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Abstract

Sprinting and speed is a fundamental skill and physical attribute crucial in seam bowlers and batters within cricket. The aim of this study was to assess differences in mechanical properties during sprinting between youth and senior international cricketers and between seam bowlers and batters. Retrospective 40m sprint times and anthropometric measures of 56 international cricketers (19 senior seam bowlers, 7 under-19 seam bowlers, 16 senior batters, 14 under-19 batters) were used to calculate the theoretical maximal force (F_0), theoretical maximal velocity ($V_{(0)}$), theoretical maximal power (P_{max}), slope of the force-velocity relationship (F-V slope), maximal ratio of horizontal-to-resultant force (RF_{max}), decrease in the ratio of horizontal-to-resultant force (DRF) and optimum velocity (V_{opt}). There were no significant ($P > 0.05$) differences in sprint times nor sprint mechanical profile variables between position or age. However, there was a *moderately* greater F_0 (N/Kg) (ES = 0.78; 90% CI 0.19 - 1.34) and RF_{max} (ES = 0.75; 90% CI 0.11 - 1.35) in senior seam bowlers when compared to batters. Furthermore, FV Slope (ES = 0.79; 90% CI 0.15 - 1.40) and DRF (ES = 0.75; 90% CI 0.11 - 1.35) were *moderately* greater in senior compared to under-19 batters. When expressed relative to body mass, it appears that senior international seam bowlers show trends towards a more force biased profile during sprinting when compared to batters. These findings will help coaches to optimise physical preparation strategies in youth and senior international cricketers.

Key Words: Batters, Cricket, F-V Profile, Seam Bowlers

Introduction

Cricket is a team sport that has three competitive formats (multi-day, one-day and Twenty20) with competition lasting between 3 h (Twenty20) and 5 days (multiday) [1]. The demands of cricket vary between match format and position (batters, seam bowlers and wicketkeepers) [2], as noted by the greater number of high intensity efforts during Twenty20 when compared to other formats [2]. Furthermore, seam bowlers cover between 20-80% more distance and perform high intensity locomotive activities up to 8 times more often compared to other positions (batters, spinners and wicketkeepers) across cricket game formats [2]. However, all positions and game formats require noteworthy volumes of maximal accelerations and high intensity running [2-4]. Consequently, understanding and optimising the mechanical properties of sprint acceleration profiles is vital in improving the efficiency of sprinting and performance in cricket.

Over recent years, sprint acceleration profiles (up to 40m) have been recorded using timing gates or a radar gun and modelled to evaluate the mechanical properties of force application during sprinting [5, 6]. Employing the aforementioned methods enables determination of the force-velocity-power profile to be derived from the acceleration-time curve. This assessment allows coaches and sport scientists to assess biomechanical limitations of over ground sprint acceleration in the field. The biomechanical model is an analysis of the sprinters' kinematics and kinetics during the acceleration phase of sprinting. The model is practically convenient, only requiring anthropometric and spatiotemporal data to be collected by the practitioner. An inverse dynamic approach is then applied to the centre of mass, to allow for the analysis of sprinting [5]. Theoretical maximal force (F_0), theoretical maximal velocity (V_0), theoretical maximal power (P_{max}), slope of the force-velocity relationship (F-V Slope), maximal ratio of horizontal-to-resultant force (RF_{max}), decrease in the ratio of horizontal-to-resultant force (DRF) and optimum velocity (V_{opt}) are all derived from the acceleration-time curve. Until recently [7, 8], the mechanical properties of sprinting have only been assessed in a limited variety of sport such as soccer [9-11], rugby [12], American football [13] and in world class sprinters [14]. Sprint mechanical reference values now exist across a multitude of different sports, playing level and gender [7, 8], with notable differences observed. However, none have been documented within cricket.

Given the large difference in physiological demands of positional roles within an American football team [15], it is unsurprising that differences in mechanics were reported within a sample of 1254 athletes [13]. However, differences in sprint mechanics were only found between positions that were either heavily dependent or not dependent on running. This study in American football appears to be the only analysis of mechanical profiling across different positions within a specific sport. Understanding the optimal mechanical profile for specific positions will assist coaches in developing individual and position specific training programmes.

