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21 Questions for JB Morin on the Topic of Speed
By: Bret Contreras

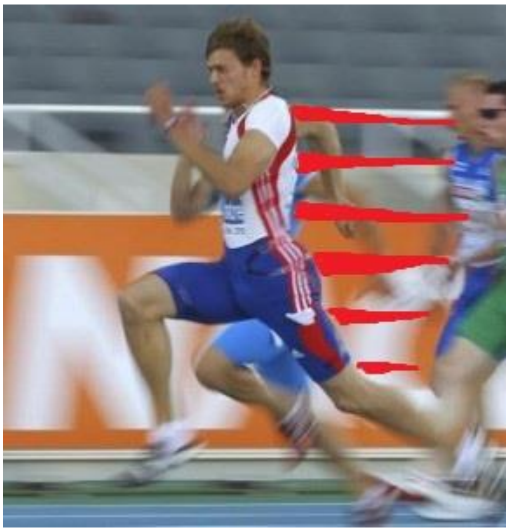
Several weeks ago I wrote a post reviewing a study on Christophe Lemiatre and what makes him so darn fast. The study was conducted by French professor JB Morin; an incredible researcher in the field of sprint biomechanics and speed development. JB was kind enough to sit down and answer 21 questions I threw at him. Understanding sprint biomechanics is not easy, and there are many different theories out there; some more evidence-based than others. Luckily we are learning more over time with excellent studies emerging on a monthly basis. This interview should help improve your understanding and confidence in sprint mechanics and the determinants of speed.

1. Hi JB, first off let me congratulate you for undertaking one of the most amazing studies I've ever read. You guys are coming out with some really great research! What is your background in sports and academics?

Thanks Bret. In academics I'm a Sports Science MSc, and I did a PhD thesis in Sports Science as well. In sports, I was a 400m hurdler. At age 22 I tried trail running for a while, but then I had knee-trouble, so I switched to mountain biking and now I'm a MTB and road cyclist. Interestingly, cycling research regarding mechanical effectiveness and the ratio of forces has been around for over 30 years, which gave me some of the ideas for my recent research.

2. Interesting! Now let's get right to it. Based on your findings, what makes Lemaitre so damn fast?

From what we measured on the specialized treadmill (there could be other things we didn't measure…maybe he has a huge amount of fast-fibers but we don't know this yet), he has a better ability to orient the total force vector with a forward incline (he doesn't have more total force production than his peers, or even specialists from other sports than athletics), and he has the ability to produce the highest horizontal force amongst his peers, and especially at faster velocities.



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3. Can you please explain this in Laymen's terms? Maybe you can provide an analogy?

At 6m/s on the treadmill, he's producing more horizontal force than the National sprinters. Some of the non-specialist sprinters couldn't produce any net horizontal force at that speed on that treadmill.

For the analogy, say that if he were pushing a big car, at the beginning he wouldn't be that much better than his peers. But as the car built up speed, he'd keep getting better than his peers due to his ability to produce more horizontal force at higher velocities. Eventually he'd be the only person amongst his peers who could produce force as the car sped up sufficiently. This is what makes Lemaitre superior in this regard.

4. Brilliant analogy! I think that effectively sums it up. This study was performed using your special torque treadmill. How does the treadmill affect the force and power measurements compared to overground sprinting?

First, the treadmill allows for the measurement of force and power. It affects velocity in that the treadmill sprinting is slower than what's seen overground (although these two velocities are very well correlated, as we've observed and recently reported in a recent study published in the same Journal). We've recently completed a study to determine how the forces are affected, but the values are within the range of what's seen with overground force plates in terms of Newtons. For sure, the locomotion is indeed different since you're tethered at the hips, you're not moving forward, and you're spinning the torque treadmill with your feet (which is not the same as overground running).

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But the fastest sprinters overground were also the fastest sprinters on the treadmill, so the treadmill still allows for some interesting comparisons. And all of our studies with this treadmill share the same design, in which we compare the mechanics of subjects from various sprint levels on the same device.

5. Some experts might doubt the study you conducted based on the premise that the treadmill can't possibly produce accurate data. Is there any merit to these folk's concerts, and if you were to reproduce the study using a hypothetical 100m track of continuous force-plates, how do you think the results would differ?

The treadmill doesn't allow for the same top speed velocities to be reached. For this reason, I won't publish any data on "top speed" – in fact if I were a peer-reviewer for my own data I wouldn't allow it to be published since the forces and velocities are different.

So we can't answer the question about forces right now for top speed as we don't know enough. But I think we'll duplicate Weyand's data – faster sprinters put more force into the ground. Part of our results from the "Lemaitre study" confirms this. But we'll learn more since Weyand's study only reported and discussed vertical forces; we'll be able to look at all of the forces (vertical, braking, propulsive, and resultant).

