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Who Will Win the Games?—Part 2

Tony Leyland examines what makes the ideal CrossFit athlete.

By Tony Leyland

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In the first article, I explained the mechanical factors to look for during the finals. I like Rich Froning's size (5'10", 195 lb.) when it starts getting a little heavy. On Open Workout 11.3 (165 lb. squat cleans and jerks), he completed 46 squat cleans and jerks and one additional squat clean to come first overall in that WOD. The female winner of Week 3 was Sarah Mass (5'9", 170), who completed 45 squat cleans and jerks.

But hold it a second: we all know many athletes Rich and Sarah's size who could not even come close to these performances. Although being within an optimal range of size, body proportions and muscle mass—and having good technique—is vital to winning this summer, it clearly isn't the whole picture.

What is going on inside the body?

Mechanical Efficiency

The first thing to understand is the mechanical efficiency of human muscle. Mechanical efficiency is defined as the ratio of the mechanical work output to the total metabolic cost. The actual energy cost to humans to do 1,000 joules of external work (approximately 240 calories) is considerably higher than that.

Human metabolic efficiency is actually very complex. To keep things simple, I would say the average efficiency of converting metabolic (chemical) power to mechanical power (output) is around 21-23 percent. There are a few factors that result in this low efficiency (losses in energy converting food energy into ATP, losses in converting energy from ATP into mechanical work inside the muscle, and mechanical losses inside the body). This energy loss is affected by the type of exercise and the type of muscle fibers being used (fast twitch or slow twitch), so it has been measured as ranging from 18 to 26 percent.

A simple way to understand this is to think about why you heat up considerably when working out. The heat energy generated didn't do any external work. It didn't contribute to getting that damn bar overhead! Therefore, heat energy generated during the mechanical work of muscle is, in effect, wasted energy. Your automobile also wastes lots of energy, evidenced by the very hot and noisy engine.

> Are elite CrossFit athletes able to generate more mechanical work for a given metabolic cost?

Rob Orlando is a strong athlete who's trained to increase his endurance significantly.

So the question is this: can you improve your mechanical efficiency? Are elite CrossFit athletes able to generate more mechanical work for a given metabolic cost? The answer is yes, of course. It is reported Lance Armstrong increased his efficiency by eight percent between the ages of 21 and 28. However, this is overall efficiency and is related to many factors such as technique, as discussed in the previous article. For example, you cannot improve the way you convert food to ATP by a whopping eight percent because the chemical process will always remain the same.

Most studies look at the oxygen cost of a given amount of work. If, for example, you perform a bike test and over years of training you are able to produce the same power output during the test duration (total work) for less oxygen cost, or for a given oxygen cost, you perform more work; you have become more efficient. You improved the ratio of your mechanical work output to the total metabolic cost.

The Heart and the Circulatory System

What makes a fast car? A good engine, good fuel (and enough oxygen to burn that fuel) and an efficient fuel pump. Not that different from the human body. The heart is our fuel pump, and all elite CrossFit athletes must have large stroke volumes (and hence large cardiac output), large blood volumes, optimal hematocrit (percentage of red blood cells), and the ability of all of their muscles to accept a large blood supply (high muscle capillarization).

How important is this? Many people would look at CrossFit athletes and conclude they are high-power athletes, anaerobic beasts like football players. Although they can handle themselves in anaerobic events, make no mistake, CrossFit athletes are aerobic beasts as well. Given most CrossFit WODs will last several minutes, aerobic power is as important as your muscle mass. What's the point of having a Ferrari engine with a lawnmower fuel pump? Although high muscle capillarization, blood volume, blood composition and cardiac output are irrelevant for a single maximal power output, this isn't the largest component of CrossFit Games competition WODs. Single Olympic lifts, maximal throws and short sprints do not depend on the delivery of oxygen and substrate to the muscles, so these factors would not be an issue for a CrossFit Total WOD. It is possible that one or two WODs at the Games will be very short maximal power events requiring 100 percent power output, but the majority will probably take several minutes, so you need a great heart and circulatory system.

I should very briefly review the three energy systems. Table 1 below shows an estimate of the relative contributions of the three energy systems during maximal physical activity of various durations. For example, if I work at a power output for 30 seconds, and that is the maximum time I can sustain that power output, I will be predominantly using the glycolytic system (approximately 65 percent of the energy). Obviously, the figures in the table are averages and will vary slightly between individuals.