The demands of seam bowling and batting (as assessed via time motion analysis) vary substantially [2, 3]. Batting consists of sprinting 20.2m with 180° turns [16]. During an innings, batters can perform in excess of 40 turns [16] and in Twenty20 cricket perform a mean sprint distance of 14m with a mean rest period of 53s between sprints [17]. Seam bowlers are exposed to greater volumes of high intensity linear running compared to all other positions [2, 3], partly due to run up speeds being as high as 6.8 $m \cdot s^{-1}$ [18]. These differences between positions may influence the mechanical sprint profiles of seam bowlers and batters. Research has demonstrated that it is advantageous for seam bowlers to be taller than other positions in international cricket, as greater stature can increase factors such as the bounce of the ball from the pitch [19]. With this increase in stature, body mass is expected to be greater, thus requiring a greater application of force during sprinting compared to batters (who are likely lighter) to produce the same sprint speeds. Therefore, the aim of this study is to investigate differences in the acceleration sprint mechanical profiles of international seam bowlers and batters. A secondary aim of the study was to assess differences between age group and senior international cricketers, as differences between the anthropometric characteristics of batters and seam bowlers may influence the mechanical properties of sprinting. A final aim of the study was to explore differences in stature and body mass between batters and seam bowlers across age groups.

Methods

Participants

Fifty-six (mean ± SD age; 22 ± 4 years, stature; 1.84 ± 0.07m, body mass; 81.2 ± 9.3 kg) senior and under-19 international cricketers took part in the study. Players were separated into four groups based on their position and competition level (senior batters, n = 16; senior seam bowlers, n = 19; under-19 batters, n= 14; under-19 seam bowlers n = 7). Figure 1 shows the mean ± SD and individual characteristics across each group. Senior international cricketers were defined as being involved in the Senior International Pathway Programme (either Lions or Senior Men), whereas under-19 cricketers were only involved in the under-19 programme.

All athletes avoided strenuous exercise in the 24 hours before performance testing and were free from musculoskeletal injury for three months prior to data collection. The study was based on pre-existing data sets from physical performance testing days between 01/10/2018 – 01/07/2019. Data were collected as a part of routine physical athlete profiling with athletes and parents of under-18 cricketers' consenting to its use for research purposes. Retrospective ethics was granted through the local ethics committee, in agreement with the Declaration of Helsinki.

Procedures

The study was a cross-sectional analysis comparing the mechanical sprint profiles between position (seam bowlers Vs batters) and playing level (age group international Vs senior international). Sprint performance was assessed over 10, 20, 30 and 40m and all tests were performed on the same 60m indoor cricket training surface. As 30m split times were not collected from 5 players, only 10, 20 and 40m raw sprint times have been reported in this manuscript, however all available sprint times were used in the F-V acceleration profile analysis. Participants wore suitable running trainers which had been used previously by the athletes in maximal sprinting training sessions. Prior to testing, participants performed a group warm-up delivered by the Strength and Conditioning Coach. All warm-ups consisted of 4-5 progressive sprints, building from 60 to 100% maximal effort. Following the warm-up and 3-5 min rest, three maximal 40m sprints were performed with 4 min rest between each sprint. Participants started in a split stance position 50 cm behind the start line with the head and chest within 10 cm of the first beam.

The fastest 40m sprint time and participants body mass was used for analysis. F_0, V_0, P_{max}, F-V slope, RF_{max}, DRF and V_{opt} were calculated using a published and custom built spreadsheet [20]. The aforementioned variables are calculated from the mono-exponential function of the velocity time curve generated from the sprint split times entered on the custom-built spreadsheet[20] . This is derived from the least-squared regression fitting procedure. Force velocity linear relationships were calculated using horizontal acceleration of the participants' centre of mass (from running velocity change over time) and ground reaction forces from body mass and aerodynamic friction. Consequently, F_0 and V_0 are calculated as the x and y intercepts from the force velocity regression, where the F-V slope is calculated. P_{max} was calculated as ($F_0 \cdot v_0/4$) and RF_{max} as the maximal horizontal-to-resultant force after 0.3s (beginning phase of the sprint). DRF was calculated as the linear decrease in RF (or ability to maintain a high RF during the acceleration [22, 23]. For specific calculations details see Morin and Samozino [21] and Samozino et al. [5].

