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New Perspectives in Assessing Pickup Acceleration

Mark E. Pryer[1], John Cronin[1,2], Chris Korfist[1,] Jono Neville[1] and Aaron Uthoff[1]
[1]Auckland University of Technology - Sports Performance Research Institute New Zealand, [2]Athlete Training and Health, Katy, Texas, USA
*Corresponding author: mark.pryer@gmail.com

ABSTRACT

In team sports, linear acceleration is a fundamental skill that defines success across competitive levels. While maximal acceleration capability from a static start has been studied extensively, team sport athletes mostly accelerate from a submaximal speed. This ability to maximally accelerate from a non-static start (i.e., pickup acceleration) is largely unexplored. In this review, pickup acceleration assessment using a motorized horizontal linear position encoder (1080 Sprint) is discussed in detail, various signals explained, and a sample case study of high and low pickup capability described.

Keywords: sprinting, running, team sport, kinetics, kinematics

INTRODUCTION

In team sports (e.g., soccer, rugby, and football codes), sprint acceleration is a fundamental biomotor ability. Attaining the highest change in velocity over time (i.e., acceleration) is central to winning in many sports [1, 2]. Consequently, there is substantial interest in understanding sprinting acceleration performance and its determinants so that they can be monitored and targeted during training.

While sprinting performance is multifaceted, it is often tested from a static start. The outcome information from these types of linear sprints, such as basic distance-time splits or underlying mechanical characteristics (e.g., horizontal force production), can identify athletes with velocity and/or acceleration deficiencies, determine competitive level and quantify professional draft players [3-6]. However, in intermittent-intensity team sports, athletes commonly initiate horizontal acceleration from a non-stationary position. By nature, these entry velocities are submaximal and exist on a continuum spanning low to high velocities (e.g., walk-to-run) in relatively short bursts of effort [7, 8]. The prevalence of non-stationary accelerations varies by sport [9] but typically far outnumber static-start sprints [2, 8]. For example, there is evidence that 65-85% of total sprints performed in Australian Football League games are performed from non-static starts [10]. Additionally, in Premier League matches 'leading' sprints are initiated from walking (<2 m/s), jogging (<4 m/s), or running speeds (<5.5 m/s), involve at least 0.5 seconds of high-speed running (5.5-7 m/s), and occur nearly twice as often as other high-intensity activities [11]. Simply put, it is evident that in-situ, athlete sprint capability is defined rather by the ability to 'pickup' and maximally accelerate in non-static conditions (i.e., pickup acceleration) and across a continuum of velocities.

If pickup acceleration is common within most team sport contexts, the logical question to ask is whether it is a different motor quality to static start acceleration. That is, do athletes who have great static start acceleration also have great pickup acceleration? Work under review from our lab has confirmed that pickup acceleration and static start sprinting seem to be different motor qualities, thus most likely necessitating different assessment and training methods [12]. The aim of this article therefore is to bring a new perspective to the assessment of sprint acceleration by quantifying a suggested pickup acceleration assessment using a linear position encoder, examining various signals, and using the collected data to provide and interpret a sample case study of two athletes of differing pickup acceleration capabilities.

PICKUP ACCELERATION ASSESSMENT USING THE 1080 SPRINT

The equipment used thus far to describe the kinematics and kinetics of pickup acceleration, have been instrumented treadmills [13-33], motion capture [28, 34-38], and in-ground force plates [38, 39] to name a few. While these technologies provide the "gold standard" for studying the mechanical determinants of human motion, the cost of such equipment is prohibitive, and the lack of portability typically limits the use of such technology to the lab setting. One technology that may provide valuable kinematic and kinetic insights into pickup acceleration, while addressing the limitations cited previously, is the 1080 Sprint, which can be used for assessment and training purposes. The 1080 Sprint consists of a horizontal linear encoder embedded into a motorized pulley system that can be attached to an athlete's body via a harness or other attachment points, which creates "intelligent drag" by using mechanical resistance. The 1080 Sprint operates with a sampling rate of 333 Hz. This high sampling rate allows for precise measurement and analysis of the athlete's movements and performance during training sessions. With such a high sampling rate, the device can capture rapid changes in velocity, acceleration, and force, providing detailed feedback to trainers, coaches, and athletes. In terms of measuring pickup acceleration, moving forward we will use the following naming convention (gait transition label): approach step 2 (step -2), approach step 1 (step -1), transition step (step 0), pickup step 1 (step 1), and pickup step 2 (step 2) – see Figure 1.

In the following section, we propose a sample assessment protocol that can be used to quantify the variables of interest for pickup acceleration. The assessment involves each athlete performing at least two sprints per entry velocity while being paced by an LED system to control for the entry's impact on the variables extracted. Each trial should consist of a submaximal entry, following which, athletes are instructed to maximally accelerate and sprint at full effort for the requisite distance. Time and distance series data for force, velocity, acceleration, and power can be quantified for each trial utilizing the 1080 Sprint.

Recommended assessment procedures

The 1080 Sprint device should be set behind the sprint lane at waist height or below. For detailed information on the 1080 Sprint operation and specifications, the user manual is available at https://1080motion.com/products/1080-sprint-how-it-works/ and https://1080motion.com/1080-sprint-brochure/. Once powered on, the user connects to the Bluetooth sensor and logs into the manufacturer's web portal on their tablet where the raw data is saved to a cloud-based server. Before beginning the testing battery, the device's tether must be calibrated to the desired starting point. We suggest the tether be set to a minimum of 2 m distance from the base and attached with the end secured around the athlete's waist via a belt. It is recommended the device be set to the lowest isotonic resistance setting (~1 kg) to minimize the resistance the sprinter experiences. The 1080 Sprint has been commonly used to collect sprint performance-based metrics and has been validated for distance-time (i.e., split times), step time, acceleration, force, V_{max} (maximum velocity), and other sprint determinants (e.g., Theoretical maximal force, velocity and power (F0, V0, and Pmax, respectively) against laser timing gates [40, 41], force plates [42], shoe insole pressure sensors [43], global positioning satellite devices [40, 44], and radar [40, 45] (coefficients of variation range from 0.98 to 7.2%; standard error of measurements range -0.08 to 0.05 s; intraclass correlation coefficients 0.86-0.95, and a fixed bias of 1-8% for step length and step averaged velocity).

