Q4E Case Study 43 - Small things make a big difference. The elite sprinter.

	Proposed subject useage	
	Sports Science **(A/AS level / Degree Yr 1/2/3)**	
	This is the second applied biomechanical case study conducted, analysed and presented by Dr P Brice, using the v31 Quintic Biomechanical Analysis Software platform, whilst providing biomechanical consultancy to an elite Olympic sprinter.	

Background

There is something magical about watching elite athletes sprint very fast. From the outside looking in, the observed movements may appear almost effortless but for anyone who has tried to sprint fast, we know that sprinting is an extremely difficult, complex and physically demanding skill especially in the context of elite athletic performance.

The underpinning biomechanical knowledge and understanding of elite human sprinting is well documented in the scientific literature and within the coaching domain.

The notable applied biomechanists of Ralph Mann and Peter Weyand have become pioneers in the endeavour to fully explore and understand the kinematic and kinetic biomechanical characteristics of what differentiates the fastest elite sprinters.

The scientific evidence is very clear when it comes to the fastest sprinters in the world, they typically possess large (relative) step lengths combined with a high step frequency, spend very small amounts of time on the ground (<0.090 secs) yet are able to apply huge mass specific ground forces (>6-8 BW's).

With such a broad appreciation of what is required from a purely biomechanical standpoint it maybe wrongly assumed that application of this insight should be a simple process. Anyone whom has coached at the highest level, with the highest calibre of athletes knows unfortunately that this is not always the case. The ability to apply this scientific knowledge through the application of quality coaching remains the differentiating factor that the best coaches in the world are able to exploit and maximise, to gain the greatest performances from the athlete.

In order to sprint faster, common sense would inform us that the athlete would be required to improve one or both of the parameters of step frequency or step length, ideally both. What is non-negotiable is that you cannot develop one variable at the expense of the other. For example, a gain of 0.15m in overall step length cannot be achieved with a subsequent reduction in step frequency of 0.30Hz. If this was the outcome, the net result and direct impact to the athlete would be zero improvements to overall velocity.

Purpose

This case study is of an elite sprinter and has been used to highlight the various functionalities within the Quintic biomechanical software that allow for different levels of objective data to be generated. The primary outcome is to facilitate more informed and impactful performance conversations to occur between the coach and athlete on the track in the daily training environment and to ultimately improve performance.

The context of this specific intervention is very important. This athlete was already very fast and had performed at multiple global championships but still had a very strong desire and aspiration to want to deliver even quicker performance times. Therefore, with this in mind the main emphasis was to provide absolute clarity to the coach and athlete on what really mattered technically (biomechanically) in order to sprint faster. In my experience it is essential to start the process of any biomechanical analysis from a simple to complex paradigm. The starting point should always centre on some form of performance question.

Invariably as the journey of analysis evolves this will subtly change course of direction as the level of understanding develops through thorough scientific investigation. Sometimes within the applied world, there can be a mind-set from scientists to want to show everyone how much they know, how much technology they are able to operate and a strange need to show how clever they are – the reality is that this could not be further from the truth. Whilst potentially making the scientist professionally fulfilled with lots of numbers and graphs this adds very little, if anything of real value to the overall training programme.

If this information falls into the themes of 'nice to know' or 'personal areas of interest' and does not include the actual critical determinants of that performance, unfortunately the subsequent data can be meaningless, lack buy in from coach and athlete and totally miss the potential performance benefits of any biomechanical support.

Depending on the specifics of the performance question, the process may subtly vary across athletes and event groups but typically these key questions will remain pertinent regardless of the specific context. These questions should hopefully shape and guide the future direction of the proposed biomechanical support.

Key Questions:

What do we already know about the athlete's biomechanical movement strategy?

What information or data do we need / want to know?

How and what do we collectively need to do in order to make this happen? (Probably the most important question!)

***Time will always be a limiting factor in elite performance, answers are demanded yesterday for questions that are posed today.

Method

The Quintic Biomechanical analysis system (v31) has the impressive flexibility and bespoke functionality that allows the applied biomechanist to explore, investigate and provide the required and appropriate level of biomechanical analysis within one complete system. The real 'art' for the applied biomechanist is how to package and deliver this type of data in the most appropriate and meaningful way to the end users – the coach and athlete. The balance of what to feedback, when to feedback and at what level of information to feedback will always be the judgement call of the applied biomechanist. This should ideally be underpinned by the professional relationships developed over time and through shared experiences. The priority and focus should be to produce biomechanical feedback that makes the complicated simple, free from overly complicated scientific jargon or buzzwords and presented in a universal language and format that engages rather than alienates.