It is vitally important to realize that when determining which energy system you are using, intensity (power output) is the key. When you look at Table 1, there is a danger of thinking time is the crucial factor. If I engage in an activity that requires such a high muscular power output that I could only sustain this power output for five or six seconds (e.g., a max-wattage row), most of the energy will be supplied by the phosphagen system. However, if I walk from my front door down the driveway to my car in five or six seconds, the predominant energy system will be the oxidative system. Why? Because I can sustain the power output required to walk to my car for hours. This is a key point, and one that is often confused. Although time is discussed and is an issue, it is power output that is the determining factor as to which energy system you use.

Approximate Power Output	Duration	% Energy Phosphagen	% Energy Glycolytic	% Energy Oxidative
100%	5 seconds	85	10	5
80%	10 seconds	50	35	15
50%	30 seconds	15	65	20
40%	60 seconds	8	62	30
	2 minutes	4	46	50
30%	4 minutes	2	28	70
25%	10 minutes	1	9	90
	30 minutes	Negligible	5	95
	60 Minutes	Negligible	2	98
20-25%	120 Minutes	Negligible	1	99

Table 1: Percentage usage of three energy systems by duration. Data adapted from McArdle WD, Katch F, and Katch VL. *Exercise physiology: Energy, nutrition and human performance*. Baltimore, MD: Williams & Wilkins, 1996. p. 129, and Coaching Association of Canada. Physical preparation. In: *Coaching Theory Level 3, National Coaching Certificate Program*. Gloucester, ON: 1990.

So given that the Open WODs were AMRAPs from 5-20 minutes, and that, with the exception of the thruster ladder, the regional events lasted between 3 and 20-plus minutes, you needed to generate your power via the oxidative system

Whenever the general fitness public/media talk about high $\dot{V}O_2$ maximums, they are usually talking about marathon runners, triathletes, cyclists, etc. These elite single-mode athletes do have great $\dot{V}O_2$ maximums in their activities. To be able to sustain a power output for, say, 10 minutes or more, you are probably only working at 25 percent of your maximum power output. This may seem to be a low power output, but all things are relative.

The world records for the 5,000 meters are 12:37.35 (male) and 14:16.63 (female). To think that a man can run 5 kilometers at a pace of 2 minutes and 31 seconds a kilometer and that this is a moderate power output for him (perhaps only 25 to 30 percent) is sobering. Similarly, it is hard to look at some of the work done in CrossFit WODs and understand the requirements are nowhere near peak power outputs for that athlete.

What sets CrossFit oxidative-system challenges apart from the single-mode aerobic beasts is that CrossFit athletes need a high $\dot{V}O_2$ max in a very broad range of activities. What is your kettlebell-swing $\dot{V}O_2$ max, your rowing $\dot{V}O_2$ max, your toes-to-bar $\dot{V}O_2$ max, etc.? To win this summer, the athletes will have big hearts and a way to get that blood to all their muscles. Basically, an incredibly wide range of high $\dot{V}O_2$ maximums is required.

Table 1 also shows us that CrossFit athletes must be training the phosphagen and glycolytic energy systems also. We all know that even with elite performers, some of the work in the WODs will be broken. With handstand push-ups, they may have to pause, recover a little and then attempt another set. Clearly, they do this because they have worked the glycolytic system and become fatigued. Any WOD that is only 2-4 minutes long will also require a considerable contribution from the glycolytic system. Obviously, any max-power-output WOD, like a max Olympic lift, is stressing the phosphagen system.

Few CrossFit events will challenge only one of the body's energy systems.

> I think my favorite Greg Glassman quote is this: "Strive to blur distinctions between 'cardio' and 'strength training.' Nature has no regard for this distinction."

It is all, of course, very complex when it comes to CrossFit WODs, and I discuss this in my July 2008 *CrossFit Journal* article Human Power Output and CrossFit Metcon Workouts. I think my favorite Greg Glassman quote is this: "Strive to blur distinctions between 'cardio' and 'strength training.' Nature has no regard for this distinction."

Similarly, did the thruster-ladder WOD exclusively target the phosphagen system? Definitely not; approximately 27 seconds of recovery is not enough to replenish ATP after a high-intensity effort. Therefore, this WOD used both phosphagen and glycolytic systems.