It is suggested that athletes are tested on a consistent surface that allows for sufficient traction (i.e. artificial turf, hardwood, rubberized track) under controlled conditions (e.g. indoors) so that environmental and biological variation is minimized. Furthermore, athletes should wear the same footwear and similar training clothes for each session. The sprint lane setup should consist of a

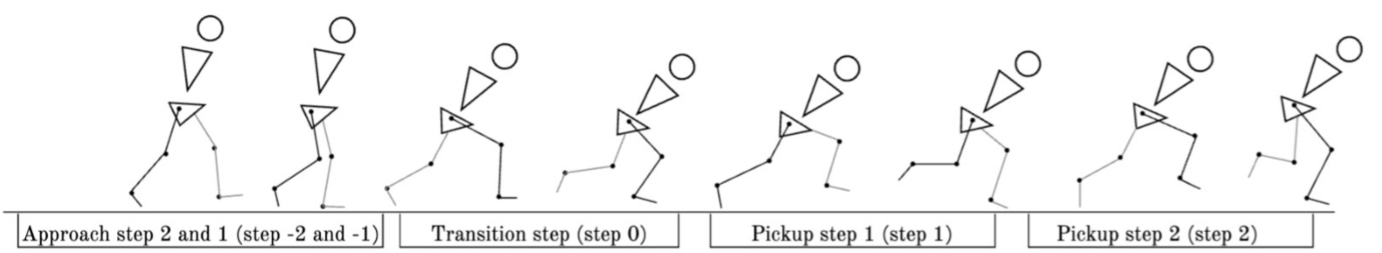


Figure 1. Diagrammatic of a walking entry pickup acceleration showing steps -2 through 2.

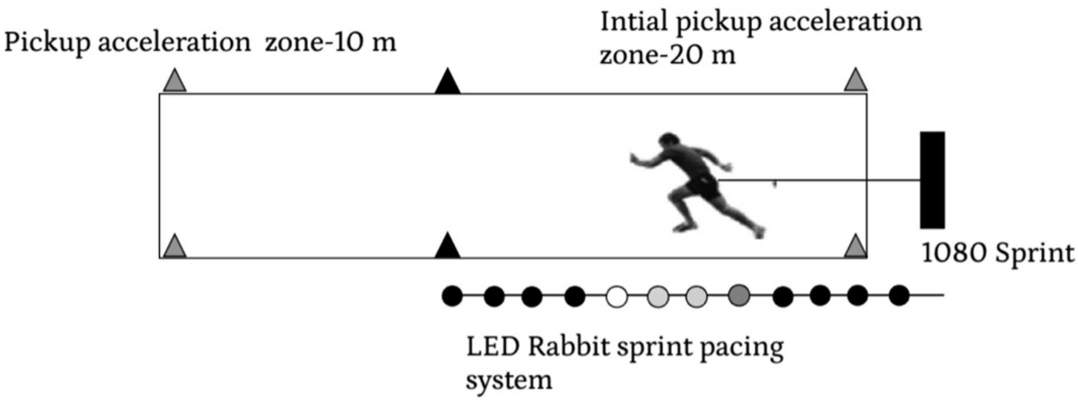


Figure 2. Suggested methodological setup for pickup acceleration testing.

20 m initial zone adjoining a 10 m pickup zone (30 m total) as depicted in Figure 2. Sections should be marked by different colored cones. To cue and verify velocity, it is suggested that athletes use a 25 m LED pacing system (LED Rabbit, BV Systems, LLC, Shawnee, KS), with the LED start point set at least 2 m behind the start (see Figure 2). The LED rabbit provides visual cueing by illuminating LED lights in series to give feedback to the athletes on whether they need to accelerate or slow down. The suggested configuration of the sprint lane necessitates that the LED strip is placed to one side of the 'initial acceleration zone' running up to the end of the 20 m entry (see Figure 2). Further information on the different modes utilized on the LED rabbit can be found at https://www.theledrabbit.com/modes.

The assessment protocol should involve an initial familiarization session to prepare participants for the pacing technology and sprint assessment methods. For each session, athletes should perform a standardized warm-up of full-body stretches and sprint prep movements such as skipping, hopping, and graded-intensity running [46]. Each testing session should have athletes perform a minimum of four pickup accelerations (we used and can generally recommend at least two each at standardized entry velocities of 1.5 m/s and 3.0 m/s in randomized order). For each trial, the athletes can begin in a split stance with their preferred foot forward. Upon being given the 'OK' athletes should accelerate to the pace set by the LED Rabbit system for a minimum of 13 m, followed by a maximal effort acceleration for 10 m to allow for the collection of the relevant pairwise data. 13 m was chosen through pilot testing in our lab as the minimum distance needed to ensure an adequate and stable entry velocity before initiating maximal sprint acceleration. A minimum of 2 minutes of rest should be given between trials to guarantee maximal effort and adequate recovery time. If the athlete does not properly maintain their entry velocity, the trial should be discarded. Further reinforcement of the testing protocols and procedures should be given before the first rep of the first condition. Additional instructions provided could be as simple as "at the end of the paced 20 m initial pickup acceleration zone, maximally accelerate through the end of the last set of cones".

Once the pickup sprints have been completed, the raw data can be viewed as it is stored on the server, by using the same login from the 1080 Sprint application interface on the web portal. Each athlete profile is listed under the clients' list, wherein all the trials are sorted by date and session in chronological order. Once the trial to be examined is selected, you can choose to view the raw velocity-distance (see Figure 3), velocity-time, and other germane measures, to collect velocity, acceleration, force, step time, and step length for the two approach steps (step -2 and -1), the transition step (step 0), and two following pickup steps (step 1 and 2) (see Figure 1). Outputs consisted of horizontal force (F*h*), velocity (*v*), acceleration (*a*), step length (SL), change in horizontal force (ΔF*h*), change in velocity (Δ*v*), change in acceleration (Δ*a*), and change in step length (ΔSL). The variables and change scores of interest were picked due to the overall importance to sprint performance [47, 48].

UNDERSTANDING PICKUP ACCELERATION SIGNALS

All raw data used in the next sections were extracted and processed using a manual selection of the steps residing in the pickup window using the 1080 web portal. This manual selection allowed for the analyzed steps to be determined with accuracy. Broadly, this step sequence was identified on the raw signal between 13 and 20 m. It needs to be noted however, that code can be developed to determine these steps automatically.