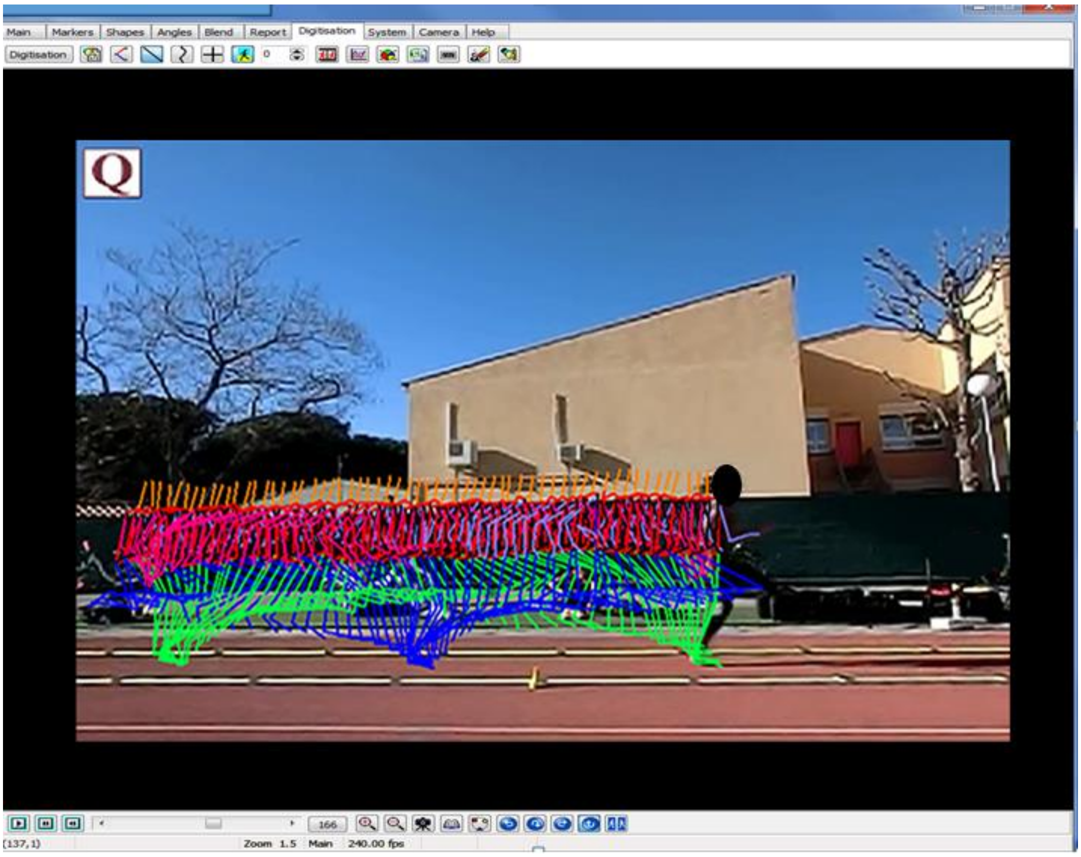

Figure 1: High speed fixed camera set up and generation of an 18 point female centre mass stick figure model

The creation of a complete female centre of mass model opens up huge possibilities in the biomechanical knowledge and understanding that may not have been previously known for this specific athlete. Using the v31 Quintic system, a high speed fixed camera (Casio, Exilim ZR1000) operating at 240 fps, with a field of view of 8m was used to capture two continuous stride cycles for each limb of a maximal 30m flying sprint (figure 1).

From this high speed video an 18 point female centre of mass model was created and the data processed that provided key metrics to be reported throughout the whole sprinting gait cycle:

- The instantaneous centre of mass velocities (horizontal and vertical)
- Key joint range of motions – hips, knees, ankles
- Angular velocities of the individual upper and lower limbs

Whilst there is an associated time resource in the generation of these detailed centre of mass profiles, the added benefit to this approach was now that we had an objective global understanding of key movement relationships, how the body segments were moving in space, how they each interacted upon ground contact and what they did in preparation for the subsequent ground contact (flight phase).

