16, 18, 22) and uncertainty (23) surrounding the 2-h marathon, we used this as an opportunity to engage our exercise physiology students in this timely discussion.

Activity

Background. In the Department of Kinesiology and Integrative Physiology at Michigan Technological University, we routinely use a blended learning approach (i.e., integration of face-to-face and online instruction) to deliver our undergraduate and graduate exercise physiology courses so that class time can be used for active learning activities (10, 11, 19). The objective of the 2-h marathon activity was for exercise physiology students to gain knowledge of the physiological responses and mechanisms associated with endurance exercise by investigating, what would it take to achieve the first ever sub-2-h marathon? Accordingly, we used problem and project-based learning methods (9, 24) to facilitate student engagement, critical thinking, sustained inquiry, collaboration, and problem solving skills needed to address a real-world problem. Over the past 3 yr, the activity was implemented in both the undergraduate and graduate exercise physiology courses. Specifically, the 2-h marathon topic was discussed over three class sessions in the undergraduate exercise physiology course and across several weeks in the graduate advanced exercise physiology course (Fig. 1).

Undergraduate course. Foundational content on the endocrine, neural, metabolic, cardiorespiratory, and musculoskeletal systems were provided through a combination of video lectures and in-class discussions (i.e., flipped classroom model) over a series of several weeks. As part of the musculoskeletal section, undergraduate students were provided Joyner and colleagues’ viewpoint (18) to read before an in-class discussion, but without the follow-up commentary (22). For the initial in-class discussion (day 1), students met in small groups and were instructed to identify additional factors beyond $V\dot{O}_{2\text{max}}$, lactate threshold, and running economy that might influence marathon performance. After completing this discussion and sharing ideas through a guided report-out, all students were provided the extensive commentaries (22) that were published in response to the viewpoint from Joyner and colleagues (18). Student predictions were validated as they found out that several factors that they had tentatively identified (e.g., age, genetics, geographical location, etc.) were indeed raised in the follow-up commentary (22). At the end of class, students were challenged to develop their own commentary focused on a factor that was not discussed in the original commentaries (22). Accordingly, students met outside of class with their...
**Undergraduate Exercise Physiology**

**Day 1: Group Discussions**
- What are important marathon factors?

**Day 2: Class Presentation**
- Input from peers and instructor

**Day 3: Talk with Expert**
- Present, feedback, questions

**Graduate Advanced Exercise Physiology**

**Group Discussions**
- What is the optimal marathon runner physiology?

**Experiments**
- Why is running economy important?

**Presentation – Dept. Seminar**
- Feedback from peers and faculty

**Day 4: Talk with Expert**
- Discussion about physiology and history of running

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**Assessment.** For undergraduate students, a short quiz was administered before and after the activity to check their understanding of exercise physiology and marathon performance-related concepts. For graduate students, a survey was administered after the activity to obtain their perceptions about the activity and perceived learning. Based on the results of the pre-post activity quiz, undergraduate students improved their understanding of exercise physiology and marathon performance. Similarly, graduate students reported that they enjoyed

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**Graduate course.** Lecture content describing the determinants of endurance performance ($V_{O2\max}$, lactate threshold, economy/efficiency) was offloaded to video lectures to provide more class time for an extended project. Similar to the process described for undergraduate students, graduate students reviewed Joyner’s work (16, 18), along with the follow-up commentary (22). Additionally, students discussed several review papers covering endurance exercise performance (17), running economy (6), and elite endurance athlete training (20). They also explored books, websites, and popular press articles surrounding the recent sub-2-h marathon initiatives. Using this information, they worked together to identify the optimal runner physiology needed for the sub-2-h marathon. To appreciate the importance of running economy (oxygen cost required to run at a given speed, units of ml $O_2$·kg$^{-1}$·km$^{-1}$), students carried out an experiment to measure oxygen consumption during treadmill running, determined their own running economy, and compared their values to the literature (6, 15). Students also worked together to prepare a conference presentation (oral and poster format) highlighting their predictions and presented their poster at a department research seminar. During the seminar, students received feedback from other undergraduate and graduate students and faculty in the Departments of Kinesiology and Integrative Physiology, Biological Sciences, and Physical Therapy. Some of the concepts presented included a theoretical runner who could run a sub-2-h marathon, importance of the 80–80–180 rule (i.e., $V_{O2\max}$ of 80 ml·kg$^{-1}$·min$^{-1}$, lactate threshold of 80% of $V_{O2\max}$, running economy of 180 ml·kg$^{-1}$·km$^{-1}$), effects of drafting, alterations in running economy with training, and psychological considerations (Fig. 2). Based on feedback received at the seminar, students modified their presentations and sent an electronic copy (i.e., PowerPoint poster with audio voiceover) to Dr. Joyner for review. Students then participated in a 1-h discussion and answer session with Dr. Joyner through Skype and learned more about the physiology and history of running.

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**Fig. 1.** Overview of 2-h marathon activity implemented in undergraduate and graduate exercise physiology courses. Running physiology and marathon-related topics were discussed over 3 days in the undergraduate exercise physiology course and across several weeks in the graduate advanced exercise physiology courses. Running physiology and marathon performance-related concepts. For graduate students, a survey was administered after the activity to obtain their perceptions about the activity and perceived learning. Based on the results of the pre-post activity quiz, undergraduate students improved their understanding of exercise physiology and marathon performance. Similarly, graduate students reported that they enjoyed.
the activity, and that it enhanced their learning of exercise physiology. Furthermore, all of the graduate students recommended that the activity be performed again. Taken together, these results demonstrate that the 2-h marathon activity offered an authentic academic experience that facilitated learning.

**Future Directions**

Now that the 2-h marathon is within striking distance (2:00:25), the activity could be adapted by having students identify specific strategies (12) to shave off the remaining 25 s (~1 s/mile, 0.3% improvement). A discussion about limitations to female marathon performance would also be timely (8, 13, 14) and facilitate investigation into sex differences in athlete performance. Finally, comparison of how human marathon runners measure up to other animals suited for long distance running/walking (e.g., horse, sled dog) would prompt an even broader discussion of animal physiology and performance (21).

**Summary**

For this activity, undergraduate and graduate exercise physiology students explored what it would take to achieve the first sub-2-h marathon for men. Specifically, students reviewed the literature, made predictions, conducted experiments, and analyzed data. They also communicated their findings to peers, faculty, and a world-renowned expert in the field. The 2-h marathon activity was well received by students and enhanced their learning of exercise physiology. The activity may be useful for educators who teach physiology and could be adapted to emphasize additional concepts. Finally, we envision that, by engaging and challenging our students to participate in the 2-h marathon discussion, they will be able to help us continue to search for the answers needed to push the limits of human performance further.

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**DISCLOSURES**

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

**AUTHOR CONTRIBUTIONS**


**REFERENCES**


