Article title: Kinematic factors associated with start performance in World-class male sprinters

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ABSTRACT: (243 words)

The aim was to investigate the kinematic factors associated with successful performance in the initial acceleration phase of a sprint in the best male athletes in the World at the 2018 World Indoor Athletics Championships. High speed video (150 Hz) was captured for eight sprinters in the men's 60 m final. Spatio-temporal and joint kinematic variables were calculated from the set position to the end of the first ground contact post-block exit (GC1). Normalised average horizontal external power (NAHEP) defined performance and was the dependent variable for a series of regression analyses. Clear relationships were found between GC1 NAHEP and 10-m time, 60-m time, change in velocity, acceleration and contact time in the first ground contact (r = –0.74, –0.64, 0.96, 0.91 and –0.56, respectively). Stepwise multiple linear regression of joint kinematic variables in the first ground contact revealed that trunk angle at take-off and thigh separation angle at take-off explained nearly 90% of variation in GC1 NAHEP (R^2 = 0.89). The athletes' projection at take-off with a forward leaning trunk and large thigh separation is characteristic therefore of excellent initial acceleration performance and this will be a good visual guide for technical coaching instruction. This was the first study of its kind to adopt such a research design in a World-class sample in a representative environment. Future studies that combine detailed kinematic and kinetic data capture and analysis in such a setting will add further insight to the findings of this investigation.

Keywords: acceleration, athletics, elite, power, running

INTRODUCTION:

The start and initial acceleration phase are of key importance to the short sprints ($\leq$100 m, Mero 1988, Bezodis et al., 2015a), yet the biomechanical factors that distinguish performance in this phase at the very highest level of competition are not known. Given that the aim of the start and initial acceleration phase is to maximise horizontal velocity in the minimum possible time (Bezodis et al., 2019a), normalised average horizontal external power (NAHEP) has been proposed and justified as the criterion for successful performance early in the sprint (Bezodis et al., 2010; 2019a). NAHEP is therefore now widely used to define and distinguish effective acceleration performance in the sprint running biomechanics literature (e.g. Bezodis et al., 2015a; Otsuka et al., 2015; Willwacher et al., 2016; Brazil et al., 2018; Wild et al., 2018; Bezodis et al., 2020; Sado et al., 2020; Sandamas et al., 2020; von Lieres und Wilkau et al., 2020a).

Perhaps because of the restrictions hindering researchers from investigating performance in elite competition, ecologically valid and detailed analyses of the biomechanics of the start and initial acceleration phase in World-class (sub-10 s personal best [PB]) male sprinters in competition are limited in the scientific literature (Bezodis et al., 2019a). Indeed, to the authors' knowledge only two such studies exist (Ciacci et al., 2017; Bezodis et al., 2019b). The first analysed spatio-temporal parameters post-block exit, finding that sprinters with faster PBs had longer contact times and shorter flight times than their slower counterparts (Ciacci et al., 2017). Secondly, Bezodis et al. (2019b) investigated differences in centre of mass (CM) translation between world-class sprinters and high hurdlers, yet did not consider factors that distinguished performance within either group.

On the other hand, studies of elite and sub-elite male athletes, but still below World-class standard (100 m PB approximately between 10 and 11 s), are more prevalent in the literature (for a comprehensive review see Bezodis et al., 2019a), and tend to be based on training or laboratory-based data. Within that broad performance classification, for the first step post block exit, better sprinters touch down and take-off with the CM further down the track, have a longer step length, and also a greater horizontal velocity at take-off (Slawinski et al., 2010a). A theoretical investigation showed that reducing the amount of ankle dorsiflexion early in the first stance phase can increase NAHEP in that ground contact (Bezodis et al., 2015b), yet despite three studies investigating the block phase and first flight (Bezodis et al., 2015a; Ciacci et al., 2017; Bezodis et al., 2019b), there is little other applied evidence in the literature that has shown which joint kinematic parameters play an important role in determining initial sprint acceleration performance post-block exit.

Therefore, there is a significant gap in the peer-reviewed sprinting literature preventing scientists and coaches from forming a complete understanding of the key mechanical factors governing the explosive movement of the body during the first step post-block exit. The most effective way to address this gap, so findings are ecologically valid, would be to derive data from a highly competitive environment including the very best sprinters in the world. Such data will provide an unprecedented insight into the mechanics of maximal human acceleration. Consequently, this study investigated the kinematic factors that were associated with successful performance in the initial acceleration phase of a sprint in a sample of the very best male athletes in the World at the highest possible competition level. Developing an understanding of those key factors will aid coaches and scientists in designing technical training programs to develop and facilitate optimal performance in elite athletes.