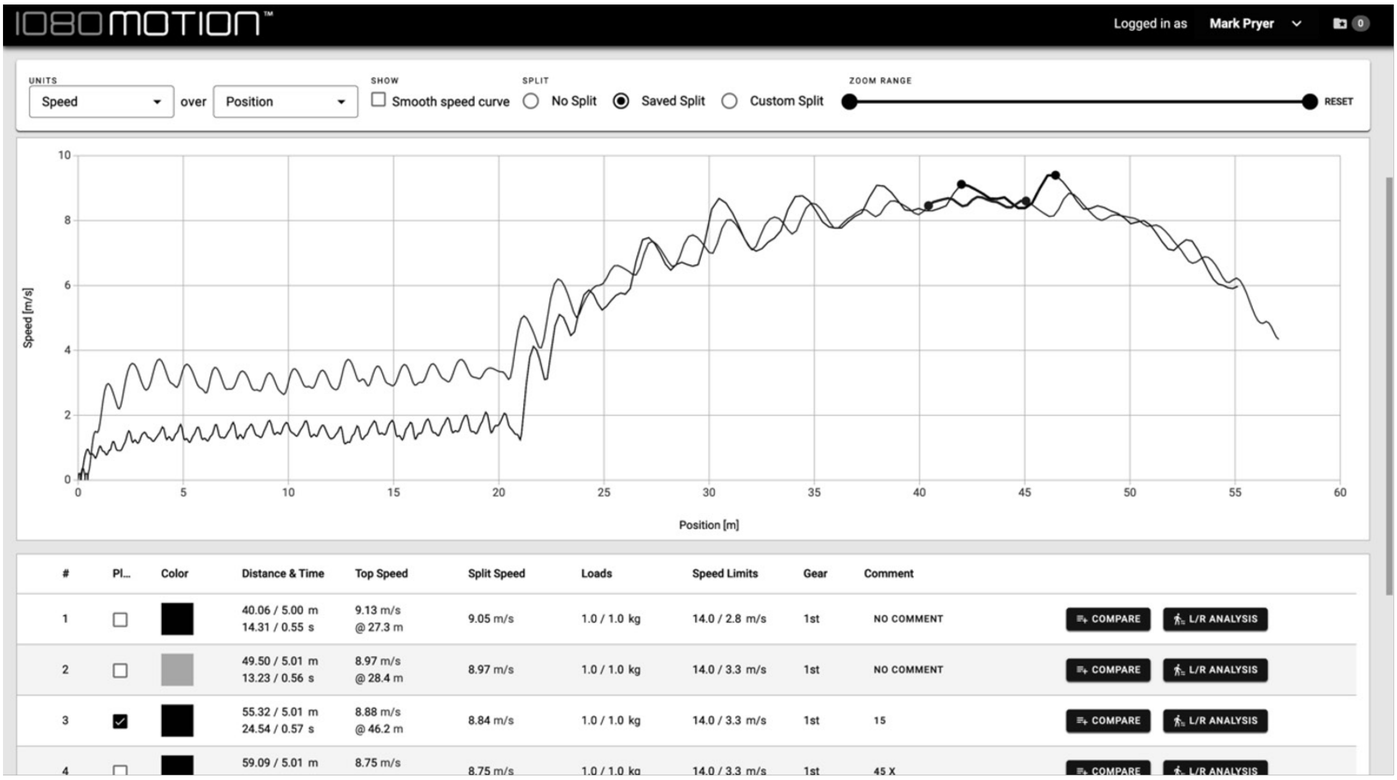


Figure 3. 1080 Motion web portal interface showing walking start (bottom) and jogging (top) entry signals.

The moment of pickup onset can be manually determined by where the athlete exhibits a visible rise in velocity on the raw distance and time series signals. The moment of pickup is confirmed by looking for a corresponding spike in velocity (see the graphs shown in Figures 4 and 5). Multiple authors [42, 43] have determined that the raw 1080 Sprint signal can clarify spatiotemporal characteristics such as step distance and step time with ground contact being inferred via a rapid rise in the velocity signal between foot strikes. Specifically, ground contact appears as valleys, while toe-off occurs slightly after the peak near each recurrent foot strike (see Figure 4b and 5b for a magnified view of the step selection). Pickup trial analysis should start at bottom of the valley of approach step -2.

Change in velocity

Velocity changes (Δ*v*) rapidly over the time course of a maximal effort sprint, with upwards of 74.5 ± 2.4% of $_{Vmax}$ hit by 4.5 m from the start and 88.9 ± 1.8% at 10 m [49]. Using the velocity-time waveform (see Figure 4a and 4b), Δ*v* was extracted by calculating the mean step velocity for each step (initial velocity at ground contact seen at the signal valley, and the final velocity of the located at toe off located at the signal peak) and subtracting the means from each step (e.g., Δ*v* between the transition step and pickup step 1 is a 0.52 m/s increase: Δv=(v8-v6)-(v6-v4); i.e., 1.23 m/s – 0.71 m/s = 0.52 m/s increase). The v1-v9 odd number points signify ground contact. Finally, points t1-t6 denote the timestamps for each step and are used to calculate acceleration measures. The points signified by even numbers v2-v10 were chosen for analysis as they represent toe-off, which is where peak velocity occurs due to propulsive forces being applied against the ground [42, 43, 50]. In the instance of a double peak on the time- or distance-series data, a closer analysis should be performed to determine the appropriate locations of the relevant metrics.

Change in acceleration

Acceleration capacity is paramount to team sport athletes and can often discriminate between higher and lower performance [5], and therefore is of principle interest to the authors i.e. pickup acceleration calculated as an average acceleration between two points. Using the raw velocity-time signal once the pickup window has been determined (see Figure 4a), the change in acceleration (Δ*a*) can be calculated by figuring the change in velocity, similar to above and dividing by the change in time (t1-t6 in Figure 4b) (i.e., *a* =Δ*v*/Δ*t*; e.g., 1.46 m/s - 1.13 m/s / 0.33 s = 0.33 m/s / 0.33 s =1.00 m/s^2 increase in acceleration for approach step 2 to approach step 1 in Figure 4b). NB:The user needs to be cognizant that as the athlete sprints further from the 1080 base, the frequency of the tether oscillation increases which can be reflected in the acceleration signal as a double peak. This is not that noticeable in the distance-time signal, however, as this signal is differentiated to quantify velocity and then velocity to quantify acceleration, any aberration in signal quality is magnified. Our work arounds on this have been either to calculate the acceleration values manually or filter the acceleration signal with a 0.5 Hz low pass Butterworth filter.

Change in step length

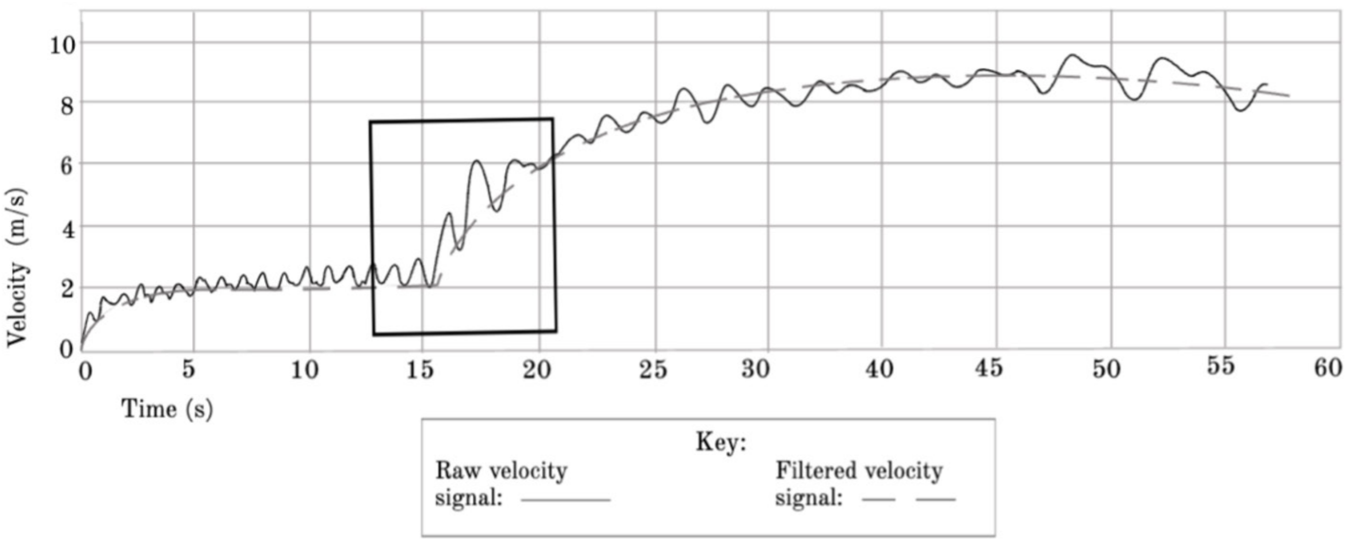
Step length has been determined to correlate with higher sprint velocities and faster athletes [51]. Step length was chosen as a measure because of work by authors in the gait transition space that have shown step length changes between the approach step, transition, and pickup steps, often changing rapidly from step to step [28, 52]. Monitoring these step distances helps provide insight into one of two determinants of velocity i.e. step length x step frequency. Step length is calculated as the distance between the two consecutive steps at initial contact. This point is taken from the velocity-distance output (see Figure 5b), specifically from the absolute bottom of the valley lying between successive foot strikes (e.g., SL between the transition step and pickup step 1 is represented as distance of V5-distance of V4 = SL (m); 18.5 m-16.5 m = 2.0 m as shown in Figure 5b.