Dual beam timing lights (Brower TC, Brower Timing System, Utah, USA) were placed at 0, 10, 20, 30 and 40m. The first timing gate was placed at the start line, mounted on tripods 1.0m above ground level, while the remaining timing gates (10 – 40m) were mounted 1.3m above ground level. Prior to sprinting body mass was recorded using SECA 862 Scales (Birmingham, UK).

Statistical Analyses

Data were analysed using SPSS (version 24.0, Chicago, Illinois, USA) and presented as mean ± standard deviation (SD). Visual inspection of the Q-Q plots and boxplots were used to assess the assumptions of normality. Levene's test was used to check for homogeneity of variance before analyses. To detect differences between age (youth, senior) and positions (seam bowlers, batters) a 2 x 2 ANOVA was conducted. Alpha level was set at 0.05. If significant interactions were detected, *pairwise* comparisons using a Bonferroni *post hoc* were performed with 90% confidence intervals (CI). The standardised magnitude of effect (ES) [24] difference was examined between groups (senior seam bowlers, under-19 seam bowlers, senior batters, under-19 batters). Based on data collected from elite experienced athletes [25] ES were set as trivial (<0.25), small (0.25-0.50), moderate (0.50-1.00), or large (>1.00).

Results

There was no significant ($P > 0.05$) difference in sprint times (10, 20 and 40m) between positions and age (Table 1). However, there was a trend towards a *moderately* quicker (ES > 0.50) sprint time across all distances for senior seam bowlers when compared to under-19 seam bowlers. Senior seam bowlers also exhibited a *moderately* quicker time compared to senior batters across 10m (ES 0.53; CI -0.05 – 1.09) and 20m (ES 0.54; CI -0.04 – 1.09).

There was a significant difference in body mass between positions ($F_{(1,52)} = 8.6$; $P < 0.01$; $\eta_p^2 = 0.14$) and age ($F_{(1,52)} = 12.5$; $P < 0.001$; $\eta_p^2 = 0.19$). Figure 1 shows a significantly higher body mass in seam bowlers compared to batters ($P < 0.01$; CI 2.7 – 9.9 kg) and senior compared to youth cricketers ($P < 0.01$; CI 3.9 – 11.2 kg). Stature was also significantly ($F_{(1,52)} = 15.8$; $P < 0.001$; $\eta_p^2 = 0.23$) different between positions (Figure 1) with seam bowlers being significantly taller compared to batters ($P < 0.001$; CI 4.1 – 10.1 cm).

****Insert Table 1 around here****

****Insert Figure 1 around here****

There were no significant differences ($P > 0.05$) in any sprint mechanical variables. Individual and mean responses are presented in Figure 2. The standardised effect size differences in sprint mechanical force-velocity profile between position and age are presented in Tables 3 and 4.

****Insert Table 2 around here****

****Insert Table 3 around here****

****Insert Figure 2 around here****

Discussion

The aim of the study was to assess differences in the acceleration sprint mechanical profiles of seam bowlers and batters across under-19 and senior international cricketers. The main findings of this study were that despite the senior international bowlers exhibiting greater body mass and stature, this was not detrimental to sprinting performance. Senior international seam bowlers even showed trends towards a greater application of force, relative to body mass in sprinting compared to senior batters. Furthermore, it was observed that senior batters have a trend towards a more velocity dominant profile when compared to under-19 batters.