METHODS:

Participants

Data were collected as a part of the Birmingham 2018 IAAF World Indoor Championships Biomechanics Research Project (Walker et al., 2019). The use of the data for this study was approved by World Athletics (formerly known as IAAF), who own and control the data, and locally via institutional research ethics approval. The eight finalists of the men's 60 m race (25 ± 3 years, PB prior to the race: 6.51 ± 0.10 s), who included the world record holder, were recorded on the evening of 3rd March 2018 at Arena Birmingham, UK. The race was the fastest of all men's 60 m races in the history of World Championships (World Athletics, 2020a) with three sprinters achieving sub-6.50 s times and the winner setting a new Championship Record (6.37 s).

Data Collection and Processing

All data collection and initial processing was carried out as previously described in Bezodis et al. (2019b, pp3-4 for more detail). Briefly, four Sony PXW-FS7 cameras operating at 150 Hz captured a three-dimensional volume covering the starting blocks to 5 m beyond the start line. Videos were processed in SIMI Motion (version 9.2.2, Simi Reality Motion Systems GmbH, Germany). To address the aim of this study, the analysis was focused on the following phases: a; block phase (from the onset of movement to the final frame of foot contact with the starting block), b; the subsequent flight phase (from the first frame after block exit to the final frame before ground contact), and c; the first ground contact post-block exit (GC1; from the first to the final visible frame of foot contact with the track). The onset of movement was defined via visual inspection of the first visible movement of the athlete in lane 8 using an additional Sony PXW-FS5 camera at close proximity, operating at 200 Hz. This camera was synchronised to the other four cameras, and the official reaction times were used to calculate the onset of movement in the other athletes from the athlete in lane 8.

Shoulder, hip, knee, ankle and metatarsophalangeal joints were digitised continuously on the side of the rear leg in the blocks from the onset of movement in the block to the second touchdown. Additionally, a 17-point whole-body model was digitised at onset of movement, block clearance, and each subsequent take-off and touchdown event. Co-ordinates were reconstructed using the Direct Linear Transformation algorithm (Abdel-Aziz et al., 2015). Three dimensional co-ordinates were projected onto a two-dimensional sagittal plane for analysis. Segmental and whole body centres of mass were calculated according to de Leva (1996), and continuous joint centre coordinates were filtered with a recursive second-order, low-pass Butterworth filter (zero-phase lag), with cut-off frequencies calculated by residual analysis (Winter, 2009; mean value for all joint centres 13.4 Hz, range 10.0-15.5 Hz).

The dependent variable was GC1 NAHEP, calculated as described by Bezodis et al. (2010). Participants' body mass could not be directly measured because of the access granted for data collection. However, despite NAHEP normalising for body mass (based on the approach of Hof, 1996), mass itself is not required to perform the calculation (see appendix). For the block phase and GC1, the times between events (e.g. block time defined from first visible movement to block exit) were combined with CM horizontal displacements and used to calculate CM velocities, acceleration and NAHEP. Touchdown and take-off distances were calculated as the coordinate of the metatarsophalangeal joint of the contact foot minus the coordinate of the CM in the antero-posterior direction. Segment angles were defined with anticlockwise as positive relative to the global forward horizontal, and joint angles with extension as positive (see Figure 1). Joint angular velocities were calculated as the differential of joint angle with respect to time.

Vertical and horizontal foot touchdown velocities were calculated as the differential of the respective segment CM displacement with respect to time. Thigh separation angle was defined as the difference between the segment angles of the thighs of the swing and ground contact legs.

*** Insert Figure 1 near here ***

Statistical Analysis

To assess the relationships between specific biomechanical data and first stance performance (GC1 NAHEP), Pearson correlation coefficients and 90% confidence intervals (using the Fisher z' method; Fisher, 1921) were calculated (Batterham & Hopkins, 2006). If the confidence intervals overlapped, i.e. completely crossed, the trivial threshold (–0.1 to 0.1) based on the smallest practically important correlation, the relationship was deemed unclear. For correlations deemed clear, the magnitude of the relationship was interpreted using the convention proposed by Hopkins (2016): moderate (0.30-0.49), large (0.50-0.69), very large (0.70-0.89) and practically perfect (0.90-1.00). To further investigate the segment and joint kinematic determinants of first stance performance, a stepwise multiple regression was performed (IBM SPSS Statistics, v. 22.0) using 0.1 as the criterion value of entry of a variable in the regression model, with the alpha level set at 0.05. Normality of the residuals was confirmed (Shapiro-Wilk = 0.93 for both standardised and unstandardised residuals), and there was minimal autocorrelation (Durbin-Watson = 2.103).