Change in horizontal force

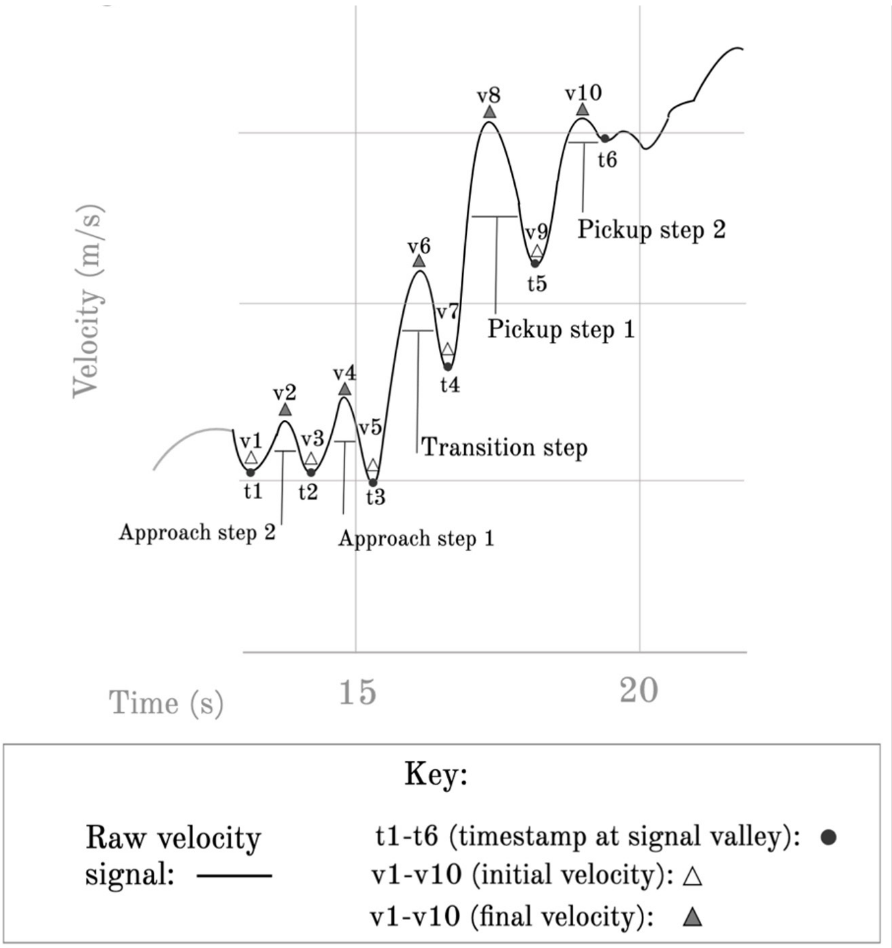
Horizontal force production is highly correlated with sprint performance in static start sprinting [53], however, despite the association in pickup acceleration being theoretically similar, the magnitude of the association has yet to be determined. Nonetheless, horizontal force will no doubt influence the kinematic changes listed earlier and therefore is of interest in the analysis of pickup acceleration. Force measurements for approach step 2 through pickup step 2 were figured from the acceleration measures calculated previously (see Figure 4b). To calculate force, each acceleration value attained previously (see Δv section) is multiplied by the mass of the athlete in kg. To normalize the raw N value to a relative value for each athlete, divide by the body mass of the athlete to get N/kg. Between step values are figured by subtracting the values of the subsequent step from the previous step. For example, the ΔFh between the transition step and pickup step 1 is determined to be -0.26 N/kg decrease in horizontal force (89 kg x 5.09 m/s^2=453.01 N/89 kg= 5.09 N/kg; 89 kg x – 6.83 m/s^2 = 607.87 N/ 89/kg =6.83 N/kg; 5.09 N/kg -6.83 N/kg=-0.26 N/kg). Large and sudden variations in acceleration/force production will be responsible for the changes in velocity, and acceleration, ultimately leading to superior pickup performance.

Practical example

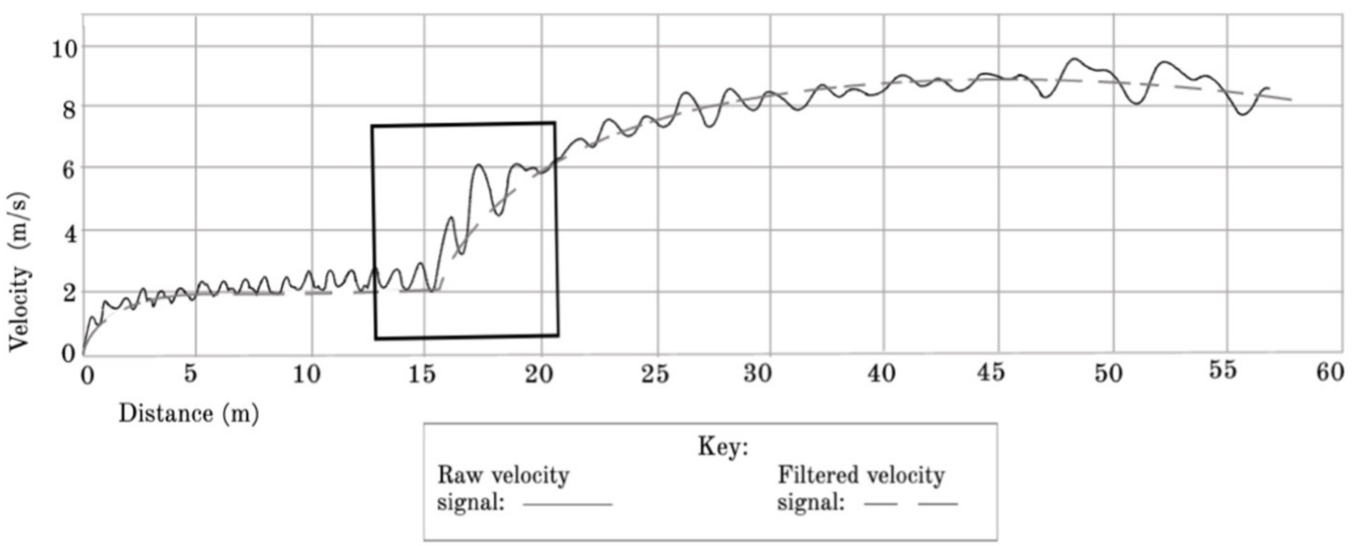
In the following section, an example is given where the data for two participants of varying pickup acceleration ability were analyzed for both a 1.5 and 3.0 m/s entry. In general athlete 1 (Ath1) reached higher peak velocities (~20% higher at the 1.5 m/s entry and ~28% higher for the 3.0 m/s entry) than athlete 2 (Ath2), indicating better pickup acceleration capacity overall. Anthropometrics and sport for each athlete were as follows: Ath1 (American football), stature, 1.85 m, body mass 89 kg; Ath2 (400 m track and field sprinter), stature:1.91 m, body mass 84 kg. Ethical approval for the study was granted by the Auckland University of