The results from this study showed no significant differences in the mechanical acceleration profiles between positions and in under-19 compared to senior international cricketers. However, it should be noted that there are a number of potential trends. Senior seam bowlers exhibited a *moderately* higher F_0 (N/kg) (ES = 0.78; 90% CI 0.19 - 1.34) and RF_{max} (ES = 0.75; 90% CI 0.11 - 1.35) compared to senior batters. As RF_{max} represents the ability to apply horizontal force during the early steps of acceleration and F_0 (N/kg) represents the initial step during the start of the acceleration, it seems appropriate that there are similar *moderately* greater values of F_0 (N/kg) and RF_{max} in senior seam bowlers compared with senior batters. Higher F_0 (N/kg) and RF_{max} suggest that senior seam bowlers are able to generate greater forces in the first few steps of sprinting. Senior seam bowlers have been shown to perform a greater number of sprints across training, during Twenty20, one day and multiday cricket [2, 3]. The volume of sprinting the senior seam bowlers have been exposed to throughout their careers may suggest why a *moderate* difference between positions at senior but not under-19 level was observed here. Even though much of the high speed running performed by seam bowlers is submaximal and could be considered lacking as an adaptation stimulus, previous research has shown improvements in sprinting performance following submaximal high speed running [26]. The greater F_0 (N/kg) and RF_{max} in seam bowlers compared to senior batters cannot be solely explained by the longer and higher number of high intensity accelerations actions during matches [17] and training [3, 27] across a career. Seam bowlers are exposed to up to 9 times body mass during the delivery phase of seam bowling [28]. This exposure can be over 300 times during a game, which over time is a considerable training stimulus, given previous research has shown as little as 120 high load drop jumps per week for 10 weeks has enhanced 10m sprint times [29]. As minimal sprinting kinematic differences have been demonstrated in fielding positions [30], it is logical to suggest that the *moderate* differences in sprinting profiles are not fielding related. It is hypothesised that consistent exposure to high forces contributes to the greater force production capabilities observed here in senior seam bowlers compared to senior batters during the acceleration of sprinting. However, this study was a cross-sectional analysis and reports no change in F_0 and RF_{max} between under-19 and senior seam bowlers, further research examining the longitudinal analysis of mechanical sprint profiles will assist in determining temporal changes between batters and bowlers.

Previous work has reported differences in the mechanical sprinting profiles between numerous sports [7, 8]. Acceleration and explosive sports such as bobsleigh, soccer and athletic jumping showed higher RF_{max} and F_0 values [7]. Consequently, it is unsurprising that there are *moderately* greater RF_{max} and F_0 values in senior seam bowlers compared to senior batters. Whilst differences in sprint mechanical profiles have been reasonably well established between sports, this study adds to the small body of work assessing differences in positional sprint mechanical profiles [13] and research in mechanically similar sports such as rugby league compared to rugby union [12] and futsal compared to soccer [11]. Based on the findings from the current study and the aforementioned previous studies, it appears that force velocity profiling may be appropriate to detect differences within and between mechanically similar sports and positions.

There was a *moderate* increase in the F-V Slope (ES = 0.79; 90% CI 0.15 - 1.40) and DRF (ES = 0.75; 90% CI 0.11 - 1.35) in the senior batters compared to the under-19 batters, despite no significant differences. As DRF represents the maintenance of net horizontal force production with increasing running speeds and has been shown to be almost perfectly correlated with differences in F-V slope [7], it is unsurprising both showed a *moderate* increase in the senior batters compared to the under-19 batters. It is unclear why senior batters have a more velocity dominant profile compared to under-19 batters. This trend was not seen in under-19 seam bowlers when compared to senior seam bowlers. It may be there is a maximal force adaptive response to seam bowling from high forces exposed to during each bowling delivery [31] across playing years, that may explain less of a shift to a more dominate velocity profile. The cross-sectional design of this study makes any conclusions around long term adaptations from seam bowling or batting very speculative.

A *moderately* faster sprint time (10, 20 and 40m) in senior compared to under-19 seam bowlers and in senior seam bowlers compared to senior batters was observed at 10m (ES = 0.53; 90% CI -0.05 - 1.09) and 20m (ES 0.54; CI -0.04 – 1.09). However, this was not significantly different. This is the first study in cricket to identify that like other sports, sprint ability may be different between positions [32-34] and age[34]. The uncorrected sprint times in this study are comparable to county cricket data [35], but are notably quicker than those previously reported in other senior [36, 37] and academy county cricketers [38]. Whilst cricket is highly skill dependant sport, it appears that there may be an enhancement in physical capacities which are associated with international cricketers. Future research should look to establish differences in demands and physical attributes of first class compared to international cricket.