It's important to highlight that the specific margins for potential improvement when working with an athlete who is already operating at a very high level can be a small window of opportunity. The ability to cross reference and compare the specific biomechanical profile of our athlete against known benchmarks or reference values are critical and allow a true sense of the coaching challenge ahead and shape the direction of the technical improvements specifically targeted to improve the gaps in the biomechanical characteristics identified.

Analysis / Results

The ground contact phase is the most important key event of the overall sprinting gait cycle. The position (shapes) that the athlete is able to attain upon initial contact with the ground will ultimately dictate the overall force outputs generated and strongly influence the sprinting velocities achievable. The ability to understand these integral mechanical cause and effect relationships is key to being able to provide the coach and athlete with specific information related to what's important for the athlete being analysed.

As an entry level biomechanical analysis, a simple series of still pictures were created at key events during the sprinting cycle across left and right limbs (figure 2 and figure 3). This allowed for the identification and a broader inspection of the basics of the sprinting technique, when referenced against what we ideally want to observe provided a great framework to troubleshoot and identify future technical directions.

What is fundamental to this approach is that our reference point of what differentiates good and bad biomechanics is informed, evidence based and not simply a subjective narrative that is what the coach believes should happen, as opposed to what is absolutely critical and essential to sprinting fast.

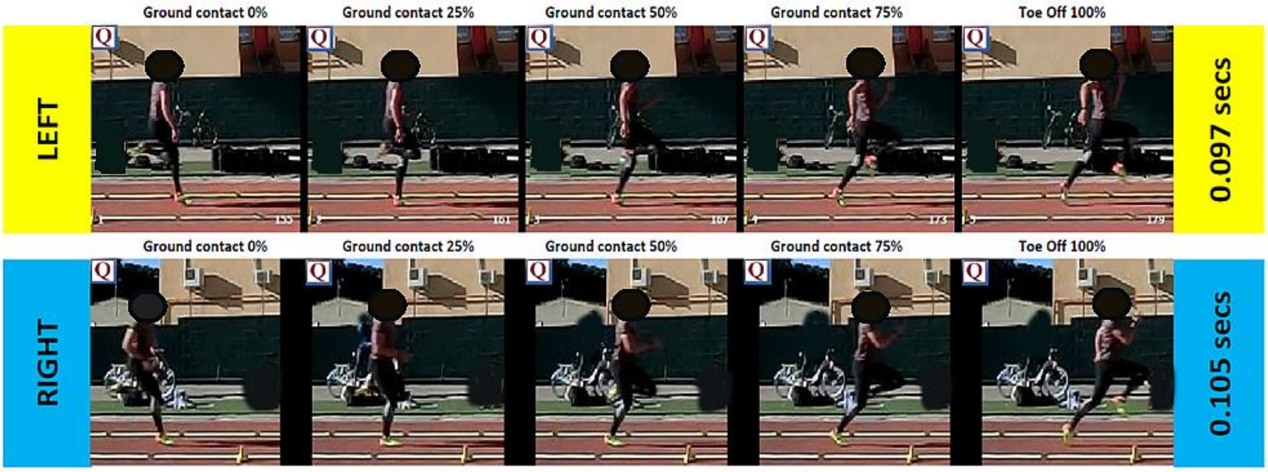

Figure 2: Key event pictures of the ground contact phase

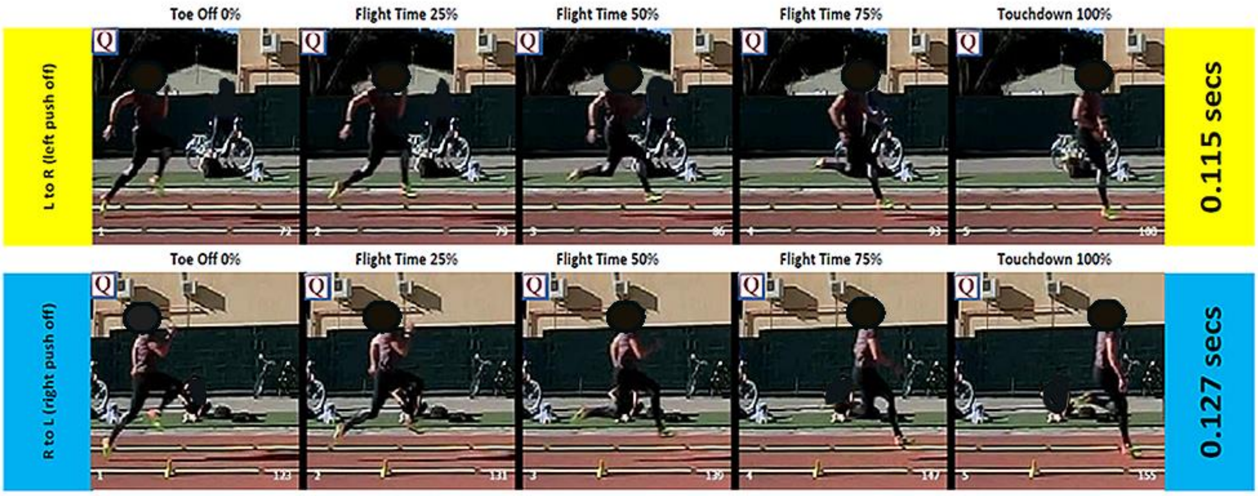

Figure 3: Key event pictures of the flight time phase

Even with such a simple feedback template, we can easily identify obvious differences in the way in which the athlete hits the ground between left and right limbs (figure 2). The left ground contact would appear to be further in front of the body, supported by an increased negative shin angle at initial contact. Additionally we observed a greater amount of knee and hip extension at toe off on the left limb.