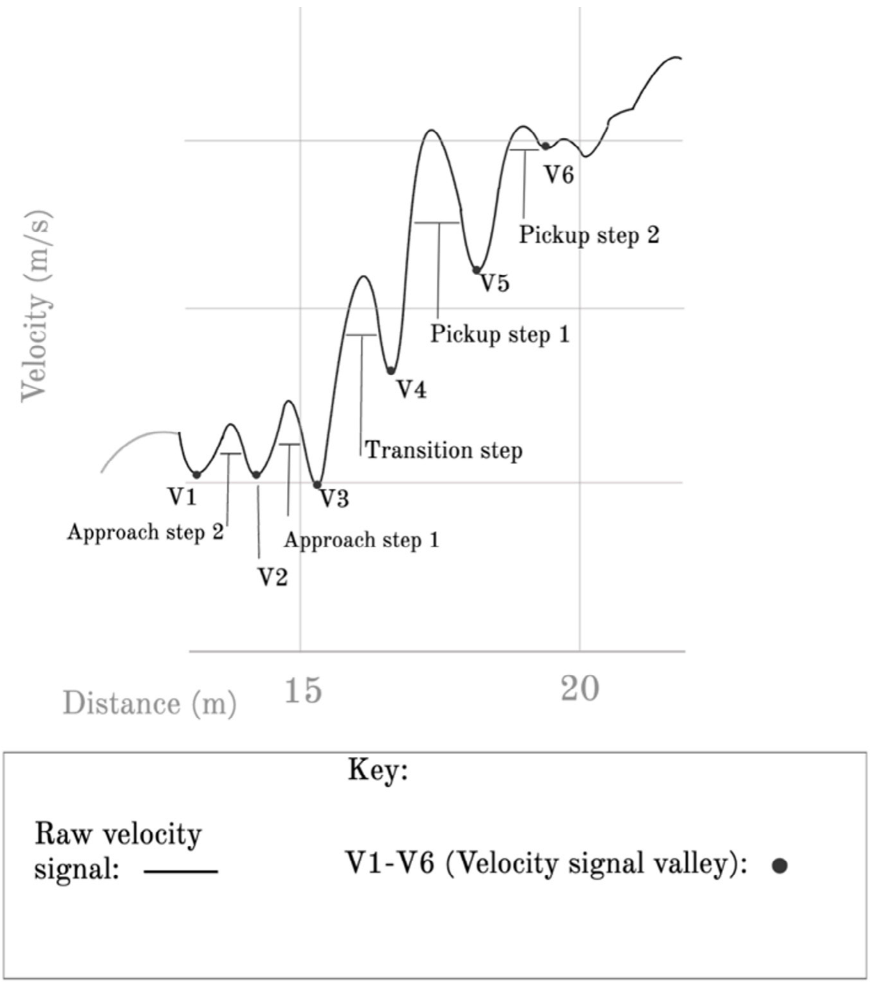
Figures 4a. Raw velocity-distance signal for a walking entry with demarcated pickup window.



Figures 4b. magnified view of the pickup window with velocity and time markers showing metric selection points.



Figures 5a. Raw velocity-time signal for a walking entry with demarcated pickup window.



Figures 5b. Magnified view of the pickup window with velocity and distance markers showing metric selection point.

Technology Ethics Committee (Approval Number 21/437).

1.5 m/s entry

Approach step 2 to approach step 1

When measuring pickup acceleration, it is best to look through the lens of how horizontal force production impacts other measures, and subsequently the rate of change (Δ). The raw values for this phase can be observed in Table 1. For the first measured step sequence (approach step 2 to approach step 1), the impact of ΔF*h* on the stability of the entry velocity before initiating a maximal acceleration is detailed in Table 2. As can be observed the ΔF*h* is minimal (≤0.31N/kg) in both athletes and therefore the changes in Δ*v* < 0.11 m/s, Δa < 0.31 m/s^2, and ΔSL <0.40 m, are relatively small signifying a consistent entry velocity.

Approach step 1 to the transition step

The next step sequence analyzed was the approach step 1 to the transition step (see Figure 1 for a step diagrammatic). In this phase, both athletes had their largest step to step ΔF*h*, however Ath1's ΔF*h* was ~23% greater than Ath2. This difference in ΔF*h* led to greater Δ*v* (~35% faster), larger Δ*a* (~23% increase), and a greater ΔSL (~124% longer) as compared to Ath2. On the transition step, Ath1 produced ~22% greater F*h* and *a*, ~9% faster velocity, and ~38% longer SL than Ath2. Indicating that while both athletes initiated their acceleration via a burst in performance, Ath1 was able to apply greater mass-specific horizontal forces, which led to a more efficient transition step.

Transition step to pickup step 1

In pickup step 1, Ath1 reached their greatest F*h*, where they increased F*h* production by ~23%, while Ath2 decreased F*h* by ~29%, resulting in Ath1 expressing ~54% more relative force than Ath2 in the pickup step 1. With this increases in F*h* Ath1 is achieving ~15% greater velocity than Ath2 during pickup step 1. The flow-on effects Ath1's increased force production and subsequent velocity changes in this phase are evident in their ~22% increased Δ*a* and a ~16% decrease in ΔSL. Alternatively, Δ*a* and

Table 1. Pickup acceleration raw data step analysis.