Before discussing other factors, I want to emphasize the importance of capillary density in all muscle groups (capillary-to-muscle-fiber ratio). You just cannot have a chink in your armor on this component. This is in part the reason the powerlifter walks into a CrossFit gym and only gets 12 reps on Tabata squats. There's nothing wrong with his or her quad strength but plenty wrong with his or her quad capillary density. Obviously, the powerlifter's stroke volume would not be adequate either.

Muscle Fiber Types and Motor Control

Briefly stated, there are three categories of muscle fibers. Type IIx fast-twitch fibers are recruited for very short-duration, high-intensity bursts of power such as maximal and near-maximal lifts and short sprints. (Note: these are also referred to as Type IIb, but we now know Type IIb fibers only occur in other animals, not humans). These fibers produce high force levels quickly, but they fatigue quickly as well. Type IIa fast-twitch fibers are more fatigue-resistant than Type IIx fibers, but they cannot produce force as rapidly. They are used more during sustained-power activities such as sprinting 400 meters or doing repeated lifts with a weight below your maximum (but not with very light weights). Finally, Type I slow-twitch fibers are used in lower-intensity exercises such as very light resistance work aimed at muscular endurance and long-duration aerobic activities such as 5- and 10-kilometer runs.

Muscle fibers are organized into motor units, and each unit is controlled by a single motor neuron (nerve). All the muscle fibers in a motor unit are the same type of muscle fiber. The cell bodies of Type I neurons have a lower threshold of excitation, which means that if the activity has a relatively low demand for power, only Type I fibers will be stimulated. If the need for force and power development becomes greater, increasing numbers of Type I motor units will be recruited by increasingly larger waves of excitation by the central nervous system (CNS). Eventually, all the Type I fibers will become involved. This would be at the point where the athlete is reaching his or her maximal aerobic capacity.

The thruster ladder was a heavy WOD that tested both the phosphagen and glycolytic systems.

Once the demand for power reaches approximately 20 percent of maximal, the CNS stimulation is strong enough to recruit some Type IIa fibers. Evidence of Type II fiber activity is provided by the presence of lactate in the muscle and blood. As the demand for force increases, larger waves of excitation from the CNS eventually result in the recruitment of Type IIx fibers (these have the highest threshold of excitation). To produce maximal force, the CNS produces the largest possible stimulation, and all available motor units serving the muscle are recruited (all three types). Note that only trained athletes are actually able to recruit all the available motor units. This is one of the reasons we see very fast gains in strength with novices to strength training, as they "learn" to recruit more existing fibers.

Athletes with similar muscle mass may be quite different in their ability to handle fast, short WODs vs. grinder WODs.

Elite CrossFit athletes will have differences in fiber type distribution and in CNS recruitment of muscle fibers. Athletes with similar muscle mass may be quite different in their ability to handle fast, short WODs vs. grinder WODs. A workout like Murph requires more-slow twitch activity than a WOD like Grace.

There will also be differences in the effectiveness of the sequence in which athletes recruit muscle groups, as well as the total number they can recruit. In kinetic-chain activities like the clean and the thruster, the timing of muscle recruitment is essential. This is in effect a technique issue, as discussed in Part 1 of this article. So like your fast motor car, you not only need a good engine and fuel pump but also a good control system.

Recovery Nutrition

Discussing the importance of good nutrition could be a book, and I know everyone reading this already understands the importance of quality daily nutrition. Therefore, I will just touch on the topic of recovery nutrition, as the physical demands of multiple WODs over the three days of competition are going to challenge the athletes' ability to recover from day to day and between WODs. Getting their nutrition correct during competition days is vitally important.

The nutrition topic is actually where the car analogy breaks down. This is because in a car, the fuel pump (heart) is the only way to get fuel to the engine (muscles). However, in humans there is energy stored in the muscles (ATP, PC and glycogen), and the heart is delivering some fuel and the oxygen required to effectively convert (burn) food energy to ATP.

Although I discussed three energy systems, many researchers and coaches view human energy metabolism in terms of four. Table 2 ranks the power and capacity of these systems. The problem with ranking systems is that you don't get a sense of the differences between the variables, but I will mention that the phosphagen system can produce ATP approximately four times faster than the oxidative system and slightly over twice as fast as the glycolytic system.