RESULTS:

Group mean ± standard deviation (SD) block, 10-m and 60-m times were 0.34 ± 0.02 s, 1.91 ± 0.03 s and 6.51 ± 0.10 s, respectively (Table 1). Clear relationships were found between first stance performance and 10-m and 60-m times (r =–0.74, very large and –0.64, large, respectively, Figure 2). After exiting the blocks with a horizontal velocity of 4.28 ± 0.35 $m \cdot s^{-1}$, sprinters increased their running velocity on average by 1.57 ± 0.17 $m \cdot s^{-1}$ during first stance, in a ground contact time of 0.175 ± 0.014 s. For data collected during GC1, change in CM velocity (r = 0.96, nearly perfect), CM acceleration (r = 0.91, nearly perfect) and contact time (r = –0.56, large) all possessed clear relationships with first stance performance. NAHEP during first stance (1.624 ± 0.269) was greater than that demonstrated in the block phase (0.953 ± 0.143), with no clear relationship observed between the two (r = 0.12, Table 1, Figure 2).

*** Insert Table 1 near here ***

*** Insert Figure 2 near here ***

Of all kinematic variables quantified during first stance (Table 2), only thigh separation (r = 0.62, large) and trunk (r = –0.59, large) angles at TO possessed a clear linear relationship with first stance performance (Figure 3). Individual scatter plots for all bivariate correlations deemed clear are presented in Figure 4. Following stepwise multiple regression analysis for kinematic data, two variables explained nearly 90% of the variance in first stance performance (R^2 = 0.89): thigh separation angle at take-off and trunk angle at take-off (Table 3).

*** Insert Table 2 near here ***

*** Insert Figure 3 near here ***

*** Insert Figure 4 near here ***

*** Insert Table 3 near here ***

DISCUSSION:

The aim of this study was to investigate the kinematic factors associated with successful performance in the initial acceleration phase of a sprint in the very best male athletes in the World. Based on the simple bivariate correlation analysis undertaken, the better performers in this study, defined by the power generated during the first ground contact post-block exit (GC1 NAHEP), were quicker to both 10 and 60 m (Table 1, Figure 2). Additionally, those better performers increased their CM velocity more in a shorter contact time in GC1, thereby achieving a greater amount of CM acceleration during that ground contact (Table 1, Figure 2). This study then addressed the lack of previously published evidence regarding the influence of joint and segmental kinematics on elite initial acceleration sprint performance. Based on bivariate correlation analyses of the first stance (Table 2, Figure 3), trunk angle at take-off and thigh separation angle at take-off were found to be associated with GC1 NAHEP, and together they explained almost 90% of the variance in first stance performance (Table 3).

The scope for comparison with equivalent previous studies is limited because of the highly novel nature of this study. Ciacci et al. (2017) reported spatio-temporal variables for four World-class male sprinters with a mean 100 m PB of 10.03 s from a Diamond League event. Comparisons reveal shorter block times (0.342 vs. 0.356 s) and greater block clearance velocities (4.28 vs. 4.16 $m \cdot s^{-1}$) in the current study. Direct comparison between the two studies is difficult, since exact differences in athlete abilities and performance on the day relative to that are not possible to identify, and there could be further differences due to potential variations in data collection and processing. Other studies have reported values of block NAHEP of 0.53 ± 0.08 (Bezodis et al., 2015a), 0.539 ± 0.053 (Otsuka et al., 2015) and approximately 0.2-0.5 (Willwacher et al., 2016). These are clearly lower than the value of 0.953 ± 0.143 reported here. There are two reasons for this. Firstly, the range of abilities of athletes studied were much greater in the previous literature than here, despite the inclusion of some World-class athletes across the samples (100 m PB range; 9.98-11.6 s (Bezodis et al., 2015a), 10.21-11.65 s (Otsuka et al., 2015), 9.58-14.00 s (Willwacher et al., 2016)). Secondly, Willwacher et al. (2016) normalised their data to height rather than leg length, due to the inclusion of a comparison with lower-limb amputee sprinters in their study. This has the effect of increasing the denominator in the NAHEP calculation, and therefore reducing the calculated value.

