
Citation:
Stavridis, I and Economou, T and Walker, J and Bissas, A and Tsopanidou, A and Paradisis, G (2022) Sprint mechanical characteristics of sub-elite and recreational sprinters. Journal of Physical Education and Sport, 22 (5). pp. 1126-1133. ISSN 2247-8051 DOI: https://doi.org/10.7752/jpes.2022.05142

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Document Version:
Article (Published Version)

Journal of Physical Education and Sport ® (JPES), Vol. 22 (issue 5), Art 142, pp. 1126 - 1133, May 2022
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Sprint mechanical characteristics of sub-elite and recreational sprinters

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Published online: May 31, 2022
(Accepted for publication May 15, 2022)
DOI:10.7752/jpes.2022.05142

Abstract
The aim of this study was to explore the sprint mechanical and kinematic characteristics of sub-elite and recreational male sprinters during the acceleration phase of a linear sprint running section. Eighteen sprinters (nine sub-elite, nine recreational) performed two all-out 30-m sprints. Three high speed panning cameras were used to record the entire sprint distance continuously. The sprint velocity-time data of each camera were determined by temporal analysis of the video recording. These values were used to determine the variables of the horizontal F-v profile (theoretical maximal values of horizontal force [F_0], velocity [v_0], power [P_{max}], the maximal ratio of horizontal to resultant force [RF_{max}], the decline in the ratio of horizontal force production as the running speed increases [DRF]) and key kinematic characteristics. Significant differences were observed between the groups for v_0 (0.79 ± 0.24 m·s^{-1}, $p = 0.005$), P_{max} (3 ± 1.17 W·kg^{-1}, $p = 0.020$) and RF_{max} (3.1 ± 1.2 %, $p = 0.021$). No statistical differences were found for F_0 (0.55 ± 0.46 N·kg^{-1}, $p = 0.25$) and DRF (0.2 ± 0.5 %·s·m, $p = 0.67$). The mean running velocity and mean step rate were higher, whereas mean ground contact time was shorter in sub-elite sprinters. There were no differences in mean step length and mean flight time. The sub-elite sprinters in our study demonstrated the capacity to generate higher amounts of horizontal forces at higher running speeds, apply horizontal force to the ground more efficiently and achieve higher step rates during sprint acceleration than recreational sprinters.
Key Words: sprint force-velocity profile, sprint kinematics, acceleration, sprinting performance.

Introduction

In sprint acceleration, the lower limbs must produce large levels of horizontal ground reaction force in order to generate high running velocities (Morin & Samozino, 2016). The magnitude of the applied force onto the ground and the ability to transmit more efficiently the force in the forward direction are key physical determinants of successful sprint-acceleration performance (Morin et al., 2011, 2012).

Historically, sprint running performance and mechanics have been studied mainly through a kinematic domain (lab- and field-based) with only a few studies, mostly recently, capturing ground reaction forces during sprinting action due to the methodological challenges pertaining to such live data collection (Gleadhill & Nagahara, 2021; Nagahara et al., 2014a; Nagahara & Girard, 2020; Rabita et al., 2015).

Recently, a new type of analysis has been added to the set of techniques available to sport biomechanists. This new mode of analysis, based on the mechanical force-velocity (F-v) profile, has offered a new layer for studying sprinting mechanics and an underlying theoretical dimension explaining the expression of movement as depicted through kinematics (Morin et al., 2019; Samozino et al., 2016). This, in turn, has facilitated a different examination level of differences in the mechanical characteristics between athletes from other sports, levels of practice and sex (Jiménez-Reyes et al., 2018; Nicholson et al., 2021; Slawinski et al., 2017; Stavridis et al., 2019; Watkins et al., 2021).

Briefly, the maximal power-output capability in the horizontal direction (P_{max}), the theoretical maximal horizontal force production (F_0), the theoretical horizontal velocity capability (v_0), of a sprinter, and the proportion of resultant force production directed into the anteroposterior direction (RF) together with the rate of decline in RF as running velocity is increased (DRF) are estimated using established field methods (Morin et al., 2011, 2019; Samozino et al., 2016). These mechanical characteristics directly determine sprinter's propulsion capacities and constitute a crucial factor for athletes to reach maximal running velocities and most importantly to cover a given distance as soon as possible.