	Power	**Capacity**
System	**Rate of ATP Production**	**Capacity of ATP Production**
ATP-PC (phosphagen)	1	4
LA (anaerobic glycolysis)	2	3
Oxidation of carbohydrates	3	2
Oxidation of fats and proteins	4	1

Table 2: Rankings of rate and capacity of ATP production (1 = fastest/greatest, 4 = slowest/least). Source: Baechle TR and Earle EW (eds.), *Essentials of Strength Training and Conditioning* (2nd ed.), Champaign, IL: Human Kinetics, 2000. p. 83.

The reason I have included Table 2 in this article is to point out that in terms of oxygen used, it is more efficient for human muscle to use glucose rather than fatty acids. In fact, it is about eight percent more efficient to burn glucose vs. fats. This glucose can be supplied by the blood or from glycogen stored in the muscle. As exercise intensity increases from rest toward $\dot{V}O_2$ max, a progressively greater proportion of energy production comes from carbohydrate. At 20 percent of $\dot{V}O_2$ max, approximately 60 percent of the energy comes from fat; at 50 percent of $\dot{V}O_2$ max, only about 40% of the energy comes from fat. At work levels above 95 percent $\dot{V}O_2$ max, carbohydrate is used almost exclusively. In addition, glucose is the only fuel the glycolytic system can use, so given most CrossFit WODs force you to be at or above $\dot{V}O_2$ max, you would be using carbohydrate.

In 2010, Graham Holmberg proved to be the athlete with the fewest weaknesses.

Research has shown that eating 100–200 grams of carbohydrate within two hours after endurance exercise is essential to building adequate glycogen stores for continued training. Waiting longer than two hours results in 50 percent less glycogen stored in the muscle. The reason for this is that carbohydrate consumption stimulates insulin production, which aids the production of muscle glycogen. Remember, insulin will increase the rate at which blood sugar is stored. It is also important to consume carbohydrate (possibly sports drinks) within 15 minutes post-exercise to help restore glycogen. The research has admittedly focused on recovery from endurance events lasting 90 minutes or more because these types of events severely deplete glycogen. While a four-minute WOD will not severely deplete glycogen, we do have to remember that there will be multiple WODs over three days, and the athletes will be working at or above $\dot{V}O_2$ max. This will require carbohydrate replenishment, but the actual amount may be slightly different than shown in these studies on endurance athletes.

Research shows that combining protein with carbohydrate within two hours of intense endurance exercise nearly doubles the insulin response, which results in more stored glycogen. The optimal carbohydrate-to-protein ratio for this effect is 4:1 (4 grams of carbohydrate for every 1 gram of protein). Eating more protein than that, however, has a negative impact because it slows rehydration and glycogen replenishment. One study found that athletes who refueled with carbohydrate and protein had 100 percent greater muscle-glycogen stores than those who only ate carbohydrate. Insulin was also highest in those who consumed a carbohydrate-and-protein drink. I just want to remind you here that insulin spikes post-exercise are good—it is chronically elevated insulin levels that are bad.

Training Errors

Any coach can train his or her athletes so that they will not be excessively fatigued coming into the Games. At this level of training, they will also be unlikely to injure themselves. Equally, any coach can over-train athletes with the "more is better" philosophy. The quarter-million-dollar prize will go to the athlete whose coach trained him or her to full potential by balancing hard training with required recovery.

Regionals are long over. Who got it right in terms of peaking again on July 29?

This is clearly not an exact equation but is very pertinent to the Games:

Performance = Fitness – Fatigue

What everyone should realize is that come July 29-31 at the Home Depot Center, the athletes and coaches should not be 100 percent focused on who is the fittest. Yes, I know that sounds like blasphemy. After all, the finals crown the Fittest on Earth, but fatigue is a big issue. Come July 29, it is about who *performs* the best, and obviously the "fittest" athlete is going to have a strong chance, but theoretically an athlete who should have won might not have tapered properly and might come into the Games fatigued. It may not be easily discernable—often it isn't—but sometimes an amazing athlete just doesn't quite have his or her A-game on a given day. Getting the blend of training and recovery correct is the hardest thing to perfect in athletic conditioning. Performance on demand is a big part of fitness, and Games athletes must "prove their fitness" during the event.