Unsurprisingly, seam bowlers were taller than batters. Specific studies have presented the stature of first class [39, 40] and international seam bowlers [41]. This is the first study to present a comparison within international under-19 and senior cricketers. Previous work has reported that anthropometric characteristics correlate with ball release speed in seam bowlers [40] . Further highlighting the importance of seam bowlers' stature, up to 80% of the wickets in international cricketers have been from seam bowlers that are above 1.83m [19]. Conversely, separate research has reported that anthropometric characteristics have less of an influence on bowling performance in senior cricketers [42]. What is clear from our results is that the greater stature observed in seam bowlers does not reduce sprint performance and may even contribute to enhancing sprint qualities. Other factors such as the higher release angle of delivery are clearly advantageous characteristics associated with taller seam bowlers [43]. It is difficult to determine the exact reason for the greater stature with seam bowlers, but as athletes are subjectively selected for national teams, it is logical to suggest coaches' have a preference towards taller bowlers. The taller seam bowlers observed in this study may also explain the *moderately* quicker sprint times demonstrated in senior seam bowlers when compared to senior batters. Elite sprinters have shown an historic increase in stature[44] with longer limbs suggested to be an advantage in sprinting [45]. A subsequent increase in stride length would mean an increase in force during the initial accelerations steps, which may explain the *moderately* greater in RF_{max} and F_0 values in seam bowlers when compared to seam batters observed here. Further research investigating the kinematic changes between positions in cricket would allow for more definite conclusions to be made.

There were differences in body mass between senior international and under-19 cricketers. The exact composition of the greater body mass is open to speculation but the likely explanation is greater muscle mass. Previous work has shown correlations between strength and bowling release speed [42] and consequently large parts of the physical preparations strategy are targeted at increasing strength [46, 47]. Other sports such as rugby have reported continued increases in body mass, and in some cases stature until athletes reach their early 20's [48]. The lower body mass reported in the under-19 cricketers may also be a result of the athletes continued growth. The greater body mass in the seam bowlers compared to batters observed here is likely due to the seam bowlers being taller.

Although collection of the data was standardised between groups, there are some limitations in the comparisons of the results presented here to other athletic populations. Within the current study, sprint mechanical profiles were calculated retrospectively using timing gates. The use of timing gates to assess sprinting profiles has been shown to be valid and reliable [49]. However, when using retrospective sprint data from timing gates there are notable limitations [7, 11]. For example, it is advised participants are placed 5-10 cm directly behind the triggering beam so the initial horizontal movement is captured. In previous work, 0.5s has been added to sprint times for all groups to compensate for the first movement triggering [7]. The same methodological approach was used in this study. However, instructions were given to the participants to move their torso towards the beam. As a result, the 0.5s may have over compensated for the forward momentum when the start beam was triggered and comparing this data to other literature may not be appropriate. Previous literature that has not added 0.5s to the sprint times has reported an overestimation in F_0 data [13]. Even though these data are subjected to this limitation, the data offer a standardised position and age comparison in international cricket within this population.

There a several notable practical applications for these data. The findings from this study will serve to enhance the targeted prescription and planning of physical preparation strategies in cricket. Given there are few differences in theoretical maximal force between under-19 senior bowlers and senior batters, it is suggested that further targeted maximal force training may support the enhancement of sprint acceleration. The data indicate a large variability in the sprint mechanical profiles within each group (under-19 seam bowlers, under-19 batters, senior seam bowlers, senior batters), therefore mechanical profile of individual athletes and individualised sprint programming of cricketers is advised to maximise performance. Future research should focus on tracking longitudinal changes in the sprint mechanics within the same individuals.

In summary, this study examined the differences in mechanical sprinting profiles between batters and seam bowlers across senior and under-19 international cricketers. Whilst, there were no statistically significant differences in the mechanical profiles of senior seam bowlers, *moderately* higher force production when expressed relative to body mass was observed, despite a higher body mass in international seam bowlers. This greater force is likely due to the regular exposure to high forces experienced during seam bowling. Senior batters appear to demonstrate a more velocity bias compared to under-19 batters. The precise reasons for these differences are currently unclear.

