

KIN 656: Endurance Biomechanics

John A. Mercer, PhD

Things to know about this course ...

Throughout this semester, we will apply biomechanical concepts in a way to understand factors that influence endurance performance. At the conclusion of the course, the goal is that you will be able to apply biomechanical terminology to understand factors that influence endurance swimming, biking, and running performance, for example. The downside of focusing on one discipline (i.e., Biomechanics) is that endurance performance is influenced by a wide variety of factors. Focusing on any single discipline limits our understanding of performance.

To thoroughly understand factors that influence endurance performance, we need to integrate biomechanics with key concepts from exercise physiology and nutrition. Likewise, we need to understand how to prevent and rehabilitate injuries (when they occur) in order that the athlete can get to the start line injury free. We will go over some of the concepts from other areas as needed; however, below are the key concepts that it is expected that you are familiar with:

1. Energy systems (aerobic and anaerobic)
2. HR-VO₂ relationship during a graded exercise test.
3. Fick Equation: $VO_2 = HR \times SV \times (a-v O_2 \text{ diff})$
4. RPE
5. Training principles (Frequency, Intensity, Time, Specificity)

As we discuss factors that influence endurance performance, it is important to first establish two key points:

1. The athlete has proper nutrition.
2. The athlete is healthy.

Proper nutrition is a foundation for completing endurance events and the athlete must know what to eat before, during, as well as after an event. Something worthwhile knowing is that the athlete needs to take in the appropriate amount of glucose during an event. Generally, a starting point with the amount of glucose to consume during an event that lasts longer than 1-2 hours is 60 g of carbohydrate per hour. There is a lot of variability in how much glucose an athlete should take in per hour ... the 60 g per hour is a starting point in trying to figure out the rate for a specific athlete. You should have had an exercise physiology and/or nutrition course that has explained the energy pathways. The ability of an athlete to complete an endurance event is predicated on the ability to take in the appropriate calories and glucose during an event.

What endurance events will we be talking about?

There are many examples of endurance events ... NY City Marathon, Boston Marathon, Race Across America, Swimming across the English Channel, and so forth. Each endurance event is unique ... so, for the purpose of this course, we are going to focus on triathlon events.

Triathlons are events that include three sports: Swimming, Biking, Running. The distances of each event vary but can be placed into these three general categories:

1. Sprint
2. Olympic (aka, International)
3. Ironman (aka, Full)

There are races that are shorter than a 'Sprint' (e.g., Super Sprint) and races that are longer than an Ironman (e.g., Ultraman) and there are many distances in between a Sprint and Ironman (e.g., Half-Ironman or 70.3) that are very popular. In all of these races, however, they are all largely endurance events (even a Sprint) and are largely aerobic in nature.

It is important to know that the term 'Ironman' is trademarked and refers to a specific race series – many people will recognize 'Hawaii Ironman' – but there are Ironman races throughout the world. There are other races of the same distance that are not under the trademark 'Ironman' (e.g., Silverman, Beach to Battleship, Vineman, HITS, Rev3, Challenge). For sake of simplicity, when I use the term Ironman, I am referring to the distance of the event, not the trademark.

The distances of a Sprint race can vary quite a bit between races. But they generally fall around a 750 meter swim, 20 K bike, and a 5 K run. The distances of the Olympic event are 1.5 K swim, 40 K bike, and 10 K run. Often, race directors may adjust these distances based upon the logistic of the course and then will refer to the distance as 'International' or 'Intermediate' or something like that.

Ironman events consist of 1.2 miles of swimming, 112 miles of biking, and 26.2 miles of running. The elite athletes complete the event in close to 8 hours while the cutoff time for any finisher is typically 17 hours. The average time to complete the event depends on the course but is generally around 12-14 hours.

When we talk about biomechanics of endurance sports, it is important to understand which sport and which distance is being discussed. A sprint triathlon looks quite different than training for an Ironman in terms of training, race strategy, nutrition, technique, and equipment, for example.

The “Root” questions.

People who are training for an endurance event are faced with making a lot of choices regarding their training and equipment. Training questions are typically centered on the training principles (Frequency, Intensity, Duration, Specificity) and nutrition. For example, athletes want to know how many hours per week should be spent on the bike or what intensity runs should be at. Likewise, athletes want to know what to eat before, during, and after training sessions as well as what to eat during an event. These are all critical questions with the answers being addressed specifically in Exercise Physiology and Nutrition courses.