Last, but not least, we are about to send for publication new and interesting results, this time obtained during real overground accelerated runs. Part of these results clearly confirms the treadmill ones, hopefully they will be published soon. If so, then the discussion will revolve around sprint biomechanics, rather than (or in addition to) treadmill vs. field measurements.

6. What's the deal with braking forces, can we eliminate them completely during maximum speed running, and is some level of braking forces ideal to allow for more time for force development?

Until we have more clear data, my thought is that a certain amount of braking is necessary. At maximum velocity (which is constant speed), horizontal braking forces and propulsive forces cancel each other out (horizontal net ground reaction force is null at constant speed). You can have large braking and large propulsive forces, or you can have small braking forces and small propulsive forces. As long as they cancel each other out during max and constant speed then that speed is maintained and you won't decelerate.

But I don't think it's wise to try to completely eliminate braking forces, especially during the acceleration phase of a sprint; I think there is an ideal amount of braking force needed to "stall" the neuromuscular system and allow for enough time for the build-up of sufficient force from the muscles. The latter resulting in greater amounts of propulsive force produced. There's probably an optimal window, with too little or too much braking being less efficient. Furthermore, the center of mass "falls" down during the braking phase, and should this braking phase be too short, the overall orientation of the ground reaction force during the propulsive phase might be too vertically-oriented (and thus not enough horizontally-oriented).

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I'm excited to very soon test this hypothesis with the data we collected during overground 40-m sprints. Last week, a paper published in the Journal of Strength and Conditioning Research (Kawamori et al.) revealed that the 10-m performance was positively correlated with the net horizontal impulse measured at the 8-m mark (this is mechanically logical), and that propulsive but not braking impulse was correlated to this performance. In addition, similar results were put forward in a classic paper by Joseph Hunter a few years ago, at the 16-m mark. This contradicts the idea I propose here, but my reasoning considers the entire acceleration phase, and although very interesting, Kawamori et al.'s data only focus on the first step and the step at 8m, in team sports players. Their study is also interesting in that neither vertical nor resultant impulses were correlated to 10-m sprint performance, only horizontal impulse was…As Hunter wrote: "the possibility of braking having some advantages could not be ruled out." This is what we will test very soon with force data collected all over 40-m accelerations.

All this shows us that efficient sprint biomechanics research forces one to be humble since getting "ideal data", i.e. overground measurements *plus* over several steps*plus* in top level athletes *plus* in competition conditions is a very tough work! Each study should therefore be considered as a little contribution bringing us one step closer to this "holy grail".

7. What about vertical forces, should we try to maximize them during maximum speed running?

I agree with the hypotheses and conclusions of Weyand on that, I think you must be able to produce high vertical forces to run at high top speed, but you reach a limit. And as you speed up, you have shorter and shorter ground contact times. So you must be able to produce great vertical forces in exceedingly shorter times. But I don't think that the fastest sprinter automatically produces the greatest maximum forces during sprinting; you want to produce sufficient vertical force rapidly in order to raise the COM but not too much as that would negatively impact speed. Because it has applications in many other sports than athletics only, I'm much more interested in the determinants of maximal acceleration rather than maximal speed.

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8. And what about horizontal propulsive forces, these forces are most correlated with maximum speed, correct?

Again, we can't say for certain; we don't have the data yet for maximum speed. My guess would be yes. Net horizontal forces are probably more highly correlated with maximum sprint speed, and maybe more with maximum acceleration than vertical forces. But again, we don't clearly know this yet.

9. Many sprint experts believe that since net horizontal force is zero at maximal speed (since braking forces are equal to propulsive forces), that they're not critical and vertical force now becomes the more important factor since it helps get the sprinter off the ground quicker. What's the problem with this line of thinking?

At top speed, you need to produce sufficient vertical force. You're not accelerating anymore. However, since you can't get rid of braking forces, you must have the ability to apply great propulsive forces while your leg is moving very fast to prevent deceleration. So if you want to improve top speed, you need to be able to produce greater horizontal propulsive forces. In fact, mechanically-speaking, there are two possibilities: either you are able (at top speed) to produce small amounts of horizontal braking impulse, and then the propulsive impulse needed to maintain a constant speed will be small, or you produce a larger braking impulse, and then…you'll need a high propulsive impulse to "compensate" and maintain constant speed. If your propulsive impulse does not match your braking one, you'll decelerate.