Bezodis et al. (2015a) reported a mean GC1 touchdown distance of –0.20 ± 0.07 m in 16 male sprinters with a range of 100 m PBs from 9.98 to 11.6 s. That investigation showed a mean foot position farther behind the CM than in the current study (-0.12 ± 0.06 m, Table 2), but in athletes of a much wider range of abilities than this study. Using a simulation modelling approach for an individual athlete with a 100 m PB of 10.28 s, Bezodis et al. (2015b) showed that the optimum touchdown distance in GC1 for the generation of NAHEP was approximately –0.09 m. That result is based on the specific individual characteristics of the athlete in question (such as leg length and stature) but suggests that there might be a similarly located optimum value for all sprinters. Bezodis et al. (2015b) used their simulation model to further show the importance of reducing ankle dorsiflexion angle in early GC1 stance to the generation of NAHEP, supporting the previous findings of Charalambous et al. (2012). The results of the current study showed a moderate but unclear contribution of dorsiflexion range of motion to GC1 NAHEP (Table 2). Further investigations in elite athletes that explore the role of the dorsiflexors in developing sprint acceleration in more detail are required.

Those athletes who were the most effective starters in this study adopted a body position at take-off from the first contact that was characterised by a large forward lean in the trunk and a large amount of separation between the two thigh segments. It is highly likely that the body position at take-off of the most successful starters described here comes about as an effect of the successful ground contact that has preceded it, rather than being the cause of the high standard of performance in itself. Nevertheless, from a technical coaching perspective, a body position at GC1 take-off characterised by large forward trunk lean, and a large amount of thigh separation is likely to be a good visual marker of highly effective initial acceleration performance.

It is well established that effective maximal sprint acceleration is dependent upon the athlete adopting a primarily horizontal orientation of the resultant external force vector (Morin et al., 2011; Rabita et al., 2015). A study of 41 non-sprint trained physical education students (Kugler and Janshen, 2010) showed that the orientation of the external force vector at maximum force was highly correlated with body lean ($r = 0.93$), and therefore that greater forward lean of the body resulted in greater propulsive forces. In the block start, Otsuka et al. (2014) showed that there was no difference in the magnitude of resultant force between well-trained (mean PB = 10.87 s) and trained sprinters (mean PB = 11.31 s), but that the anteroposterior force component was greater and the angle of the resultant force more forward, in the well-trained sprinters. Further studies of the kinematics of the acceleration phase in well-trained sprinters have confirmed that the athletes' trunk angle raises throughout the sprint (Nagahara et al., 2014; von Lieres und Wilkau et al., 2020b) at the same time as the resultant force vector become more vertical (Morin et al., 2011). However, to the authors' knowledge there are currently no studies that comprehensively investigate the relationship between joint or segment kinematics and external kinetics throughout the initial acceleration phase in well-trained or elite sprinters. Such studies have the potential to be particularly revealing regarding the underlying mechanisms that dictate initial sprint acceleration performance in this population.

There is limited evidence available in the literature to support the finding here of the importance of thigh separation angle at take-off to sprint acceleration performance. However, there are two possible mechanisms that might be responsible. Firstly, the individual segments of the body each contribute to the overall kinetic energy of the athlete's body. Slawinski et al. (2010b) investigated segmental contributions during the block phase only. They showed that the thigh segments combined created more maximal kinetic energy than any other segments (thighs – 156.1 J; thorax 142.5 J). In creating a large separation of the thighs at take-off in this study it is possible that the better starters are maximising the amount of kinetic energy created. Secondly, thigh angular velocity is thought to be an important component of sprint running. Clark et al. (2020) investigated maximum velocity trials and found strong positive relationships between thigh angular velocity and both lower limb velocity at touchdown and running speed. This suggests that the large thigh separation angle at take-off seen in this study might be putting the athletes in an effective position to create large thigh angular velocities in the swing phase immediately prior to the subsequent touchdown, to optimise the mechanics of the foot-ground interaction during that ground contact.