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Table 1. Corrected sprint times (+0.05s).

	10m (s)	20m (s)	40m (s)
Senior Seam Bowers	2.23 ± 0.07	3.46 ± 0.10	5.73 ± 0.19
Under-19 Seam Bowlers	2.26 ± 0.06	3.52 ± 0.09	5.86 ± 0.16
Senior Batters	2.26 ± 0.05	3.51 ± 0.08	5.79 ± 0.19
Under-19 Batters	2.25 ± 0.08	3.51 ± 0.10	5.83 ± 0.18

Tables 2. Standardised comparison on sprint mechanical force-velocity profile between international batters and seam bowlers.

	Comparison of Position	ES (90% CI)
F_0 (N/kg)	↑ senior seam bowlers Vs batters	0.78 (0.19 to 1.34)
	↓ under-19 seam bowlers Vs batters	-0.32 (0.45 to -1.08)
V_0 (m/s)	↓ senior seam bowlers Vs batters	-0.08 (0.48 to -0.64)
	↓ under-19 seam bowlers Vs batters	-0.22 (0.55 to -0.97)
P_{max} (W/kg)	↑ senior seam bowlers Vs batters	0.53 (-0.05 to 1.09)
	↓ under-19 seam bowlers Vs batters	-0.38 (0.41 to -1.13)
FV Slope	↓ senior seam bowlers Vs batters	-0.54 (0.04 to -1.09)
	↑ under-19 seam bowlers Vs batters	0.11 (-0.66 to 0.87)
RFmax (%)	↑ senior seam bowlers Vs batters	0.70 (0.11 to 1.26)
	↓ under-19 seam bowlers Vs batters	-0.36 (0.42 to -1.11)
DRF (%)	↓ senior seam bowlers Vs batters	-0.50 (-1.06 to 0.07)
	↑ under-19 seam Vs batters	0.08 (-0.69 to 0.84)
V_{opt} (m/s)	↓ Senior seam bowlers Vs batters	-0.08 (-0.64 to 0.48)
	↓ under-19 seam bowlers Vs batters	-0.22 (-0.97 to 0.55)

ES, effect size; CI, confidence intervals; F_0, theoretical maximal force; V_0, theoretical maximal velocity; P_{max}, theoretical maximal power; F-V slope, slope of the force-velocity relationship; RF_{max}, maximal ratio of horizontal-to-resultant force; DRF, decrease in the ratio of horizontal-to-resultant force; V_{opt}, Optimum velocity.

Tables 3. Standardised comparison on sprint mechanical force-velocity profile between senior and youth international cricketers.

	Comparison of Age	ES (90% CI)
F_0 (N/kg)	↑ senior Vs under-19 seam bowlers	0.33 (-0.41 to 1.05)
	↓ senior Vs under-19 batters	-0.83 (-1.44 to -0.18)
V_0 (m/s)	↑ senior Vs under-19 seam bowlers	0.57 (-0.19 to 1.29)
	↑ senior Vs under-19 batters	0.45 (-0.17 to 1.05)
P_{max} (W/kg)	↑ senior Vs under-19 seam bowlers	0.63 (-0.13 to 1.35)
	↓ senior Vs under-19 batters	-0.24 (-0.84 to 0.37)
FV Slope	↑ senior Vs under-19 seam bowlers	0.08 (-0.65 to 0.81)
	↑ senior Vs under-19 batters	0.79 (0.15 to 1.40)
RF_{max} (%)	↑ senior Vs under-19 seam bowlers	0.51 (-0.25 to 1.23)
	↓ senior Vs under-19 batters	-0.56 (0.07 to -1.16)
DRF (%)	↑ senior Vs under-19 seam bowlers	0.12 (-0.61 to 0.85)
	↑ senior Vs under-19 batters	0.75 (0.11 to 1.35)
V_{opt} (m/s)	↑ senior Vs under-19 seam bowlers	0.57 (-0.19 to 1.29)
	↑ senior Vs under-19 batters	0.45 (-0.17 to 1.05)

ES, effect size; CI, confidence intervals; F_0, theoretical maximal force; V_0, theoretical maximal velocity; P_{max}, theoretical maximal power; F-V slope, slope of the force-velocity relationship; RF_{max}, maximal ratio of horizontal-to-resultant force; DRF, decrease in the ratio of horizontal-to-resultant force; V_{opt}, Optimum velocity.