In specific reference to universal coaching language this promotes a much more pronounced ‘rear side’ outcome at toe off. The consequence is twofold to the athlete. The increased extension of the hip and knee (rear side) then limits the ability for the thigh to then get in front of the body in order to attack the ground for the next ground contact. The fastest sprinters have collectively understood the need to get the thighs in front of the body as fast as possible (front side mechanics) – providing a greater opportunity to apply high mass specific forces into the ground.

Using these more basic functionalities of the measurement tool within the Quintic software summary data was provided on step to step biomechanical characteristics (figure 4).

Phase of stride	Ground Contact	SL total (m)	GCT (secs)	FT (secs)	Speed (m/s)	SL (m)	SF (Hz)
R to L	L	3.87	0.096	0.129	9.45	2.25	4.20
L to R	R	5.95	0.109	0.106	10.74	2.17	4.95
R to L	L	8.14	0.098	0.127	9.58	2.26	4.24
L to R	R	10.26	0.105	0.108	10.38	2.14	4.85
R to L	L	12.49	0.099	0.126	9.87	2.28	4.33
L to R	R	14.63	0.104	0.112	10.29	2.17	4.74
R to L	L	16.87	0.091	0.131	9.76	2.29	4.26
L to R	R	19.00	0.105	0.111	10.69	2.16	4.95
R to L	L	21.26	0.094	0.132	9.66	2.29	4.22
L to R	R	23.41	0.103	0.111	10.54	2.16	4.88
R to L	L	25.64	0.000	0.129	9.76	2.28	4.28

Summary Data	
Average GCT Left (secs)	0.096
Average GCT Right (secs)	0.106
Average FT L to R (secs)	0.110
Average FT R to L (secs)	0.129
Average Step Length L to R (m)	2.16
Average Step Length R to L (m)	2.28
Average Speed L to R (m/s)	10.53
Average Speed R to L (m/s)	9.68
Average Step Frequency L to R (Hz)	4.87
Average Step Frequency R to L (Hz)	4.26

Figure 4: Key metrics of GCT, FT, SF and SL for flying 30m maximal sprint

Whilst the biomechanical fingerprint observed in figure 4 may be a typical for baseline summary for this individual athlete, it does show clear and obvious areas which require further exploration and highlights the requirement for further data that is currently not possible from these type of analysis alone. This provides a real opportunity to delve deeper into the current sprinting gait cycle with a strong rationale that the more simple levels of analysis have guided this next level of investigation.

In addition to the obvious requirements to provide information regarding instantaneous centre of mass velocities, only the six most important biomechanical variables are presented and listed below. These variables were deemed to be most strongly influencing the efficiency of the sprinting gait cycle. This is not to say others were not measured or were not important but to allow greater clarity these were selected for the purposes of this case study.