Overall, spatio-temporal data suggest that the change in CM velocity during GC1 was more important to the development of GC1 NAHEP than was the corresponding ground contact time ($r = 0.96$, nearly perfect, and –0.56, large, respectively, Table 1). This is supported by data from the block phase in 103 male and 51 female trained sprinters, presented by Willwacher et al. (2016), which showed r values across all 154 participants of 0.91 and 0.52 respectively for change in horizontal velocity and block time in relation to NAHEP. The importance of horizontal impulse to sprint acceleration performance is well established (Hunter et al., 2005; Morin et al., 2015). Impulse is the product of the force produced and the time taken to produce it and, when divided by body mass, equates to the change in velocity of the athlete. The spatio-temporal results from this study and Willwacher et al. (2016) suggest that it could be the magnitude of the propulsive force rather than its duration that is the most important component in creating impulse, and therefore increasing velocity. This is supported by a recent study by von Lieres und Wilkau et al. (2020a), who used a commonality regression analysis to show that magnitude of the propulsive force was the largest contributor to NAHEP in the initial acceleration phase in 28 well-trained sprinters. Von Lieres und Wilkau et al. (2020a) did not include joint kinematics in their regression analysis, so further studies that combine detailed measures of kinematics and kinetics in the initial acceleration phase in well-trained and elite sprinters are necessary to investigate these relationships further.

The sample size here was limited by the nature of the data collection setting, but in keeping the participants to the very best male sprinters in the World, this study gives the first insight in the peer-reviewed literature into the factors that determine initial acceleration performance in elite sprinters in competition. Indeed, in the race studied here, the medallists ran three of the 20 fastest times in the history of the event (World Athletics, 2020b). One possible outcome of that is that homogenous nature of the sample investigated here might have reduced the number of clear relationships found in the data. The benefit of focusing this novel analysis on the best sprinters in the World outweighs that risk, however. Further, the data collection environment precluded the capture of kinetic data, something that will remain unfeasible during official competitions due to the constraints imposed by the rules of the sport and technological complexities. However, this is the first study in the peer-reviewed literature to investigate the kinematic factors that determine performance in World-class male sprinters in the initial acceleration phase in elite competition. In doing so, it maintained a truly representative environment that ensured the integrity of the competitive task (i.e., the data collection took place during a World Indoor Championships final and did not interfere with the athletes' performance in any way). As such, it provides an extremely useful insight into previously unreported aspects of performance in this otherwise widely studied skill (Bezodis et al., 2019a), which will provide a useful insight from an ecologically valid setting for coaches and technical analysts when looking to improve performance in other sprinters.

In conclusion, this study identified two key joint kinematic variables that were associated with initial acceleration performance in World-class male sprinters in the World Indoor Championships final of 2018. Those two variables were trunk angle and thigh separation angle at take-off, and they are likely to provide a good visual guide to coaches and scientists when attempting to identify the technical characteristics of successful initial acceleration technique.

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CONFLICT OF INTEREST STATEMENT:

The authors have no conflicts of interest that are relevant to the findings of this manuscript.

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APPENDIX:

Average horizontal external power ($\bar{P}$) is calculated based on the rate of change of kinetic energy with respect to time in the horizontal (antero-posterior) direction (Bezodis et al., 2010);

$$\bar{P} = \frac{m\left({v_f}^2 - {v_i}^2\right)}{2 \cdot \Delta t}$$

Where v_i and v_f are the horizontal velocities at the start and end of the push phase, respectively, m is the mass of the sprinter and δt is the duration of the push phase.

Normalised average horizontal external power (NAHEP) is then calculated based on a modification of the function presented by Hof (1996), to obtain a dimensionlesss normalised power value (Bezodis et al., 2010);

$$NAHEP = \frac{\bar{P}}{m \cdot g^{3/2} \cdot l^{1/2}}$$

Where g is acceleration due to gravity, and l is some measure of length or height, in the case of this study, the sum of the length of shank and thigh segments of each athlete taken from the reconstructed data (mean value = 0.843 m).

Therefore, $NAHEP$ can be calculated when body mass is not known, thus;

$$NAHEP = \frac{\left({v_f}^2 - {v_i}^2\right)}{2\Delta t \cdot g^{3/2} \cdot l^{1/2}}$$

FIGURES:

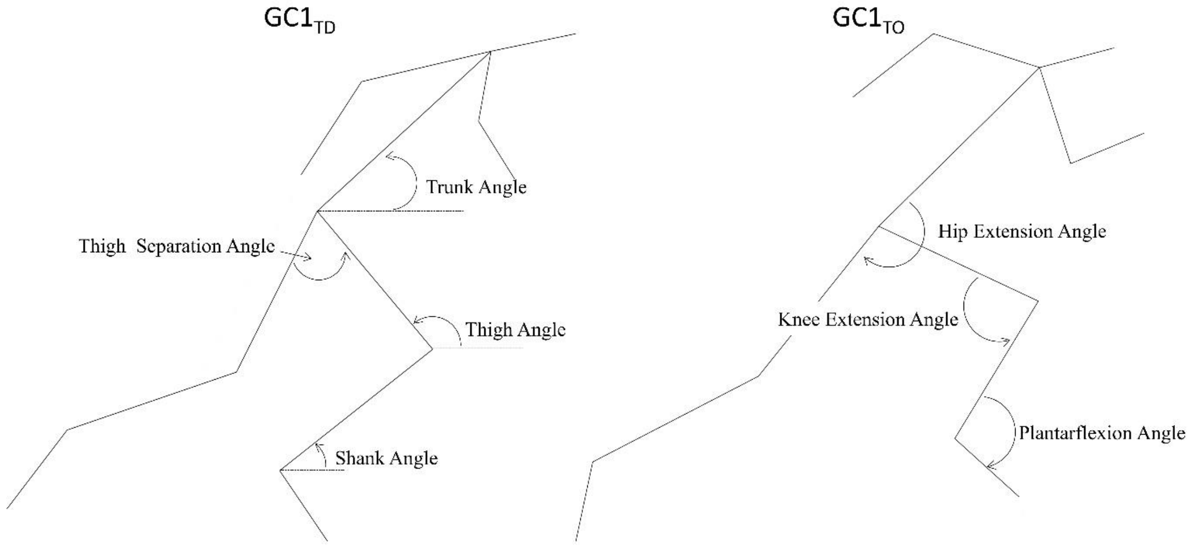

Figure 1. Spatial model showing mean scaled body positions across all athletes at the key events $GC1_{TD}$ and $GC1_{TO}$, and joint and segmental angular kinematic definitions.

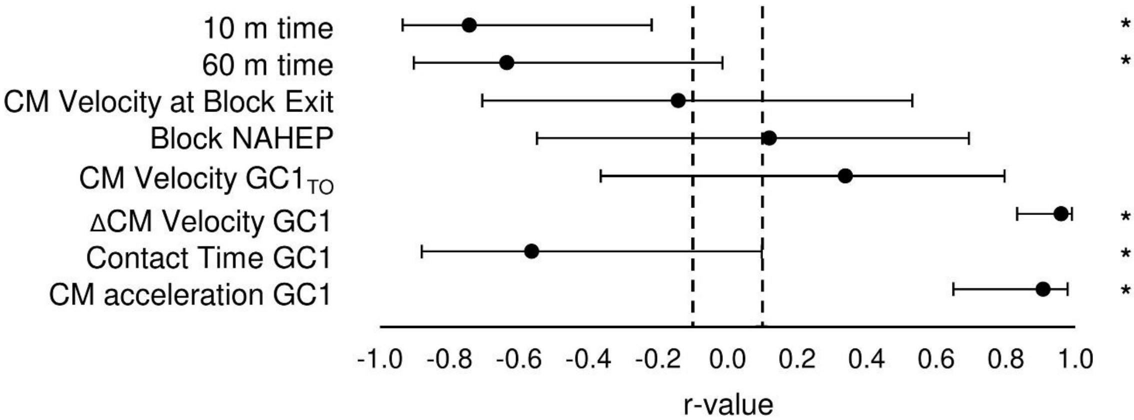

Figure 2. Correlation coefficients (± 90% CI) between first stance performance (GC1 NAHEP) and global biomechanical parameters. * denotes CI does not cross the trivial zone (r = –0.1 to 0.1).