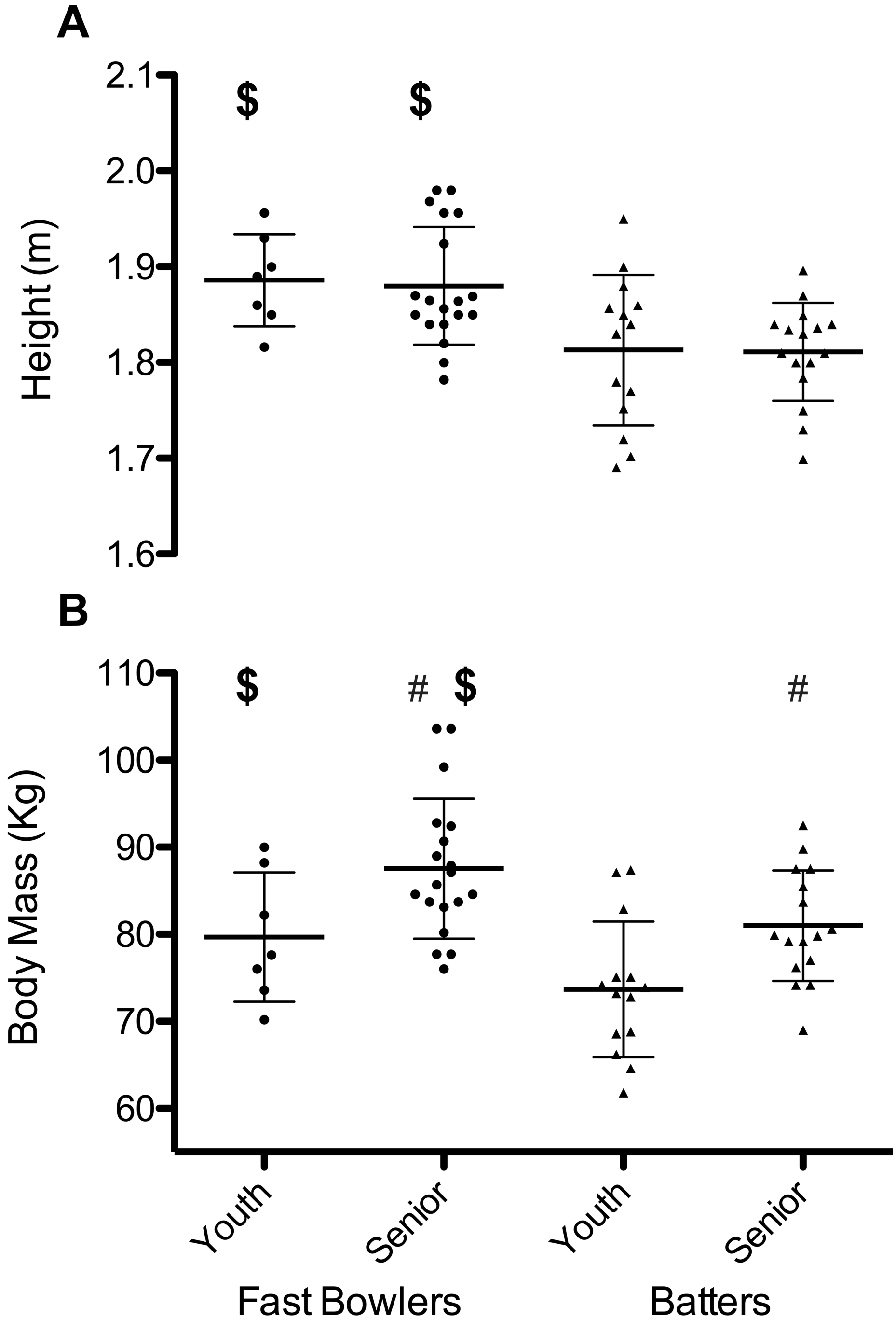

Figure 1. Individual and mean stature (A) and body mass (B) across position and group. $^{\$}$Denotes significant difference from batters ($P < 0.05$); $^{\#}$Denotes significant difference from youth ($P < 0.05$).