1. Upper leg rotational speed
2. Lower leg rotational speed
3. Horizontal distance in front of centre of mass at touchdown
4. Horizontal speed of foot at touchdown
5. Vertical speed of foot at touchdown
6. Distance between knees at touchdown

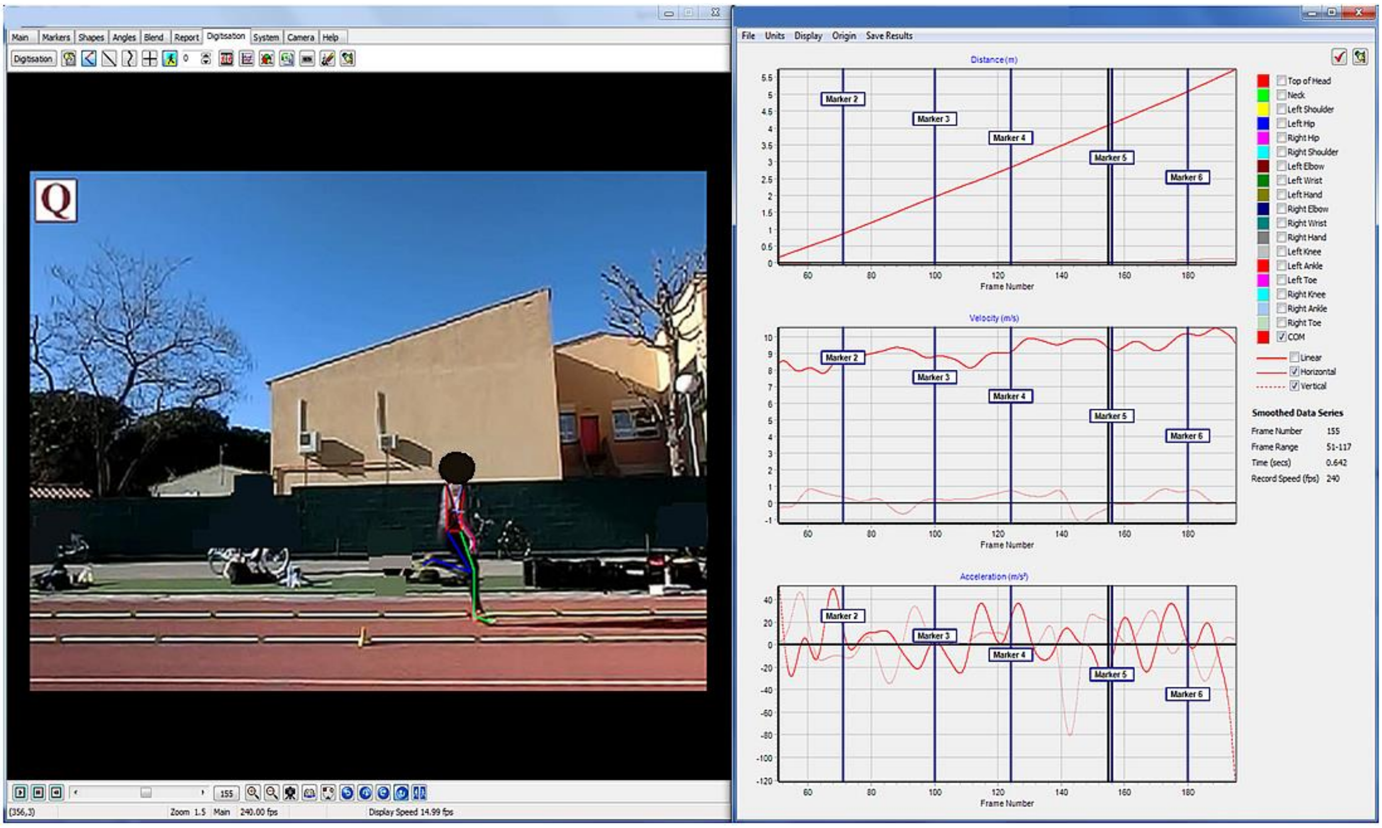

Figure 5: Centre of mass instantaneous velocity profiles

The ability to explore the data at a more granular level and provide insight into the instantaneous moments in time, rather than average speeds from step to step analysis – provides a level of detail that has previously not been explored. This provides the coach with pertinent information where the potential performance gaps are regarding specific recommendations to technical improvements.