Additionally, several kinematic parameters, such as step length, step rate, and ground contact and flight time, have been investigated regarding sprinting performance. Briefly, previous kinematic researches have established that step rate, step length and flight time rise when running velocity is increased (Brughelli et al.,

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2011; Nagahara et al., 2014b; Weyand et al., 2000). On the other hand, contact time decreases, when increasing speed up to the maximum velocity phase in adult populations (Brughelli et al., 2011).

It is known that during sprint-acceleration performances, the capability of higher level sprinters to develop large horizontal forces onto the ground and the ability to maintain a net horizontal force production despite increasing running velocity seem to be the crucial factor that differentiates the performances between faster and slower sprinters (Morin et al., 2011; Slawinski et al., 2017). However, only few studies have examined the specific sprint mechanics and kinematic determinants among sprinters of various performance levels. Rabita et al., (2015) found that elite sprinters produced greater maximal velocity, step rate and step length (8.9, 3.0 and 2.3%, respectively) compared to sub-elite sprinters (e.g., 100 m personal best time 9.95-10.29 s vs. 10.40-10.60 s) over a 40-m sprint acceleration performance.

Additionally, it has been shown that higher net rates of force development are produced from elite sprinters compared to slower sprinters (e.g., 100 m personal best time 10.06-10.43 s vs. 11.01-11.80 s) during the pushing phase on the starting block and the two first steps (Slawinski et al., 2010). Finally, faster sprinters have been found to achieve greater maximal running velocity compared to medium and lower-level competitors (+11% and + 22.1%, respectively) over a 35-m sprint run (Paradisis et al., 2019). However, to our knowledge, no other studies have examined the mechanical and kinematic differences in sprint acceleration performance among sprinters of various performance levels. Nevertheless, detailed information on the aforementioned mechanical and kinematic characteristics in a range of sprinting performances could be great importance for coaches in order to develop optimal training programs suitable for different performance levels.

Therefore, the aim of this study was to explore the mechanical and kinematic characteristics of sub-elite and recreational sprinters during the acceleration phase of a linear sprint running section. For this purpose, the force-velocity profiling method was performed (Morin et al., 2019; Samozino et al., 2016) to assess the mechanical differences between sub-elite and recreational sprinters. Such comparison with its outcomes will provide a better insight of the mechanical determinants affecting acceleration performance in male sprinters. Results are also expected to contribute to the development of training programs in accordance with individual and level-specific needs. We hypothesized that sub-elite sprinters would demonstrate more favorable mechanical and kinematic characteristics compared to recreational sprinters during sprint acceleration.

Materials & Methods

Participants

Eighteen male sprinters, including nine sub-elite sprinters who were competing at the international level (Mean ± SD: age 24.7 ± 4.4 years; stature 1.80 ± 0.06 m; weight 73.2 ± 5.3 kg), and nine recreational sprinters from regional clubs (age 20.1 ± 2.9 years; stature 1.78 ± 0.07 m; weight 68.0 ± 9.2 kg), participated in the study. Among the sub-elite athletes there were four 100-m sprinters (personal best 10.49 ± 0.24 s) and five 200-m sprinters (personal best 21.35 ± 0.63 s). Among the recreational athletes there were nine 100-m sprinters (personal best 11.77 ± 0.22 s). The experimental procedures were conducted with approval from the research ethics committee of the institute, in agreement with the Declaration of Helsinki.

Procedures

After an individualized sprint-specific warm-up, lasting ~30 minutes, including jogging and dynamic stretching followed by three progressive sprints of 40-m, participants performed two maximal 30-m sprints from a 3-point standing position, separated by 5 minutes of rest (Romero-Franco et al., 2017; Samozino et al., 2016). The testing procedures were conducted in an indoor stadium with a synthetic track.