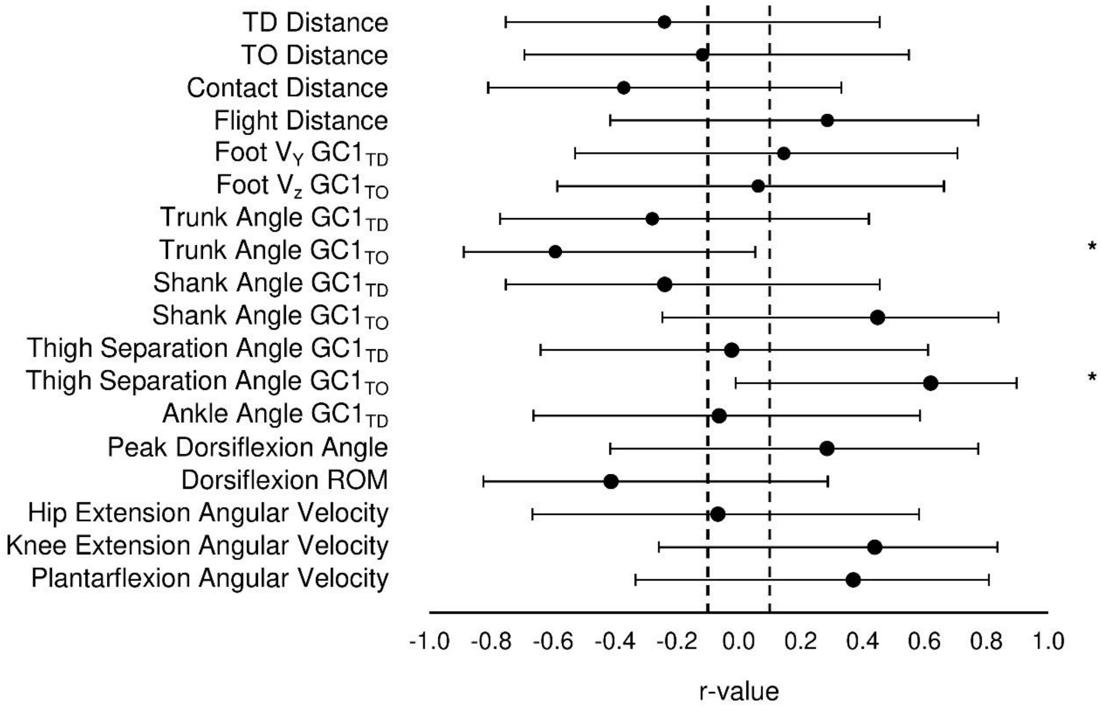

Figure 3. Correlation coefficients (± 90% CI) between first stance performance (GC1 NAHEP) and linear and angular kinematic variables. * denotes CI does not cross the trivial zone (r = –0.1 to 0.1).