Step examined	Athlete 1 1.5 m/s entry (fast pickup)	Athlete 2 1.5 m/s entry (slow pickup)	Athlete 1 3.0 m/s entry (fast pickup)	Athlete 2 3.0 m/s entry (slow pickup)
Peak velocity over entire trial (m/s)	8.88	7.11	9.90	7.19
Relative horizontal force (F*h*) (N/kg)				
Approach step 2	0.13	0.32	0.15	-0.48
Approach step 1	0.44	0.42	0.19	0.73
Transition step	5.11	4.00	3.86	2.15
Pickup step 1	6.26	2.86	3.00	1.89
Pickup step 2	2.65	3.74	1.93	1.83
Step velocity (*v*) (m/s)				
Approach step 2	1.63	1.65	3.33	3.04
Approach step 1	1.71	1.76	3.43	3.03
Transition step	2.51	2.28	4.45	3.61
Pickup step 1	4.46	3.80	5.82	4.61
Pickup step 2	5.50	4.73	7.37	5.51
Acceleration (*a*) (m/s^2)				
Approach step 2	0.13	0.32	0.15	-0.48
Approach step 1	0.44	0.42	0.19	0.73
Transition step	5.11	4.00	3.86	2.15
Pickup step 1	6.26	2.86	3.00	1.89
Pickup step 2	2.65	3.74	1.93	1.83
Relative step length (SL) (m)				
Approach step 2	0.64	1.00	1.30	1.16
Approach step 1	1.03	1.02	1.31	1.15
Transition step	1.48	0.91	1.71	1.47
Pickup step 1	1.24	1.55	1.06	1.74
Pickup step 2	1.36	1.46	1.90	2.10

Note: m= meters; m/s = meters per second; m/s^2= meters per second squared; N= Newton

Table 2. Pickup acceleration change scores across steps

Step examined	Athlete 1 1.5 m/s entry (fast pickup)	Athlete 2 1.5 m/s entry (slow pickup)	Athlete 1 3.0 m/s entry (fast pickup)	Athlete 2 3.0 m/s entry (slow pickup)
Peak velocity over entire trial (m/s)	8.88	7.11	9.90	7.19
Change in relative horizontal force (ΔF*h*) (N/kg)				
Approach 2 to approach 1	0.31	0.10	0.04	1.21
Approach 1 to transition step	4.67	3.58	3.67	1.42
Transition to pickup step 1	1.15	-1.14	-0.86	-0.26
Pickup step 1 to pickup step 2	-3.61	0.88	-1.07	-0.06
Change in velocity (Δ*v*) (m/s)				
Approach 2 to approach 1	0.08	0.11	0.10	-0.01
Approach 1 to transition step	0.80	0.52	1.02	0.58
Transition to pickup step 1	1.95	1.52	1.37	1.00
Pickup step 1 to pickup step 2	1.04	0.93	1.55	0.90

Step examined	Athlete 1 1.5 m/s entry (fast pickup)	Athlete 2 1.5 m/s entry (slow pickup)	Athlete 1 3.0 m/s entry (fast pickup)	Athlete 2 3.0 m/s entry (slow pickup)
Change in acceleration (Δ*a*) (m/s²)				
Approach 2 to approach 1	0.31	0.10	0.04	1.21
Approach 1 to transition step	4.67	3.58	3.67	1.42
Transition to pickup step 1	1.15	-1.14	-0.86	-0.26
Pickup step 1 to pickup step 2	-3.61	0.88	-1.07	-0.06
Change in relative step length (ΔSL) (m)				
Approach 2 to approach 1	0.39	0.02	0.01	-0.01
Approach 1 to transition step	0.45	-0.11	0.40	0.32
Transition to pickup step 1	-0.24	0.64	-0.65	0.27
Pickup step 1 to pickup step 2	0.12	-0.09	0.84	0.36

Note: m= meters; m/s = meters per second; m/s²= meters per second squared; N= Newton

ΔSL for Ath2 were ~-29% and ~70%, respectively. When looking at the step-to-step changes, it seems that Ath1 was better able to optimize force expression (54% higher F*h* for Ath1 on pickup step 1) with a small decrease (-0.24 m) in SL allowing a continuous positive Δ*a* to be noted, whereas the magnitude of Ath2's ΔF*h* and Δ*a* were lower possibly due to a drastic increase in SL by ~70% (e.g., overstriding).

Pickup step 1 to pickup step 2

Both athletes reached their fastest velocity in pickup step 2, with Ath1 achieving ~14% greater running velocity than Ath2 in this final phase. Ath1 reduced F*h* and a by ~58% (-3.61 N/kg, -3.61 m/s²), whereas Ath2 increased F*h* and a by 24%, (0.88 N/kg, 0.88 m/s²). Athlete 1 decreased SL by 10%, whereas athlete 2 decreased by ~6%. The decrease in *a* experienced by Ath1 compared to the increase observed by Ath2 may be due to Ath1 producing an increase SL (0.12 m), compared to a decrease of (0.09 m) for Ath2. Despite Ath1 reducing F*h*, a, and SL in the final pickup step, their superior velocity was likely due to their relatively greater cumulative F*h* and a from the transition step to pickup step 2 compared to Ath2 (14.02 N/kg and 14.02ms² vs 10.06 N/kg and 10.06 ms², respectively).

3.0 m/s entry

Approach 2 to Approach step 1

The 3.0 m/s entry velocity results are similar to the 1.5 m/s entry velocity (see Table 1 for raw values and Table 2 for change scores). First, though ΔF*h* from approach step 1 to approach step 2 is slightly higher than the slower entry due to the doubled entry velocity, it's still ≤1.21 N/kg for both athletes. Once again this shows that the entry velocity was relatively consistent, the minimal ΔF*h* resulting in a small Δ*v* (≤ 0.16 m/s), Δ*a* (≤ 1.21 m/s²), and ΔSL (≤0.01 m).

Approach step 1 to the transition step

During this step-to-step phase, the greatest ΔFh and Δ*a* were observed for both athletes. Despite this, Ath1 produced ~61% more ΔF*h*, and a SL that was 12% longer (3.67 vs 1.42 N/kg and 1.31 vs 1.15m, respectively), which gave rise to a greater Δ*v* (~ 43%), and Δ*a* (61%) as compared to Ath2. This lead to the peak velocity for Ath1 on the transition step being ~19% faster than Ath2. Once again, it appears as though Ath1 was able to achieve a greater burst when transitioning into the acceleration.

Transition to pickup step 1

In this sequence both athletes showed a slight decrease in F*h* and *a*, however the magnitude of change for Ath2 was less than Ath1 (-12.09% vs -22.28%, respectively). For Ath1 a small increase in *v* (1.37 m/s) was noted alongside a decrease in SL (-0.65 m), in spite of reductions to both F*h* and *a* (-0.86 N/kg, -0.86m/s²). Ath2 saw relatively less Δ*v* (1.00 m/s) likely resulting from an ~18% increase in SL, despite displaying smaller ΔF*h* and Δ*a* (-0.26 N/kg, -0.26 m/s²). With these differences between the two athletes, Ath1 reached a ~21% higher velocity than Ath2 by the end of this sequence (5.82 vs 4.61 m/s, respectively). Strategically, it seems that Ath1 was able to achieve higher velocities in this step sequence by lengthening their stride on the transition step, followed by shortening the first pickup step to reposition the lower leg in preparation for the next step length increase. This allowed for self-organization on the transition step towards an optimal kinematic pattern while utilizing the F*h* from the transition step as a propulsive mechanism.