Three high-speed panning cameras (Casio EX-F1, Tokyo, Japan; sampling frequency 300 fps) were used to record the entire sprint distance continuously. The cameras were placed perpendicular to the running direction of athletes at the distances 5-m, 15-m and 25-m and mounted on stable tripods 10-m from the runway (Figure 1). Their operating settings were adjusted as proposed by Pueo (2016). The cameras had overlapping fields of view and each camera was used to record data for 10-m intervals (Cronin et al., 2008). Eight marking poles were positioned along the 30-m distance to determine the 5-m split times. The marking poles placed at adjusted positions to avoid parallax error (Romero-Franco et al., 2017).

Furthermore, for the extraction of step length, sixty-two custom reference markers, each 5 cm × 5 cm in diameter, were placed on either side of the running lanes, forming one-meter zones along the entire runway. The camera positioning allowed all reference markers to be visible on the captured motion of interest. The panning recording procedures were performed according to previous recommendations (Chow, 1993; Gervais et al., 1989). The timely synchronization of the first and second cameras were performed based on the frame in which the athlete's right hip crossed the corresponding marking poles at 10-m reference marker. Accordingly, the timely synchronization of the second and third cameras were performed based on the frame in which the right hip crossed the corresponding marking poles at 20-m reference marker (Figure 1). The fastest trial, being considered for further analysis.

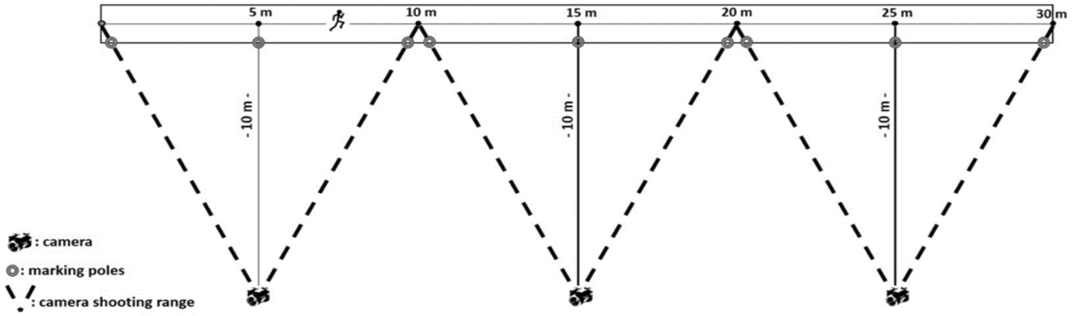

Figure 1. Experimental set up.

Data collection and analysis

The analysis of video data was conducted using Quintic Biomechanics v31 software package (Quintic Consultancy Ltd, United Kingdom). The split times for every 5-m interval were determined by temporal analysis of the video recording of each camera. The first detection of propulsive movement from the 3-point standing position was defined as the start of the sprint (Haugen et al., 2018). The selection criterion for the definition of the split times was the moment in which the right hip crossed the corresponding marking pole. Moreover, 5-m split time and running velocity per 5-m interval were calculated from the modelled spatiotemporal data of each camera (Romero-Franco et al., 2017; Samozino et al., 2016). The intraclass correlation coefficient (ICC) between trial 1 and trial 2, based on 30-m sprint time, was very high (0.998, with 95% confidence interval (CI) = 0.996 - 0.999).