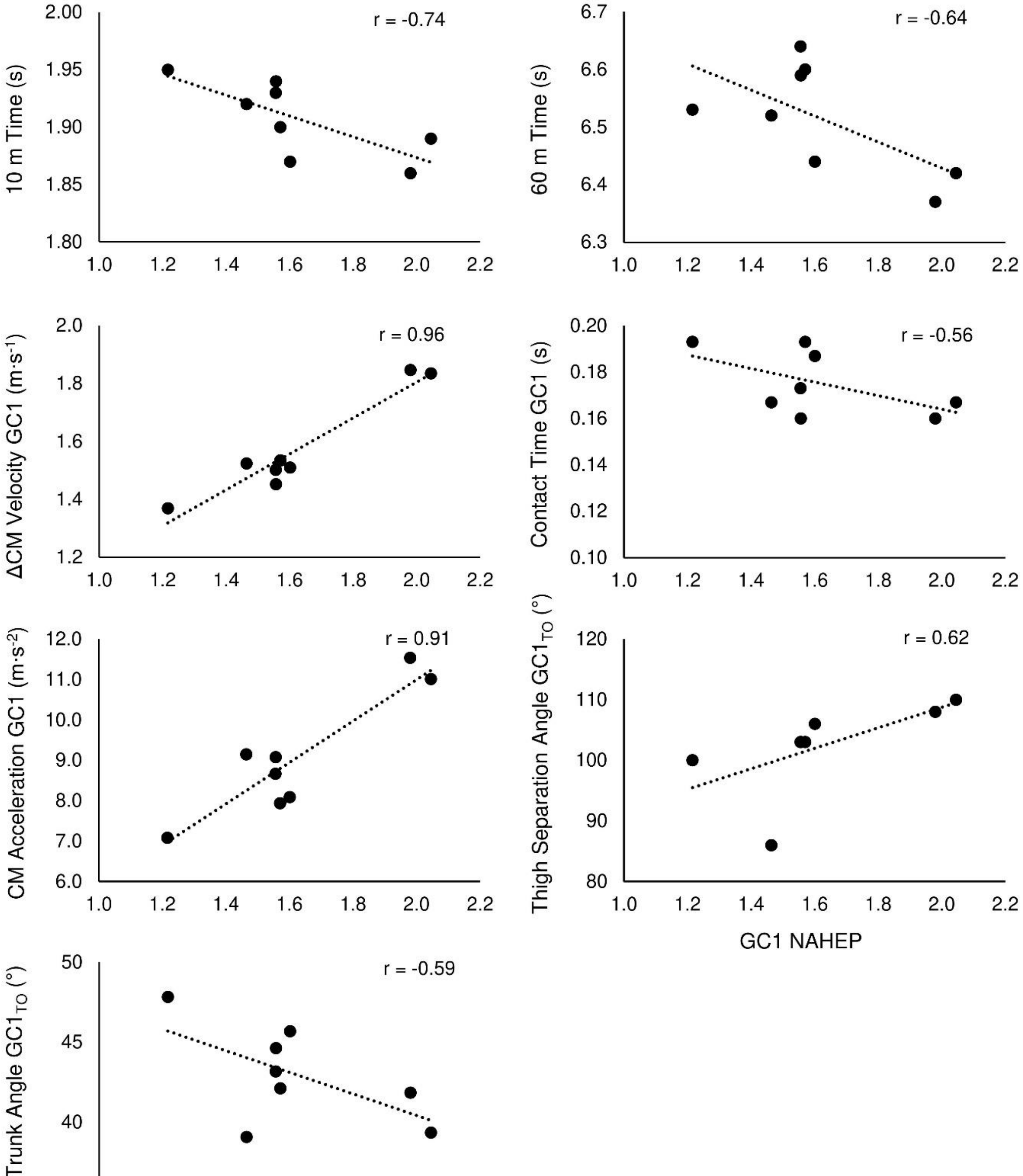

Figure 4. Individual correlation scatter plots for those variables with a clear correlation with GC1 NAHEP.

TABLES:

Table 1. Global biomechanical parameters.

Variable	Mean		SD	r-value
10-m time (s)	1.91	±	0.03	–0.74 *
60-m time (s)	6.51	±	0.10	–0.64 *
Block Time (s)	0.34	±	0.02	N/A
CM Velocity at Block Exit ($m \cdot s^{-1}$)	4.28	±	0.35	–0.14
Block NAHEP	0.953	±	0.143	0.12
CM Velocity $GC1_{TO}$ ($m \cdot s^{-1}$)	5.85	±	0.35	0.34
ΔCM Velocity GC1 ($m \cdot s^{-1}$)	1.57	±	0.17	0.96 *
Contact Time GC1 (s)	0.175	±	0.014	–0.56 *
CM acceleration GC1 ($m \cdot s^{-2}$)	9.07	±	1.52	0.91 *
GC1 NAHEP	1.624	±	0.269	

*Note: r-value is the Pearson correlation coefficient with GC1 NAHEP. * denotes a clear correlation.*

Table 2. Kinematic data relating to first stance (GC1)

Variable	Mean		SD	r-value
TD Distance (m)	–0.12	±	0.06	–0.24
TO Distance (m)	–0.87	±	0.03	0.12
Contact Distance (m)	0.74	±	0.07	–0.37
Flight Distance (m)	0.43	±	0.06	0.29
Foot V_y $GC1_{TD}$ ($m{\cdot}s^{-1}$)	0.24	±	0.86	0.15
Foot V_z $GC1_{TD}$ ($m{\cdot}s^{-1}$)	–1.64	±	0.41	0.06
Trunk Angle $GC1_{TD}$ (°)	39	±	3	–0.28
Trunk Angle $GC1_{TO}$ (°)	43	±	3	–0.59 *
Shank Angle $GC1_{TD}$ (°)	35	±	3	–0.24
Shank Angle $GC1_{TO}$ (°)	26	±	3	0.45
Thigh Separation Angle $GC1_{TD}$ (°)	-70	±	15	–0.02
Thigh Separation Angle $GC1_{TO}$ (°)	102	±	7	0.62 *
Ankle Angle $GC1_{TD}$ (°)	87	±	8	–0.06
Peak Dorsiflexion Angle (°)	74	±	5	0.29
Dorsiflexion ROM (°)	14	±	7	–0.41
Peak Hip Extension Angular Velocity ($°{\cdot}s^{-1}$)	202	±	41	–0.07
Peak Knee Extension Angular Velocity ($°{\cdot}s^{-1}$)	169	±	20	0.44
Peak Plantarflexion Angular Velocity ($°{\cdot}s^{-1}$)	395	±	95	0.37

*Note: r-value is the Pearson correlation coefficient with GC1 NAHEP. * denotes a clear correlation.*

Table 3. Angular kinematic regression model for first stance performance (GC1 NAHEP)

Model		Unstandardised Coefficients	95% CI	Standardised Beta Coefficients
Dependent:	GC1 NAHEP	Con. 1.434	0.495 to 4.406	
Independent(s):	Thigh Separation Angle $GC1_{TO}$ *	0.027	0.013 to 0.041	0.748
$R^2 = 0.89$	Trunk Angle $GC1_{TO}$ *	−0.061	−0.093 to -0.029	−0.725
R^2 Adj = 0.85				

** denotes significant ($p < 0.05$) contribution to the regression model.*