Training questions can also be about technique. For example, what stride frequency should be used when running? What should be a target stroke rate during swimming? What position should be used on the bike? The answers for these types of questions fall within Biomechanics and we will address in this course. Part of what we will do this semester is to categorize questions as

‘Exercise Physiology’, ‘Nutrition’, or ‘Biomechanics’ questions. That can be helpful when framing an answer to a question.

However, all of the questions (and any question asked) can really be grouped into two main “Root” questions:

1. How do I go faster?
2. How do I go longer?

Before going any further ... it is important to state that the first level of answer to either of these questions is: Stay healthy. A key to training for an endurance event is getting to the start line injury free – that gives the athlete the best chance to complete the event.

I want to be careful here to avoid giving the impression that this course is only about understanding what makes the fastest athletes the fastest. That is not the case ... in fact, I am very interested in how to help the ‘mere mortal’ athlete or helping someone do their first triathlon. However, it is helpful to recognize the underlying question of any question asked about endurance performance.

A root question is one which is the basis for all other questions. For example, when an athlete asks: What should I eat during a race? What they are really asking is: What should I eat to be faster? If you hang around people who do endurance events, it is very common to hear someone state “If I didn’t bonk, I could have ran those last couple of miles.” So the question ‘What should I eat?’ Is really something more like “The last race I did, I bonked on the run. I don’t want to bonk again ... what should I eat during a race so that I can run the last miles and be faster?”

Another example of how an athlete may ask a question that is reduced to a root question is: What running shoe should I buy? What they are likely asking is something more complicated like this: “The last time I trained for a race, I had a running injury. I couldn’t train as much so my race was a lot slower than I wanted it to be. I want to avoid a running injury, so what kind of running shoe should I buy? If I don’t get injured, I’ll be able to be better trained for my race and go faster.”

Lengthy ... but hopefully you see the point. Take any question about endurance events, the root of the question is likely ‘How do I go faster?’ Questions about which wet suit to buy, whether or not to include track workouts for running, or what bike position should be set at, are all rooted in ‘How do I go faster?’

It is important to recognize that going faster is a relative term. That is, training to increase 5 K speed 1 minute is quite different if the athlete’s 5 K speed is 19 minutes vs. 30 minutes. The approach, equipment, and possibly hydration/nutrition plan may be different based upon how fast an athlete is and/or how much faster he/she wants to go. To help with our discussions (and, ultimately, answers to questions), we will group people into one of these three categories:

1. Front of Pack: FOP
2. Middle of Pack: MOP

3. Back of Pack: BOP

These are general terms and can refer to FOP overall (e.g., top 5-10% finishers) or could be within an age group (e.g., top 3 places in the 35-39 year old age group). FOP are competing for overall place and/or age group places. The MOP category includes a wide range of abilities of athletes – they may be on the cusp of getting on the podium for an age group or may be worrying about making a cutoff time. The BOP are generally people who have taken on the challenge of completing vs. competing an endurance event. These athletes include the ‘slow-steady’ athlete and possibly some MOP (or FOP) who had some injury but are just trying to finish a race. However, it is important to recognize that a BOP can also be in some stiff competition ... for example, athletes over 75 years old may be BOP but working hard to win their age group. Likewise, the athletes trying to beat a cutoff time are can be in a bitter battle with the clock.

All of these athletes are competitors and have the respect of completing endurance events. However, their needs, expectations, and talent may be such that answers to some questions about endurance performance need to be qualified for each group.

An alternative way to refer to the level of athlete is to use terms like:

1. Elite
2. Competitive Age Grouper
3. Finisher

In these categories, the ‘Elite’ athlete is competing for overall place and may be a professional athlete. The ‘Competitive Age Grouper’ is competing for a top 1-3 finish in his/her age group whereas the ‘Finisher’ is planning on just finishing a race. This is still not perfect way to categorize athletes since some athletes may be competitive overall regionally but not nationally and therefore may not really be ‘elite’ athlete. In any case, the idea here is to identify what level athlete a person is ... the answer to whatever question is being asked may be dependent on this classification.

For example, consider the question: “What wet suit should I buy?” The answer to that question is rooted in ‘How do I go faster?’ The answer will be partly based upon what level of athlete is asking the question. A FOP swimmer may need one type of wetsuit where as a BOP swimmer would likely benefit the most from coaching/training vs. buying equipment to increase speed. A FOP swimmer’s choices may be more limited than a BOP for which type of wet suit would work. Furthermore, the answer to this question is complicated by water temperature ... sometimes, the best answer to this question is based upon keeping the athlete warm.