The stance and swing phases of each step during the entire sprint-acceleration were also analyzed to define the moment of touchdown and toe-off. Touchdown was defined as the frame at which the foot of the athlete made contact with the ground and toe-off as the frame at which the athletes' foot loses the last contact with the ground (Paradisis & Cooke, 2006). The appropriate frames defining touchdown and toe-off were identified through visual inspection by the researcher who analyzed all the trials (Paradisis & Cooke, 2001). Contact time was defined as the time interval between initial foot contact and toe-off and flight time as the time interval between toe-off to subsequent toe touchdown. Step length was determined by the locations at which the athlete's toes contacts with the ground during a stride (Chow, 1993). The distance from the toe to the custom reference markers was determined by projecting the position of the participant's foot during the touchdown onto a line between two near markers (Chow, 1993; Economou et al., 2021; Gervais et al., 1989; Nagahara et al., 2014b; Zisi et al., 2022). Additionally, the step length was expressed as a percentage of each athlete's stature. Step rate was determined by dividing running velocity by step length. All kinematic properties were presented as means per 5-m distance intervals. The accuracy of the data collection and of the calculated step parameters has been examined previously and provided very high ICC (0.999, with 95% CI = 0.998 - 0.999) (Panoutsakopoulos et al., 2021).

The sprint mechanical profile was constructed using previously established methods (Morin et al., 2019; Samozino et al., 2016). F_0 and v_0 were extrapolated from the linear sprint F–v relationship as the intercept of the force and velocity axes of the linear regressions, respectively. P_{max} was computed as $(F_0 \cdot v_0) \div 4$. RF_{max} was calculated as the proportion of the total force production that is directed in the forward direction. DRF was computed as the slope of the linear RF–v relationship, as the running speed increases until the end of the acceleration (Samozino et al., 2016).

Statistical analysis

All data are reported as means ± standard deviation (SD) with 95% CI. Normal distribution of the data was checked by the Shapiro-Wilk normality test. Independent samples t-tests were performed to examine the differences of the mechanical parameters between the sub-elite and recreational sprinters. Cohen's d effect size (ES) was used to determine the magnitude of the differences between groups with interpretation thresholds of: trivial ($d < 0.2$), small ($d \geq 0.2$), medium ($d \geq 0.5$) and large ($d \geq 0.8$) (Cohen, 1992). All statistical analyses were processed using the statistical package SPSS v26 (IBM Corp., USA). An alpha level of 0.05 was chosen as the criterion for statistical significance.

Results

The data of the sprint mechanical variables for both groups are presented in Table 1. Significant differences were observed between the groups for v_0 ($t = 3.298$, $p = 0.005$, $d = 1.56$) and P_{max} ($t = 2.574$, $p = 0.020$, $d = 1.21$, Figure 2). RF_{max} was also significantly greater in the sub-elite athletes ($t = 2.553$, $p = 0.021$, $d = 1.14$). No significant differences between groups were found for F_0 ($t = 1.190$, $p = 0.251$, $d = 0.56$, Figure 2) and DRF ($t = 0.442$, $p = 0.665$, $d = 0.18$).

Table 1. Descriptive data and inferential statistics of sprint mechanical profiles displayed by group.

Variable	Group	Mean ± SD	95% CI	t	P	Effect size
F_0 (N·kg^{-1})	Sub-elite	8.34 ± 0.80	7.72 - 8.94	1.190	0.251	0.56
	Recreational	7.79 ± 1.14	6.91 - 8.66			
V_0 (m·s^{-1})	Sub-elite	10.43 ± 0.48	10.05 - 10.80	3.298**	0.005	1.56
	Recreational	9.63 ± 0.53	9.22 - 10.05			
P_{max} (W·kg^{-1})	Sub-elite	21.73 ± 2.22	20.03 - 23.43	2.574*	0.020	1.21
	Recreational	18.73 ± 2.71	16.64 - 20.80			
RF_{max} (%)	Sub-elite	49.0 ± 2.0	47.4 - 50.6	2.553*	0.021	1.14
	Recreational	45.9 ± 2.8	43.6 - 48.2			
DRF (%·s·m)	Sub-elite	−7.33 ± 1.0	−8.1 - −6.6	0.442	0.665	0.18
	Recreational	−7.56 ± 1.1	-8.4 - −6.7			

Note: *F_0 = theoretical maximal horizontal force; v_0 = theoretical maximal horizontal velocity; P_{max} = maximal horizontal power; RF_{max} = proportion of horizontal to resultant force; DRF = decline in ratio of forces. * = $p < 0.05$; ** = $p < 0.01$.*