Pickup step 1 to pickup step 2

As would be expected, both athletes achieved their highest running velocity in pickup step 2, with Ath1 reaching ~25% faster speeds than Ath2 (7.37 vs 5.51 m/s, respectively). In pickup step 2, both athletes experienced a drop in F*h* and *a*, leading to moderate step-to-step changes in velocity and step length. Ath1 decreased F*h* by 1.07 N/kg (~36% lower than pickup step 1) whereas Ath2 decreased their F*h* by 0.06 N/kg (~3% lower). In lieu of the decrease in Ath1's F*h* and a output, they increased *v* by ~27% and SL by ~79% compared to the previous step. Ath2's Δ*v* and ΔSL was ~16 and 17% respectively, and Δ*a* was ~-3%. Although Ath1 had a larger drop in a, their raw F*h* in the pickup step 2 was greater by 5%, and only lower than Ath2's highest peak F*h* obtained in the transition step by 10% (1.93 vs 2.15). Like in the 1.5 m/s entry, Ath1 displayed superior acceleration ability primarily via applying a larger burst in horizontal force on the transition step which culminated into a greater aggregate acceleration and less of an overextended step length than Ath2 (8.79 vs 5.87 N/kg and 4.67 vs 5.31 m, respectively).

In conclusion, whether the superior pick-up acceleration of Ath1 is proportional to the physical outputs (greater and faster horizontal force expression), technical factors (body position and force orientation), anthropometrics (taller and heavier - more muscle mass), being naturally faster or a combination of all four is difficult to determine. The information provided by the kinematic and kinetic analysis, nonetheless, provides some insight into how to measure and monitor pickup acceleration. For example, it is clear that the burst transition over two steps used by Ath1 appears to be superior to the progressed transition strategy used by Ath2.

SUMMARY AND PRACTICAL APPLICATIONS

The aim of this article was to provide guidance on assessing pickup acceleration using a linear position encoder, explore various signals, and use real-life data to provide and interpret a sample case study. Pickup acceleration differs from static start acceleration in terms of the initial starting velocity and individual step architecture, and therefore needs to be characterized differently to static start acceleration. In this article three distinct phases, the entry or approach steps, the transition step, and the pickup steps, were highlighted as the steps that practitioners should focus on to understand the pickup ability of their athletes. The use of technology such as the 1080 Sprint or Dynaspeed Muscle Lab systems, seem ideally suited to provide the data needed, given their portability and utility in the field. In the case study presented, Athlete 1 used a two-step strategy focused on the transition and first pickup step to attain higher levels of performance compared to the graduated acceleration strategy focused on the transition step to pickup step 2 for Athlete 2. This two-step strategy allowed for greater magnitudes of force, velocity, acceleration and step length to be produced in a burst-type action, compared to a more gradual increase in velocity. Specifically, Athlete 1 was faster due to producing ~23% and ~61% greater changes in force between the approach and transition step for the respective 1.5m/s and 3.0m/s entry velocities, leading to higher acceleration values through the use of optimizing step lengths to support the transition. Using this methodological approach would allow for several outcomes. First this method could be used to create bespoke programming and define inherent weaknesses and inefficiencies in the athlete's sprint-derived skill set, or diagnostic use in a return-to-play setting. Second it could allow for the eventual creation of a normative dataset, from which practitioners could then use to stratify performance levels for talent identification to compliment static start procedures. Future research is needed to further build upon the current pickup acceleration works and elicit more granular information on performance defining kinetics and kinematics.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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ETHICAL APPROVAL

Ethical approval for the study was granted by the Auckland University of Technology Ethics Committee (Approval Number 21/437).

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REFERENCES

1. Faude, O., T. Koch, and T. Meyer, Straight sprinting is the most frequent action in goal situations in professional football. J Sports Sci, 2012. 30(7): p. 625-31.
2. Haugen, T., et al., The role and development of sprinting speed in soccer. Int J Sports Physiol Perform, 2014. 9(3): p. 432-41.
3. Black, W.T., R, The National Football League combine: Do performance measures predict draft status among NFL draftees. Sport Jour 2021.
4. Sierer, S.P.B., C. L.; Mihalik, J. P.; Shields, E. W.; Tomasini, N. T., The National Football League combine: performance differences between drafted and nondrafted players entering the 2004 and 2005 drafts. J Strength Cond Res, 2008. 22(1): p. 6-12.
5. Edwards, T.P., B; Banyard, H. G.; Haff, G.G; Joyce, C, Sprint acceleration force-velocity-power characteristics in drafted vs non-drafted junior Australian football players: preliminary results. Sci and Med in Football, 2020. 5(3): p. 204-207.
6. Devismes, M., et al., Sprint force-velocity profiles in soccer players: impact of sex and playing level. Sports Biomech, 2021. 20(8): p. 947-957.
7. Duthie, G.M., et al., Sprint patterns in rugby union players during competition. JSCR, 2006. 20(1): p. 208-14.
8. Varley, M., Acceleration and fatigue in soccer-thesis, in College of Sport and Exercise Science. 2013, Institute of Sport, Exercise and Active Living (ISEAL), Victoria University, Melbourne, Australia.
9. Gabbett, T.J., Sprinting patterns of National Rugby League competition. JSCR, 2012. 26(1): p. 121-30.
10. Benton, D., An analysis of sprint running patterns in australian rules football: The effect of different starting velocities on the velocity profile, in Sch of Human Move & Sport Sci. 2000, University of Ballarat. p. 150.
11. Di Salvo, V., et al., Analysis of high intensity activity in Premier League soccer. Int J Sports Med, 2009. 30(3): p. 205-12.
12. Pryer, M.E.; Cronin, J; Korfist, C; Neville, J; Uthoff, A, Are static start acceleration and pickup acceleration different motor qualities? (in review). JSCR, 2025.
13. Getchell, N. and J. Whitall, Transitions to and from asymmetrical gait patterns. J Motor Behav, 2004. 36(1): p. 13-27.
14. Giest, T.N. and Y.H. Chang, Biomechanics of the human walk-to-run gait transition in persons with unilateral transtibial amputation. J Biomech, 2016. 49(9): p. 1757-1764.
15. Hreljac, A., Determinants of the gait transition speed during human locomotion: kinetic factors. Gait & Post 1993. 1(4): p. 217-223.
16. Hreljac, A., Preferred and energetically optimal gait transition speeds in human locomotion. Med & Sci in Sport & Ex, 1993. 25(10): p. 1158 – 1162.
17. Hreljac, A.I., R. T.; Escamilla, R. F.; Edwards, W. B.; MacLeod, T., The relationship between joint kinetic factors and the walk-run gait transition speed during human locomotion. J Appl Biomech, 2008. 24(2): p. 149-57.
18. Hreljac, A.A., A; Ferber, R; Mercer, J A., Row, B S., An electromyographical analysis of the role of dorsiflexors on the gait transition during human locomotion. J Appl Biomech, 2001. 17: p. 9.
19. Hreljac, A.I., T; Escamilla, R; Edwards,WB; MacLeod, T, The relationship between joint kinetic factors and the walk–run gait transition speed during human locomotion. J App Biomech, 2008. 24: p. 8.
20. Hreljac, A.I., R.T; Escamilla, R.F.; Edwards, W.B., When does a gait transition occur during human locomotion? J of Sports Sci and Med, 2007. 6(1): p. 7.
21. Li, L., Stability landscapes of walking and running near gait transition speed. J Appl Biomech, 2000. 16(4): p. 428-435.
22. Li, L. and J. Hamill, Characteristics of the vertical ground reaction force component prior to gait transition. Res Q Exerc Sport, 2002. 73(3): p. 229-37.
23. Li, L. and L.L. Ogden, Muscular activity characteristics associated with preparation for gait transition. J of Sport and H Sci, 2012. 1(1): p. 27-35.
24. Nimbarte, A.L., Li, Effect of added weights on the characteristics of vertical ground reaction force during walk-to-run gait transition. Human Move, 2011. 12(1).
25. Pires, N.J., B.S. Lay, and J. Rubenson, Joint-level mechanics of the walk-to-run transition in humans. J Exp Biol, 2014. 217(Pt 19): p. 3519-27.
26. Prilutsky, B.I. and R.J. Gregor, Swing- and support-related muscle actions differentially trigger human walk-run and run-walk transitions. J Exp Biol, 2001. 204(Pt 13): p. 2277-87.
27. Raynor, A.J.Y.C.J.A., B.J; Quek J, Are transitions in human gait determined by mechanical, kinetic or energetic factors? Human Move Sci, 2002. 21(5-6): p. 785-805.
28. Van Caekenberghe, I., et al., Overground vs.