Thus, I really consider the acceleration phase and the top speed phase different from this point of view. Although I hypothesize (our data might soon prove me wrong…or not) that you need a certain amount of braking impulse during the acceleration, I think it should be reduced at top speed. At this moment, the distance your center of mass goes forward during the contact, and the net impulse you can produce, becomes critical. Furthermore, at this moment, I think that the backward push of the (almost totally extended) leg is crucial. And I also hypothesize that the role of hip extensors is underestimated. Although it appears from former studies that these muscles "shut down" around mid-contact, their action before contact (during the "pawing action") and during the braking phase might be determinant.

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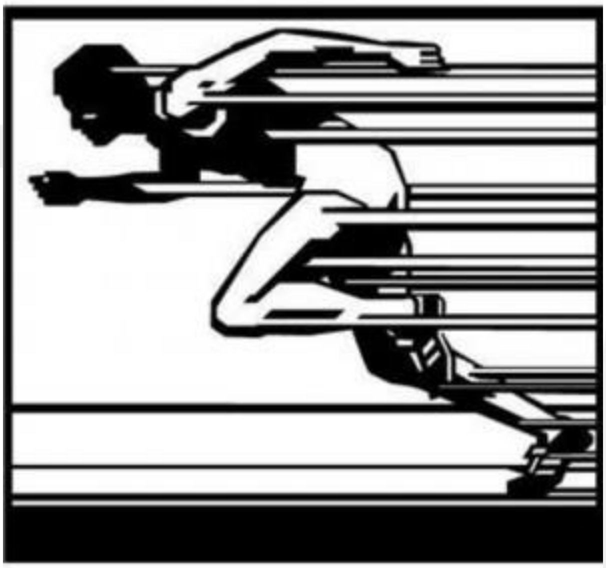
10. Do you think that we can cue sprinters to affect their force production on the ground, or is the ground contact time too short to do so?

The idea is to be able to produce the most force while on the ground. I think you can indeed affect force production while on the ground through cueing, but the goal is not to try to stay on the ground for longer times just so the sprinter has more time to produce force. I'm not sure if cuing for pawing-back or popping off the ground rapidly would lead to better sprint times – the athletes probably figure out the optimal blend all on their own. I must say here that "pawing-back" the leg while in the air just before contact or while on the ground might be two different actions, maybe two different abilities, and maybe not equally efficient in leading to a high amount of horizontal impulse. This is another hypothesis I'd like to test.

11. Assuming that two elite sprinters weight the same and have identical ground-contact times and vertical forces, does the sprinter with the greater horizontal force per stride run faster?

My guess would be yes; he would accelerate more during the initial portions of the sprint and reach a higher top speed.



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12. Usain Bolt and Christophe Lemaitre have the insane ability to continue accelerating through a substantial portion of the 100m sprint. What do you attribute this to?

If I remember correctly, if you take the speed-time curve of Bolt, he accelerates up to something like 80m. For Lemaitre it's more like 65m, and he does indeed decelerate. Everyone decelerates, but he decelerates less than his competitors. Bolt and LeMaitre have excellent "endurance" for net horizontal force production. Each of them is amazing at the 200m sprint. If Bolt wanted to, he could probably break the 400m record. They have an uncanny ability to transmit forces, and I bet they have great foot/ankle properties that allow for optimal transfer of power from the glutes and hamstrings down into the ground. I like the approach of "producing AND transmitting force effectively to the supporting ground". Sprint training should focus on both.

13. What makes sprinters slow down? As they fatigue, what happens to their forces and power output?

I don't know. Until we get sound measurements I can't say. I'd guess that you're getting neuromuscular fatigue which lowers your vertical and propulsive forces. In addition, the neuromuscular fatigue might reduce the ability of the feet to transmit force into the ground, since the foot/ankle deforms more at the end of the sprint compared to the beginning of the sprint. But until we have sound measurements, these are just hypotheses.

14. What muscles do you feel are most important for speed? Is every muscle in the body equally valuable or are some more important than others?

Speed is vague. You need knee extensors and you need plantarflexors. But I really think you also need powerful hip extensors to accelerate. At full speed, you need stiff ankles and powerful leg extensors. You need it all! Remember that at top speed your lower limb touches the ground in an almost-fully-extended position. Anatomically, the muscle groups generating a backward motion of the limb are rather hip extensors than knee extensors (the knee is almost fully extended).

That said, you need it not to "deform" too much, same for the ankle. It is an easy answer to say "everything is necessary", but I think that as speed increases during a typical acceleration, and at top speed, producing the force, and transmitting it to the ground predominantly relies on different muscle groups. Especially, as speed comes close to maximum, the ability of ankle and knee "stabilizers" to allow these joints not to deform too much during the huge impacts at each step might be a prerequisite for an efficient propulsive action of hip extensors…and a high horizontal impulse production.