Another popular question is “Should I buy an aero helmet?” Again, the answer is rooted in ‘How do I go faster?’ with the specific answer depending on the level of athlete. The BOP cyclist would likely not benefit at all from an aero helmet simply because they do not cycle fast enough for there to be any advantage.

It is extremely important to recognize that the vast majority of athletes are MOP and BOP. Far too often, recommendations on training and equipment are made with broad strokes of a brush and based off of what FOP athletes are doing. In many cases, the equipment and training

techniques of FOP athletes may simply not be appropriate for MOP and/or BOP athletes. For example, a BOP cyclist does not need to purchase a \$10,000 time trial bike! Part of the mission of this course is to provide information that is useful for the ‘mere-mortal’ athlete ... if you are working in the fitness industry, these are the types of athletes you most likely will be working with. The bottom line is that it is important to frame answers to questions about “How do I go faster?” in terms relative to the level of athlete.

Finally, it is important to understand that the answer to ‘How do I go faster?’ type questions can sometimes be very basic. For example, many athletes can improve their endurance time by practicing transitions. A great transition is not necessarily the fastest transition. Sometimes, for long endurance events (e.g., Ironman) it is best to use transitions wisely and prepare for the next event (e.g., taking the time to apply sun lotion, change socks, take in nutrition, etc.) vs. simply trying to transition as fast as possible.

The second root question “How do I go longer?” is asked specifically by athletes who want to complete a longer endurance event – for example, going from a Sprint to an Olympic or to an Ironman distance event. Or maybe someone is going to take on their first triathlon. Although the root question may still be ‘How do I go faster?’, in many cases, when moving up in distance or doing a first race, the athlete (generally MOP, BOP) does not have a time-goal in mind but rather may simply want to complete an event. Not having a time goal can actually be great advice for many athletes (including FOP) especially in long races like an Ironman. There is a lot that can go wrong during an event: From cramping to mechanical problems, there are many issues that an athlete has to deal with when exercising for 8-17 hours.

Many questions that are rooted in ‘How do I go longer?’ are related to training and nutrition. However, it is important to recognize when an athlete may be asking a biomechanics question that is rooted in this category. For example, an athlete can use a very aggressive aero dynamic bike fit for a sprint race but could not sustain holding that position for an Ironman bike leg.

When we discuss questions asked by athletes, it is important to listen to the question and try to place it in a ‘root’ question. Is the athlete asking ‘How do I go faster?’ or ‘How do I go longer?’ Your answer to whichever question is asked should address one of these two root questions.

Common Questions

Take a look at the questions below and consider how you would answer if the root question was ‘How do I go faster?’

- Should I buy an aero helmet?
- What running shoes should I use?
- Should I do intervals?
- What stride frequency should I use?
- Should I use a power meter during cycling?
- Should I buy a full-body wet suit?
- Do I need a tri-bike (vs. road bike with aero bars)?

There are no easy answers to any of these questions. To try to answer the questions, you first need to know what distance and what level of athlete is asking the question. As a biomechanist, I like to think in terms of equations and graphs ... so below is a figure representing all the possible answers to a simple question like “Should I buy a full-body wet suit?” There are three axes to this graph:

1. Goal for time to complete the event.
2. Distance of the event.
3. Ability of the person.

The purpose of this graphical representation is to further highlight that the answer to the question should be specific to the person asking the question. However, some answers may be applicable to a group of athletes (e.g., FOP, MOP, or BOP). In any case, there are a lot of background type questions that need to be asked such as what experience the person has, what equipment was used, what injuries did the person have as well as what kind of time the person has to train or what other commitments (e.g., family, work) the person has.

In total, answering simple questions like the ones presented above is not easy. In this course, we are going to focus on providing an answer from a biomechanics perspective. This is obviously limited ... as is the case when you focus on any single area ... so sometimes we will deviate from biomechanics to provide a more thorough answer.

Biomechanics background

What type of background do you need in biomechanics for this course? Regardless of what courses have or have not taken, there are some basic terms that I need you to know. Those terms are listed in the Biomechanics Terminology worksheet. That worksheet has a column for each term, the word definition, equation (where appropriate), and units (where appropriate). It is important to the flow of this course that you know these terms.

I have included information in both pdf and in video presentations that gives background information on the terms. If you are not familiar with the terms, please review the documents and videos. You must have a basic working definition for all the terms. The goal of this course is to help solidify the understanding of those terms by applying biomechanical concepts to understand factors that influence endurance performance.