treadmill walk-to-run transition. Gait Post, 2010. 31(4): p. 420-8.
29. Segers, V.L., M.; Aerts, P.; De Clercq, D., Kinematics of the transition between walking and running when gradually changing speed. Gait Post, 2007. 26(3): p. 349-61.
30. Segers, V.A., P.; Lenoir, M.; De Clercq, D., Spatiotemporal characteristics of the walk-to-run and run-to-walk transition when gradually changing speed. Gait Post, 2006. 24(2): p. 247-54.
31. Thorstensson, A. and H. Roberthson, Adaptations to changing speed in human locomotion: speed of transition between walking and running. Acta Physiol Scand, 1987. 131(2): p. 211-4.
32. Turvey, M.T., et al., Can the transitions to and from running and the metabolic cost of running be determined from the kinetic energy of running? J Motor Behav, 1999. 31(3): p. 265-78.
33. Zhang, S.P., J.; Li, L., Non-linear changes of lower extremity kinetics prior to gait transition. J Biomech, 2018. 77: p. 48-54.
34. Diedrich, F.J. and W.H. Warren, Jr., Why change gaits? Dynamics of the walk-run transition. J Exp Psych Hum Percept Perform, 1995. 21(1): p. 183-202.
35. Diedrich, F.J. and W.H. Warren, The dynamics of gait transitions: effects of grade and load. J Motor Behav, 1998. 30(1): p. 60-78.
36. Segers, V.A., P.; Lenoir, M.; De Clercq, D., Dynamics of the body centre of mass during actual acceleration across transition speed. J Exp Biol, 2007. 210(Pt 4): p. 578-85.
37. Segers, V.D.S., K.; Van Caekenberghe, I; .Aerts, P.; De Clercq, D., Biomechanics of spontaneous overground walk-to-run transition. J Exp Biol, 2013. 216(Pt 16): p. 3047-54.
38. Segers, V.V.C., I; De Clercq; D, Aerts, P., Kinematics and dynamics of burst transitions. J Motor Behav, 2014. Vol. 46(Issue 4): p. 10.
39. Segers, V., et al., External forces during actual acceleration across transition speed. J Appl Biomech, 2008. 24(4): p. 340-50.
40. Fornasier-Santos, C., et al., Sprint acceleration mechanical outputs derived from position- or velocity-time data: A multi-system comparison study. Sensors (Basel), 2022. 22(22).
41. Rakovic, E., et al., Validity and reliability of a motorized sprint resistance device. JSCR, 2022. 36(8): p. 2335-2338.
42. Sugisaki, N., et al., Validity of spatiotemporal and ground reaction force estimates during resisted sprinting with a motorized loading device. Scand J Med Sci Sports, 2024. 34(3): p. e14597.
43. Røkke, O., Validation of force-, velocity-, and acceleration-time curves and temporal characteristics as output data from the 1080 Sprint, in Dept of Phys Perf. 2018, Norwegian School of Sports Sciences. p. 63.
44. Komino, P.L.M., Y; Zadro, I; Osgnach, C; Morin, J.B., Sprint acceleration mechanical outputs: direct comparison between GPEXE Pro2 and 1080 Sprint devices. Sport Perf Sci, 2022. 163(v1): p. 1-4.
45. Feser, E.L., K; Clark, K.P; Bezodis, N; Korfist, C; Cronin, J, Comparison of two measurement devices for obtaining horizontal force-velocity profile variables during sprint running. Intl J of Sports Sci & Coach, 2022.
46. Silva, L.M., et al., Effects of warm-up, post-warm-up, and re-warm-up strategies on explosive efforts in team sports: A systematic review. Sports Med, 2018. 48(10): p. 2285-2299.
47. Barr, M.S., J; Newton, R;, Sprinting kinematics of elite rugby players. J of Aus Strength and Cond, 2013. 21: p. 14-20.
48. Morin, J.B., et al., Mechanical determinants of 100-m sprint running performance. Eur J Appl Physiol, 2012. 112(11): p. 3921-30.
49. Clark, K.P., et al., The National Football League combine 40-yd dash: how important is maximum velocity? JSCR, 2019. 33(6): p. 1542-1550.
50. Vellucci, C.L. and S.M. Beaudette, A need for speed: Objectively identifying full-body kinematic and neuromuscular features associated with faster sprint velocities. Front Sports Act Living, 2022. 4: p. 1094163.
51. Lockie, R.G.M., A. J.; Schultz, A. B.; Jeffriess, M. D.; Callaghan, S. J., Influence of sprint acceleration stance kinetics on velocity and step kinematics in field sport athletes. JSCR, 2013. 27(9): p. 2494-503.
52. De Smet, K., et al., Spatiotemporal characteristics of spontaneous overground walk-to-run transition. Gait Post, 2009. 29(1): p. 54-8.
53. Cross, M.R.B., S. R.; Morin, J.B.; Brughelli, M.; Dé, R.; Samozino, P. Mechanical determinants of sprinting acceleration in rugby athletes. in 23rd annual Congress of the European College of Sports Science. 2018. At: Dublin, Ireland.