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15. Now let's talk applications to training. Do we just need powerful hips or is there more to the equation?

As I just mentioned, you need a strong motor in the hips (and in the knees and ankles, for the early phase of acceleration, from a crouched position). But you also need stiff ankles (and knees as speed increases) to transmit the force with effectiveness. You can have a superior motor (glutes and hamstrings, or even quads) but if you have a flat tire (weak ankles or knees that deform too much at the ground), you won't move very fast.

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16. I know you're interesting in cycling as well. Does this same principle apply to cycling?

Producing and transmitting force in cycling is paramount. If you have big glutes / quads / calves but your ankle stabilizers are tired, your heel goes down, your foot goes up, and your push is wasted. When I train cyclists, I have them do exercises to work their ankle strength and endurance (just as I would do with basketball players) and they look at me like I'm insane. They say, "But we're cyclists, why are you giving us track exercises?" I have to educate them about the importance of the ankles.

17. What are some drills and exercises that you recommend for sprinters?

Exercises that put the body at an incline such as sled work, towing, elastic bands, and incline sprinting are great.

Speed, speed, speed is critical. You don't need to obsess with weight; you need to think "explosion." You need force, but you need to produce force very quickly. Don't forget about velocity! Whatever the load you push or draw, focus on doing it as fast as possible.

I also like to train the ankles for endurance. For example, take a 20lb barbell on the shoulders and jump from right foot to left foot while on the balls of your feet, or jump with a high frequency on one foot only for 20 reps, then on the other, and so on, or from right to left over a lane line, etc.... Do this for 3 minutes – they'll burn like crazy. This will build tremendous ankle endurance. In addition, these muscles are involved in our overall balance while standing, so they have a high endurance, don't hesitate to "burn" them until you can not stand on your feet, they recover very fast.

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18. Are there any drills and exercises that you feel are overrated for sprinters?

Everything is good, but in the right amounts. Deep squats are good. But too much of them and with too much weight is not ideal. Coaches usually employ excellent exercises but the dosages are not always ideal. In general, never stray too far from velocity. But I have to admit, many coaches over-emphasize the squat. For many sports such as soccer, their quads are already strong and they sometimes need to focus more so on their posterior chain, for both performance and injury prevention reasons…

19. Are there any cues that the French sprint coaches are giving to the French sprinters that differ from the norm?

For what I'm aware of, there is no consensus in France and every coach has his own view and practice. For instance, some of them are not too concerned with maximum strength. When we say, "strength training," all too often people assume "heavy strength training." But some of the guys in France use lighter loads and work more on the velocity side of things, with very specific strength exercises. Although I don't know how people train all over the world, I think we also do more work for the foot/ankle complex.

In France, overly muscular athletes have often been perceived as anabolic steroids users, and it is possible that this has refrained coaches from using heavy strength training too much. France has a huge anti-doping stance, and ironically this might have benefited France because we've figured out ways to improve our sprinters by improving their power through velocity and/or force application technique, and not so much through force and bigger muscles.

20. Any insight as to how Christophe Lemaitre trains?

Lemaitre has an outstanding ability to transmit the force onto the ground, and I think he is also very "endurant" in doing so. This is his strength. But I feel he could benefit from improving his ability to produce force. He has excellent sprint endurance too. I'm curious to see if he'll improve his 100m time this year, but I think he'll definitely improve upon his 200m time. It's common knowledge here in France that Lemaitre never did any serious strength training prior to breaking the 100m barrier.

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Maybe a couple sessions per week for a couple months, but never anything very intense or drawn-out. In a newspaper article here in France, his coach stated that Lemaitre's maximum deep squat was 240 lbs, which many track coaches would believe to be incredibly low. These days he's doing a little more maximum strength work, but I don't expect it to have too much of an impact right off the bat as it takes time for training gains to come to fruition.

21. Thank you very much for your time JB! It is much appreciated. Last question: Do you have any exciting research in the woodworks?

We certainly do. We're doing some testing on acceleration using overground force plates to see if we get the same measurements that we did in the treadmill study. So in essence we'll be critiquing our own study on the treadmill by comparing to overground sprinting.

We'll also be looking at sprint speeds, isokinetic torques for the quadriceps (knee extension), hamstrings (both knee flexion and hip extension), glutes (hip extension) and foot motion during the sprint cycle to see what correlates best. Data have now been collected, and we'll discuss the role of hip extensors in the "pawing" action, both in the air and then during contact, and in turn in the horizontal force production during accelerated runs. We synchronized EMG, 2D video and treadmill GRF measurements, to try and see what muscle groups are the most involved and the most efficient in generating horizontal force production.