In figure 6 we are able to track and objectively quantify the amount of horizontal foot speed in relation to the centre of mass speed. This is a crucial interaction in sprinting and the influence on overall sprinting efficiency is fundamental. The overall concept being that the foot should be actively moving backwards towards the body as fast as possible, to minimise braking forces, reduce ground contact time and to apply a sudden sharp impact to the ground in order to facilitate the highest average ground reaction forces possible during the ground contact.

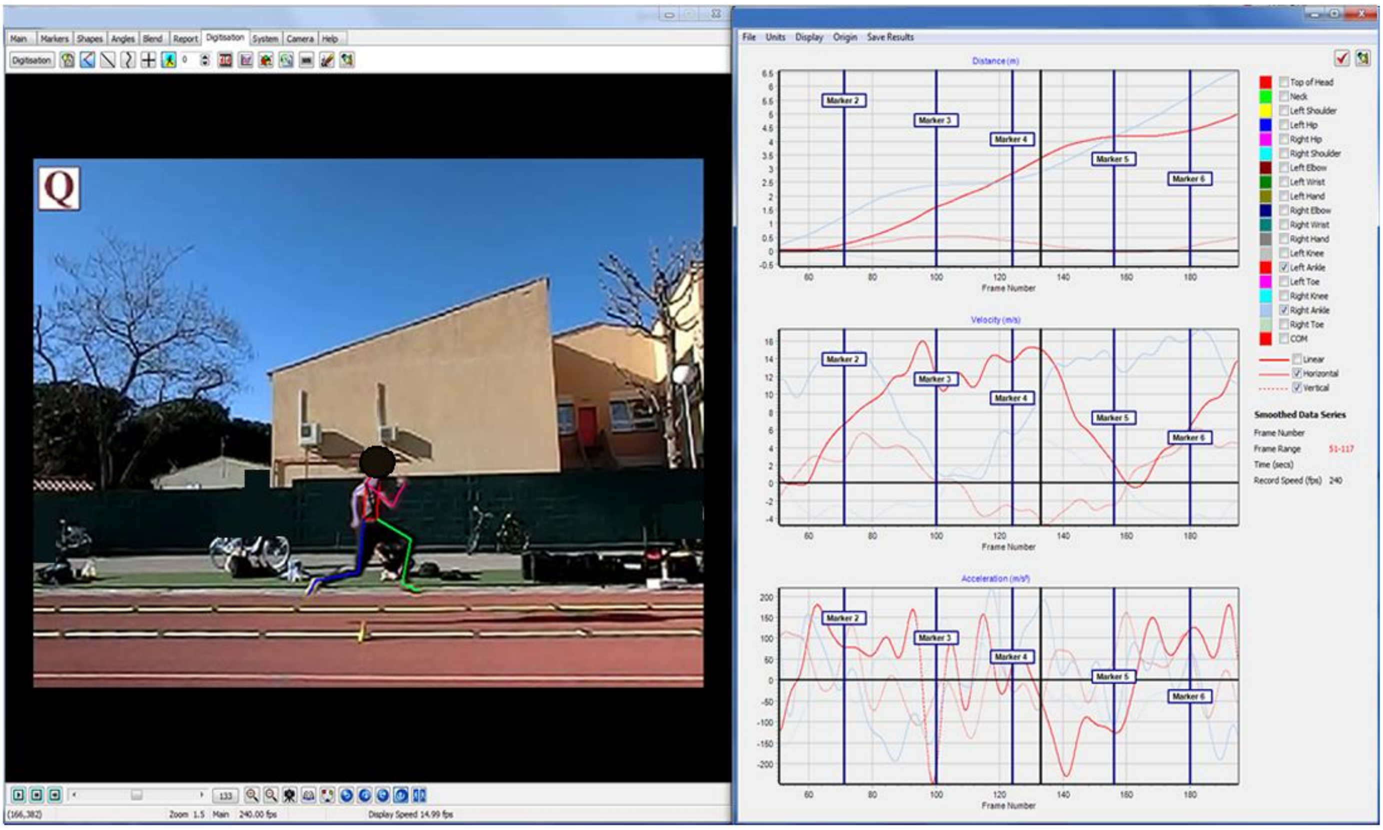

Figure 6: Horizontal foot speed throughout the sprinting gait cycle

A key outcome from this measurement alone was that both left and right angular velocities of the ankle (negative foot speed) were significantly slower when compared with known benchmark values. The left ankle horizontal velocity was 10% slower than the right ankle. It's important to recognise that the athlete's current biomechanical movement strategy allowed for extreme levels of performance to date. When thinking about adding anything to the technical programme, key questions must be considered regarding the potential 'risks and rewards' before any introduction of this new information. Any changes especially in the technical direction should always be explored fully prior to making huge leaps faith regarding any potential performance benefits to the coach and athlete.