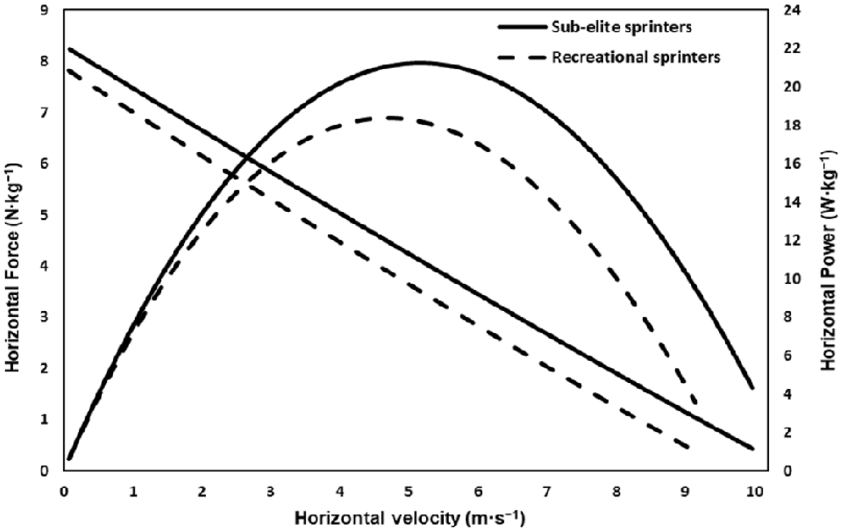

Figure 2. Graphical representation of the linear F-v and parabolic power-velocity relationships as profiled from the mean values of the sprint testing between sub-elite (black line) and recreational sprinters (dashed line).

There were significant between-group differences for mean step rate in the 0-5 m (t = 2.824, p = 0.012, d = 1.33), 5-10 m (t = 2.257, p = 0.038, d = 1.07), 10-15 m (t = 2.728, p = 0.015, d = 1.29), 15-20 m (t = 2.540, p = 0.022, d = 1.21), 20-25 m (t = 3.403, p = 0.004, d = 1.62) and 25-30 m intervals (t = 3.084, p = 0.007, d = 1.46). No significant between-group differences were observed for mean step length, mean relative step length and mean flight time in all distance intervals. The mean ground contact time was lower for the sub-elite sprinters in the 15-20 m (t = -3.394, p = 0.004, d = 1.20), 20-25 m (t = -2.966, p = 0.009, d = 1.45) and 25-30 m intervals (t = -2.500, p = 0.024, d = 1.46). The data of the sprint kinematic characteristics were displayed at Tables 2 and 3.

Table 2. Descriptive data and inferential statistics of the kinematic characteristics displayed by group.

	Distance (m)	Group	Mean ± SD	95% CI	t	p	Effect size
Mean velocity (m·s^{-1})	0-5	Sub-elite	3.99 ± 0.19	3.85 - 4.13	4.767***	< 0.001	2.25
		Recreational	3.57 ± 0.19	3.43 - 3.72			
	5-10	Sub-elite	7.40 ± 0.26	7.19 - 7.60	3.086**	0.007	1.46
		Recreational	7.01 ± 0.26	6.81 - 7.22			
	10-15	Sub-elite	8.43 ± 0.28	8.22 - 8.65	3.207**	0.006	1.52
		Recreational	7.96 ± 0.34	7.69 - 8.22			
	15-20	Sub-elite	9.05 ± 0.29	8.82 - 9.27	4.095**	0.001	1.93
		Recreational	8.44 ± 0.33	8.19 - 8.70			
	20-25	Sub-elite	9.38 ± 0.31	9.14 - 9.63	4.086**	0.001	1.93
		Recreational	8.76 ± 0.33	8.50 - 9.02			
	25-30	Sub-elite	9.64 ± 0.35	9.37 - 9.91	3.983**	0.001	1.87
		Recreational	8.94 ± 0.40	8.63 - 9.24			
ng th	0-5	Sub-elite	1.13 ± 0.10	1.05 - 1.21	−0.987	0.338	0.45
		Recreational	1.17 ± 0.09	1.11 - 1.24			