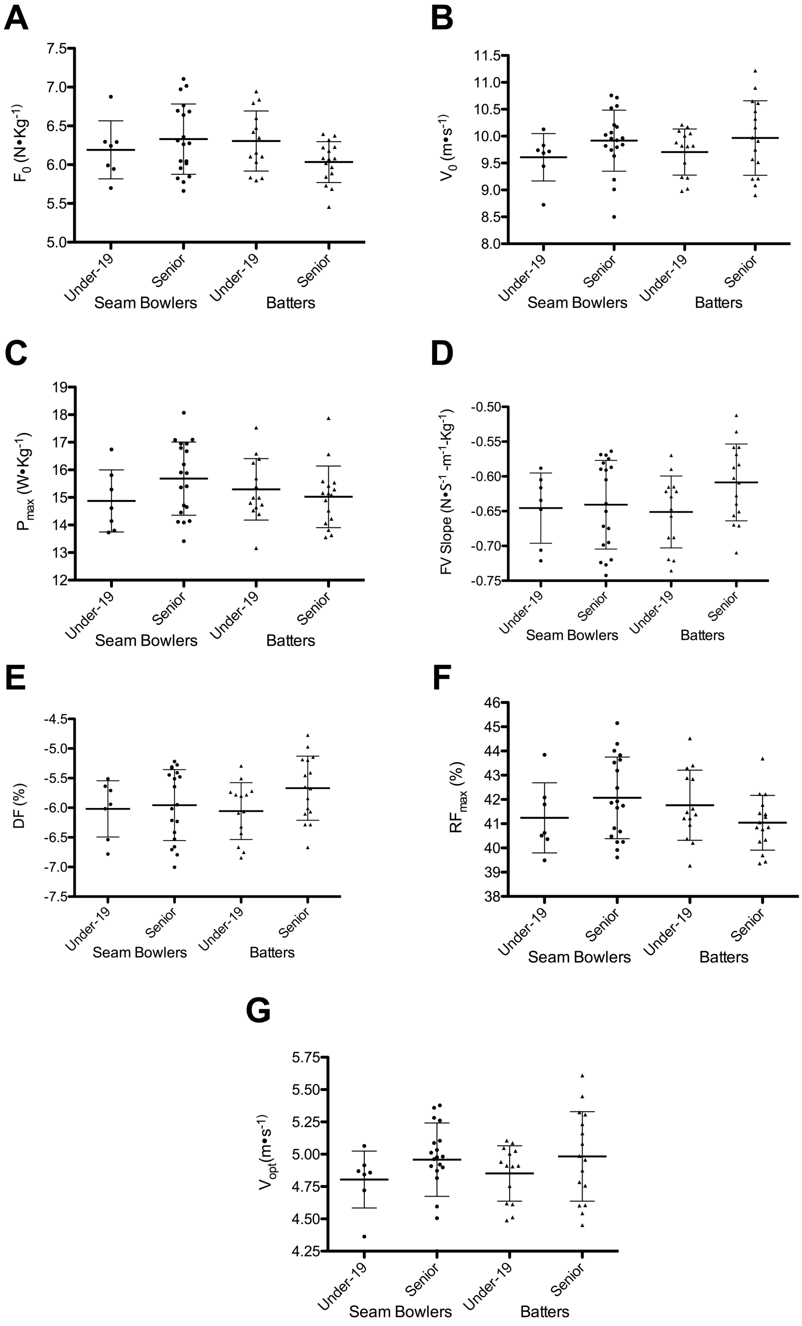

Figure 2. Individual and mean theoretical maximal force (A), theoretical maximal velocity (B), theoretical maximal power (C), slope of the force-velocity relationship (D), decrease in the ratio of horizontal-to-resultant force (E), maximal ratio of horizontal-to-resultant force (F) optimum velocity (G), max speed (H) across position and group.