I do not discuss this factor lightly. Even full-time professional coaches and governing bodies will get this wrong. Swimming Canada fired its national-team head coach after the 2004 Olympics. In those games, Canada failed to win a swim medal for the first time since 1964, and, overall, Canadian Olympians swam 28 times in Greece yet achieved only four personal bests. The problem many believe was placing the national trials too close to the actual Olympics. What is worse than performing badly at the games? Not being at the show! The athletes peaked to make the Olympic team but then were not able to taper down and re-peak for the Olympics. Many of us believe it wasn't a problem with the coaching per se but rather the timing of the national trials.

So regionals are long over. Who got it right in terms of peaking again on July 29, and did those pre-qualified athletes find the right blend of rest and intensity to climb back into the top ranks again?

Warm-Up Errors

Long static stretches reduce muscle stiffness, which sounds like a good thing. It actually is if you are involved in a stretching/flexibility session. However, if you are about to go out and perform multiple 30-inch box jumps, it isn't a good thing. The effectiveness of the stretch-shortening cycle I mentioned in the previous article is diminished if muscle stiffness is lower. In addition, static stretching has been shown in numerous studies to weaken the muscle. Fowels and colleagues showed 13 maximally tolerable passive calf stretches reduced maximal voluntary contraction by 25 percent (1). This is due to both neural factors (diminished activation) and disruption to muscle fibers.

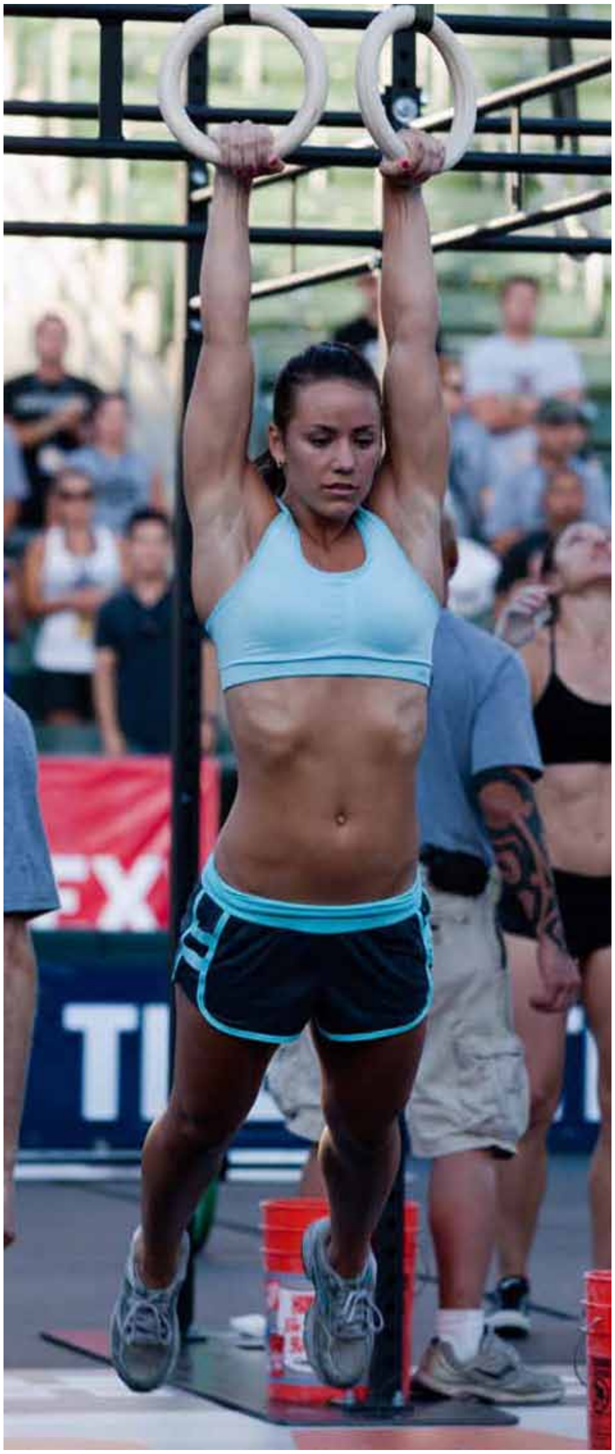
As the Games went on in 2010, athletes had to be able to recover from previous tests in order to perform at an elite level.