	5-10	Sub-elite	1.57 ± 0.08	1.51 - 1.63	−0.626	0.540	0.31
		Recreational	1.60 ± 0.12	1.51 - 1.69			
	10-15	Sub-elite	1.82 ± 0.06	1.77 - 1.86	−1.078	0.297	0.53
		Recreational	1.85 ± 0.09	1.79 - 1.92			
	15-20	Sub-elite	1.90 ± 0.09	1.84 - 1.97	−0.170	0.867	0.07
		Recreational	1.91 ± 0.13	1.81 - 2.01			
	20-25	Sub-elite	2.01 ± 0.09	1.94 - 2.08	−0.457	0.654	0.20
		Recreational	2.03 ± 0.08	1.96 - 2.09			
	25-30	Sub-elite	2.08 ± 0.11	1.99 - 2.15	−0.251	0.805	0.12
		Recreational	2.08 ± 0.08	2.02 - 2.14			
Relative step length	0-5	Sub-elite	0.63 ± 0.05	0.60 - 0.67	−1.102	0.287	0.49
		Recreational	0.66 ± 0.06	0.61 - 0.71			
	5-10	Sub-elite	0.88 ± 0.03	0.85 - 0.90	−0.813	0.428	0.36
		Recreational	0.89 ± 0.06	0.85 - 0.94			
	10-15	Sub-elite	1.02 ± 0.03	0.99 - 1.04	−1.126	0.277	0.51
		Recreational	1.04 ± 0.06	0.99 - 1.09			
	15-20	Sub-elite	1.07 ± 0.04	1.04 - 1.09	−0.137	0.893	0.11
		Recreational	1.07 ± 0.06	1.02 - 1.11			
	20-25	Sub-elite	1.12 ± 0.06	1.07 - 1.17	−0.568	0.578	0.21
		Recreational	1.14 ± 0.05	1.10 - 1.18			
	25-30	Sub-elite	1.16 ± 0.06	1.11 - 1.20	−0.349	0.732	0.16
		Recreational	1.16 ± 0.05	1.13 - 1.20			

** = p < 0.05; ** = p < 0.01; *** = p < 0.001.*

Table 3. Descriptive data and inferential statistics of the kinematic characteristics displayed by group.