A similar movement strategy was observed with the upper thigh angular velocity values. Whilst both limbs were significantly slower when compared against reference values, the left limb in particular demonstrated reduced angular velocity speeds of the hip when compared to the right. This highlights the intriguing ability of the human body to function and function at a high level even with these perceived whole body inefficiencies.

This is invaluable information allows the coach to objectively know where the differences are against both benchmark values but also specifically, know the differences predominantly effecting one limb more than other – with the left consistently slower than the right. This allows really specific and targeted technical coaching cues to be introduced that have absolute clarity on the areas of the sprinting cycle that need the most attention.

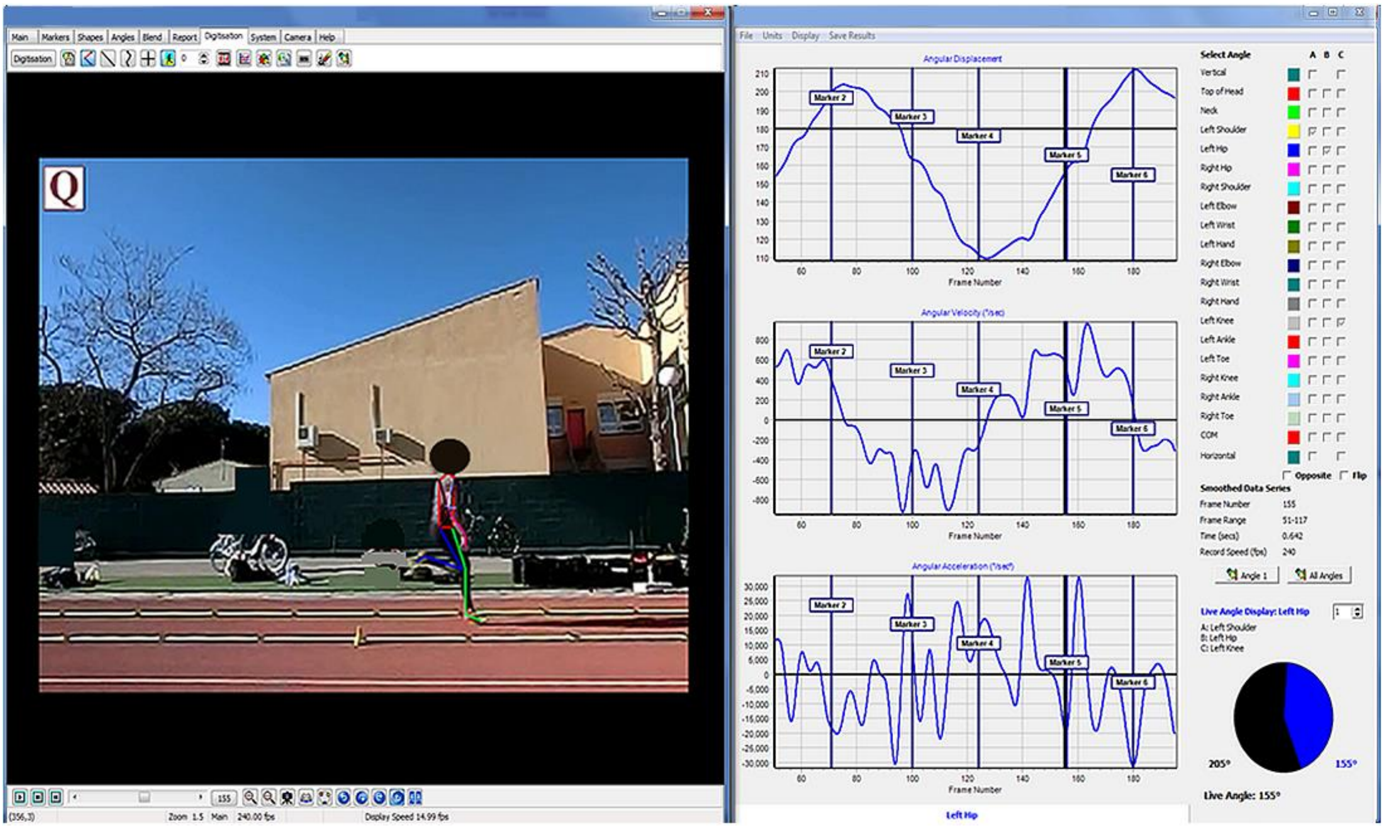

Figure 7: Angular velocity of the left thigh during the sprinting gait cycle

Key Findings:

1. ***Upper leg angular velocities***
   Outcome – focus of creating greater thigh speed into the ground, specific focus on the left limb compared to the right

2. ***Lower leg angular velocities***
   Outcome – continued focus on negative foot speed into the ground, especially the last 20% of the flight phase in preparation for ground contact

3. ***Horizontal distance in front of centre of mass at touchdown***
   Outcome – Strong emphasis on being active into the ground contact, promoted by higher angular velocities of the thigh and lower leg.

4. ***Horizontal speed of foot at touchdown***
   Outcome – focus on being active into the ground, it is essential the movement is initiated from the larger muscle groups first (thigh) and then a more whipping action of the ankle back towards the body. Huge consequences to injury incidence if this mechanical profile is an ankle led movement strategy.

5. ***Vertical speed of foot at touchdown***
   Outcome – focus on being active into the ground but also concentrate on stepping down into the track – especially in the last 5-8 frames of flight prior to initial contact

6. *Distance between knees at touchdown*

Outcome – Directly related to what the athlete does at toe off. Remembering the primary aim of getting the thighs in front of the body – so once the athlete has left the ground, the free limb must be brought forward as fast as possible with aggressive and fast hip flexion.

Conclusion

Technical changes however small can be very challenging to resolve and require huge investments of time and energy. Often the progression in making technical changes are rarely, if ever, linear in progression, the more likely path is a distinctly bumpy road with many twists and turns along the way. Until the athlete has been able to engrain these new technical coaching instructions into consistent upright maximal sprinting positons in training, are we able to see these then transfer into the actual competition performances. This will always be the true test of whether any scientific intervention has actually worked and impacted with improvements in the overall performance outcome.

Overall the reported data revealed key pieces of invaluable information that highlighted the areas of technique that currently held the greatest opportunity for improvement. Whilst differences exist between right and left limbs, predominantly the need for greater angular velocities in preparation for ground contact (late swing phase) were key areas for development. Promoting a more active action of the free limb prior to ground contact was thought also to make for a closer horizontal foot distance to the centre of mass.

The real value in this type of biomechanical support will typically not be observed after a 'one off' type session, but the ability to repeat the exact process after a consistent block of technical training (maybe after 6-8 weeks) – targeting these specific areas identified from this report.

Whilst not the primary purpose of this case study, it does highlight a very interesting topic area that has created much debate within the realms of applied biomechanics. We may logically assume that balanced (right and left the same) is the way humans should perform the tasks of linear sprinting. Over the years I have observed multiple cases whereby athletes have demonstrated considerable asymmetries across a number of key metrics (as defined in this case study) – differences of over 25% or 0.20m in real terms on step lengths between left and right limbs.

Yet interestingly these athletes have presented with zero injuries, were able to tolerate the demands of daily training and have learnt to manipulate and coordinate their bodies in such a way that maximises their unique biomechanical movement profile to perform at a very high level.

I have also observed on numerous occasions where the total opposite has occurred. Athletes have been able to demonstrate almost perfect symmetry and balance across many of the key metrics. Yet frustratingly have been plagued with injuries, inabilities to train consistently and have suffered for their entire careers and never truly fulfilled their potential.

So the idea or over riding concept that one size fits all should not be the go to mantra when working with elite individuals – especially those who have the ability to sprint really fast!

In this specific case study the Quintic biomechanical software was at the heart and soul of all performance conversations via its ability to objectively quantify the aspects of performance that are most relevant to sprinting fast. We should always strive to create individual movement biomechanical profiles wherever possible, whilst reference and benchmarks values will always provide context. The ability to 'globally' understand the athlete in front of you should always remain the primary focus.

Why guess when you can measure!

Dr P. A. Brice, Performance Biomechanist

- Head of Biomechanics, Nederland’s Olympic Track and Field Team
- Former Lead Biomechanist, UKA London 2012 Olympic Games
- drpaulbrice@gmail.com
- Twitter @drpaulbrice