Jason Khalipa used an ice bath to recover in 2009. After a brutal opening event, he came back to finish fifth overall.

Another potential problem is not being adequately warmed up. The only exception to the rule of power output determining energy-system usage (see Table 1) is when you start exercising from a resting state. In this situation, even at moderate power outputs, you will work anaerobically until your cardiorespiratory system "ramps up" to deliver enough oxygen to the working muscles. So although you may have the ability to deliver enough oxygen to work aerobically at a given power output, you cannot just "flick a switch" and attain that cardiac output immediately. This is one reason why warm-ups are so important—you do not want to start working anaerobically during a WOD before you absolutely have to. If you do, you will start burning glycogen when fatty acid could have provided the fuel, and obviously anaerobic glycolysis does result in high muscle acidity and local muscle fatigue. You have a limited amount of glycogen but relatively unlimited amount of fatty acids. However, if you partake in too extensive a warm-up, you could deplete fuel substrates and fatigue both muscle and central nervous system. Tricky isn't it?

Recovery

How the CrossFit athlete envies the marathon runner (not really, but you'll see what I mean). If your sport is a one-time event and you may not have to peak again for a few months, your recovery process is effectively simplified. If you are a soccer player and you play weekly and occasionally twice per week, it is a little more complicated. A tennis player has a bit more of a problem as he/she may play the next day. The CrossFit athlete competing in the Games may have two or three or more WODs in one day—that's a major issue.



Will another dark horse show up at this year's Games, as Camille Leblanc-Bazinet did in 2010?

CrossFit athletes must be as ready to go as possible prior to each WOD. They need to address hydration, replenishment of electrolytes and glycogen. I mentioned this in the nutrition section, but massage and other techniques like trigger-point therapy and/or contrast baths/showers can help with muscle recovery.

Placebo Effects

We cannot forget the mind here. Many athletes perform rituals that seem to be physiologically and mechanically irrelevant. However, placebo effects are very powerful—if the athlete thinks it will work, it may indeed help. There are limits to this effect. If you do something clearly detrimental, it will be a problem. Nevertheless, many studies show the beneficial effects of "sugar pills" (imagined drugs with no pharmaceutical agent).

The Winner Is … ?

So at the end of all this, am I going to predict who will win the Games? No.

However, I hope I have discussed many of the factors that come into play for the main event in Carson. Quite possibly, I might have missed additional factors; it is very complex, and that's why we hold the competition.

Obviously, I cannot predict the winner because of several factors:

- I do not know what the WODs will be.
- I don't know differences in technique efficiency between Salo's and Spealler's clean and jerk or Clever's and Thorisdottir's kettlebell swing, and even if I did take the effort to study this biomechanically, there are hundreds of other movements added into the mix. I couldn't finish this work in my lifetime.
- I do not know the training status of each athlete; mistakes will be made.
- I do not know the nutritional status of the athletes going into the Games.
- I do not know their warm-up routines.
- I do not know how well they will use nutrition, massage and other techniques to enhance recovery between WODs.

It would be a lifetime's work to measure all these components, and even if I did, I still wouldn't be able predict the winner because of a factor in which I have no academic expertise.

That factor is motivation. Although I am not a psychologist, after 45 years in this field as an athlete and coach, I do have a lot of personal experience regarding motivation, as do all of you reading this article. We could find many good, young CrossFit athletes who cannot win because of the mechanical factors discussed. However, when you get to the elite athletes—the ones whose bodies are of an optimal size and the ones who are technically gifted, well nourished and are supremely trained across broad time and modal domains—then it is the X-factor that will win it. Who can endure the most pain, and whose brain can override the messages telling them to stop?

This is why the Games exist: nobody can predict the results on paper.

I'll leave you with a couple of quotes I like:

"Gold medals aren't really made of gold. They're made of sweat, determination and a hard-to-find alloy called guts." —Dan Gable, U.S. Olympic gold medalist (1972, wrestling)

"Pain is temporary. It may last a minute, or an hour, or a day, or a year, but eventually it will subside and something else will take its place. If I quit, however, it lasts forever." —Lance Armstrong

Let the Games begin.

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References

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