	Distance (m)	Group	Mean ± SD	95% CI	t	p	Effect size
Contact time (s)	0-5	Sub-elite	0.161 ± 0.012	0.152 - 0.170	−1.345	0.197	0.80
		Recreational	0.171 ± 0.019	0.157 - 0.186			
	5-10	Sub-elite	0.128 ± 0.010	0.120 - 0.135	−2.051	0.057	1.04
		Recreational	0.138 ± 0.011	0.129 - 0.146			
	10-15	Sub-elite	0.116 ± 0.009	0.109 - 0.122	−1.985	0.065	1.39
		Recreational	0.131 ± 0.006	0.125 - 0.137			
	15-20	Sub-elite	0.106 ± 0.009	0.099 - 0.112	−3.394*	0.004	1.20
		Recreational	0.119 ± 0.008	0.113 - 0.125			
	20-25	Sub-elite	0.104 ± 0.010	0.097 - 0.112	−2.966*	0.009	1.45
		Recreational	0.117 ± 0.007	0.111 - 0.122			
	25-30	Sub-elite	0.103 ± 0.009	0.97 - 0.110	−2.500*	0.024	1.46
		Recreational	0.114 ± 0.010	0.107 - 0.122			
Flight time (s)	0-5	Sub-elite	0.070 ± 0.010	0.062 - 0.078	−0.800	0.435	0.56
		Recreational	0.074 ± 0.013	0.064 - 0.085			
	5-10	Sub-elite	0.092 ± 0.010	0.085 - 0.099	0.000	1.000	0.44
		Recreational	0.092 ± 0.010	0.085 - 0.100			
	10-15	Sub-elite	0.102 ± 0.004	0.098 - 0.106	−1.600	0.129	0.46
		Recreational	0.106 ± 0.007	0.101 - 0.112			
	15-20	Sub-elite	0.105 ± 0.008	0.099 - 0.111	−1.249	0.229	0.81
		Recreational	0.109 ± 0.006	0.104 - 0.114			
	20-25	Sub-elite	0.112 ± 0.007	0.107 - 0.117	0.000	1.000	0.27
		Recreational	0.112 ± 0.007	0.107 - 0.117			
	25-30	Sub-elite	0.116 ± 0.007	0.110 - 0.121	−0.378	0.710	0.11
		Recreational	0.117 ± 0.005	0.113 - 0.121			
Step rate (Hz)	0-5	Sub-elite	3.45 ± 0.31	3.21 - 3.69	2.824*	0.012	1.33
		Recreational	3.06 ± 0.27	2.85 - 3.27			
	5-10	Sub-elite	4.73 ± 0.27	4.52 - 4.94	2.257*	0.038	1.07
		Recreational	4.41 ± 0.33	4.16 - 4.66			
	10-15	Sub-elite	4.66 ± 0.25	4.47 - 4.85	2.728*	0.015	1.29
		Recreational	4.30 ± 0.31	4.05 - 4.54			
	15-20	Sub-elite	4.77 ± 0.27	4.57 - 4.98	2.540*	0.022	1.21
		Recreational	4.44 ± 0.29	4.21 - 4.66			
	20-25	Sub-elite	4.68 ± 0.24	4.49 - 4.87	3.403**	0.004	1.62
		Recreational	4.32 ± 0.20	4.16 - 4.48			
	25-30	Sub-elite	4.66 ± 0.28	4.45 - 4.88	3.084**	0.007	1.46
		Recreational	4.30 ± 0.22	4.13 - 4.47			

** = p < 0.05; ** = p < 0.01; *** = p < 0.001.*

Discussion

The present study examined the sprint mechanical characteristics between sub-elite and recreational male sprinters during a 30-m linear sprint. Supporting our hypothesis, the two groups showed different force-power-velocity profiles. Significant differences were found for v_0, P_{max} and RF_{max}. This observation partially explains the differences in sprinting performance between the two groups, with sub-elite athletes exhibiting superior mechanical characteristics compared to recreational athletes. On the other hand, the theoretical maximal horizontal force (F_0), which represents the capability to generate high level of horizontal force at low running velocities, did not differ between sub-elite and recreational sprinters. Additionally, the graphic representation of the inverse linear F-v relationship, indicates that sub-elite sprinters can develop higher horizontal force at any given velocity than recreational sprinters (Figure 2). However, the differences in the mechanical characteristics in the acceleration phase between the two groups are more prominent in the velocity component of the F-v relationship.

Analytically, v_0 provides an indication that the sub-elite sprinters benefit from inherent internal mechanisms and functions by having the capacity to a) attain higher running velocities, and b) produce larger horizontal forces at higher velocities than recreational sprinters. This is also explaining the finding that the same sprinters generated greater overall mechanical power output (P_{max}) than their lower-level competitors. Additionally, the proportion of horizontal to resultant force (RF_{max}) was higher in the sub-elite sprinters suggesting a more effective pattern of force application, allowing them to direct more of the total force towards the anteroposterior direction. This in conjunction with the capability to generate large forces at high velocities create a powerful combined effect that enables the faster sprinters to propel their body forwards quicker than the slower sprinters. This observation is related to the significant differences of mean running velocity values in all distance intervals between the sub-elite and recreational sprinters of our study. These results are consistent with the study by Rabita et al. (2015) who reported that elite sprinters are able to achieve higher forward orientation of the generated force at null velocity, compared to lower-level competitors.

Interestingly, the ability to maintain the RF related mechanical effectiveness throughout the acceleration phase as it was measured through DRF was similar between the two groups, indicating the same rate of decrease in RF with increasing running speed Thus, the sub-elite sprinters in our study did not handle the rate of loss in the efficiency of force application differently, but they remained in a superior position compared to the rest of the sprinters because of their initial RF values. Our findings support the observations of previous studies that high-level athletes can apply higher propulsive forces onto the ground (Jiménez-Reyes et al., 2018; Morin et al., 2011).

Regarding sprint kinematics, there were significant differences in the mean step rate between the two groups, whilst there were no significant differences in the mean step length. The higher step rate suggests that the sub-elite sprinters keep their nervous system in a state of readiness, achieving faster leg turnover than recreational athletes. Moreover, higher step rate implies a high rate of nervous activation and a high rate of cross-bridges cycle within the fast muscle fibers (Salo et al., 2011). Furthermore, the higher step rate in the 15-30 m intervals may be attributed to the shorter ground contact time in the sub-elite group. This agrees with Morin and colleagues (Morin et al., 2012), who found that a higher step rate is caused by a shorter contact time.

This study confirms in part findings in our previous studies, where we observed high-level sprinters producing greater step length and step rate values (6.0% and 4.7%) than a group of medium-level sprinters (Paradisis et al., 2019). A typical pattern depicting kinematic differences between performance levels supports that better sprinters show higher step lengths and rates values (Rabita et al., 2015). These kinematic characteristics are diminished when differences in performance are getting smaller. Hence, in the present research, step rate was one of the kinematic characteristics that affect performance. However, it is important to reference that elite sprinters are divided into step rate-reliant athletes and step length-reliant athletes (Salo et al., 2011) therefore, in other cases the performance may be affected by the step length.

Furthermore, contact time was shorter in the 15-30 m intervals for the sub-elite sprinters whereas flight time showed no significant differences between the sub-elite and recreational athletes. Similar tendencies (−13.5% for contact time) were presented previously (Paradisis et al., 2019). All the above temporal observations confirm that shorter ground contact times can lead to higher running velocities (Morin et al., 2012; Paradisis & Cooke, 2006; Weyand et al., 2000).

There is less information regarding the differences in sprint mechanics between sub-elite and recreational athletes. Therefore, a strength of the current study is that it provides data of the specific sprint mechanics and kinematics determinants from the sub-elite to recreational male sprinters. The outcomes of the differences in sprinting mechanics between two distinct groups of sprinters in this study, provide us with a unique understanding of the origins of the performance differences between the two groups and an indication of the direction coaches could take to develop running speed. In practical terms, this type of data can reveal the neuromuscular and technical components affecting the sprint acceleration performance and guide coaches to distinguish the strengths and weaknesses in their athletes depending on whether a force-oriented or velocity-oriented profile dominates. From a practical point of view, athletes with horizontal force deficits, at the begging of the sprint, should prioritize their training by using horizontal resistance training at low velocities, such as pushing or pulling heavy sleds. Whereas athletes with velocity deficits should be prescribed more maximal velocity sprinting by using overspeed training and light sleds (Hicks et al., 2020; Morin & Samozino, 2016).

Limitations of the study need to be mentioned. The sample size is small and may reduce the statistical power. Further experimental research with higher sample sizes, involving athletes with various performance level, should be conducted to confirm our findings.

Conclusion

The sub-elite sprinters in our study demonstrated the capability to reach higher running speeds, generate greater amounts of anteroposterior forces at higher running speeds, apply force to the ground more efficiently, achieve higher step rate and spend less time in contact with the ground during the acceleration phase of a linear sprint running section than recreational sprinters. Therefore, the current study indicate that the force-velocity profiling method can reveal the neuromuscular and technical components affecting the sprint acceleration performance among sprinters of various performance levels. The findings improve our understanding of the type and nature of contributing factors to speed development in male sprinters and as such inform coaches of the need to develop appropriate training stimuli to trigger the right responses.

Conflicts of interest

The authors state no conflict of interest.

Funding

No funding was received for this study.

Acknowledgements

The authors would like to thank Dr. Jean-Benoit Morin for reviewing the draft manuscript.

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