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Comparing power hitting kinematics between skilled male and female cricket batters

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ABSTRACT

Organismic, task, and environmental constraints are known to differ between skilled male and female cricket batters during power hitting tasks. Despite these influences, the techniques used in such tasks have only been investigated in male cricket batters. This study compared power hitting kinematics between 15 male and 15 female batters ranging from university to international standard. General linear models were used to assess the effect of gender on kinematic parameters describing technique, with height and body mass as covariates. Male batters generated greater maximum bat speeds, ball launch speeds, and ball carry distances than female batters on average. Male batters had greater pelvis-thorax separation in the transverse plane at the commencement of the downswing ($\beta = 1.14$; $p = 0.030$) and extended their lead elbows more during the downswing ($\beta = 1.28$; $p = 0.008$) compared to female batters. The hypothesised effect of gender on the magnitude of wrist uncocking during the downswing was not observed ($\beta = -0.14$; $p = 0.819$). The causes of these differences are likely to be multi-factorial, involving aspects relating to the individual players, their history of training experiences and coaching practices, and the task of power hitting in male or female cricket.

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KEYWORDS
Batting; technique; cricket; batsmen; elite

Introduction

The ability of cricket batters to clear the boundary is a major contributor to success, particularly in the shorter formats of the game (Douglas & Tam, 2010; Irvine & Kennedy, 2017; Petersen et al., 2008). Previous research has investigated the relationships between body kinematics and bat speed during power hitting in male batters ranging from club to international standard (Peploe et al., 2019). Three kinematic parameters explained 78% of the observed variation in maximum bat speed: separation between the pelvis and thorax segments in the transverse plane (often referred to as the X-factor; McLean, 1992) at the commencement of the downswing; lead elbow extension during the downswing; and wrist uncocking during the downswing. Male batters who exhibited greater magnitudes of these three parameters were found to generate faster bat speeds, resembling previous research in golf (Chu et al., 2010; Myers et al., 2008; Robinson, 1994; Sprigings & Neal, 2000), baseball (Escamilla et al., 2009), and tennis (Landlinger et al., 2010), as well as subsequent research in badminton (King et al., 2020).

If skilled female batters generate lesser carry distances than their male counterparts (at a similar competition level) then it may be expected that they also generate lesser bat speeds and exhibit lesser magnitudes of the three kinematic parameters described above. However, these assumptions may not be true. For example, those parameters where differences exist between male and female elite cricket fast bowlers (Felton et al., 2019) are not the same as those parameters previously linked to performance outcomes in a cohort of male fast bowlers (Worthington et al., 2013). From a dynamical systems theory perspective, individual movement patterns are determined by the process of self-organisation (Kelso, 1995) and the interaction of organismic, environmental, and task constraints (Newell, 1986). Movement patterns may differ between male and female cricket batters due to differences in constraints which exist in all cases or on average. These include anthropometry (Stuelcken et al., 2007), force-velocity relationships (Torrejón et al., 2019), field of play boundary size (ICC, 2020a, 2020b), ball size and mass (ICC, 2020a, 2020b), bat inertial properties, incoming ball speed (Felton et al., 2019), and the characteristics of fielders. Coaching practices and training experience may also differ due to funding, professional status, and perceived or real differences in the above constraints (Fowlie et al., 2020; Munro & Christie, 2018). A kinematic comparison of male and female cricket batters of a similar relative competitive level can highlight the combined effects that these various influences have had on the emerging movement solutions, while readily available anthropometric factors such as body height and mass can be controlled for within any comparison (Nimphius, 2019). This may be particularly necessary given a known effect of body mass on generated bat speeds and related performance outcomes in baseball (Hoffman et al., 2009; Szymanski et al., 2009, 2010).

The majority of reported kinematic differences between male and female golfers involve pelvis and thorax rotations during the swing (Egret et al., 2006; Horan et al., 2011, 2010; Zheng et al., 2008). However, no differences have been reported between male and female golfers for the separation angle between pelvis and thorax (Horan et al., 2010). While

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experienced male golfers extend their lead elbow by 10° on average during the downswing, experienced female golfers flex their lead elbow by 24° on average (Egret et al., 2006). This represents a clear difference in movement strategy, although the observed lead elbow flexion was not replicated in higher ability professional female golfers (Zheng et al., 2008). It remains to be determined whether the constraints present for skilled male and female cricket batters lead to the emergence of similarly unique swing kinematics. Knowledge of the combined effects of these constraints on swing kinematics could facilitate the generation of future research questions regarding specific causal relationships.

The aim of the present study was therefore to compare power hitting kinematics between skilled male and female cricket batters while controlling for differences in body mass and height. Based on factors previously associated with greater bat speeds between male batters, it was hypothesised that skilled female batters would exhibit lesser magnitudes of separation between the pelvis and thorax segments in the transverse plane at the commencement of the downswing, less lead elbow extension during the downswing, and less wrist uncocking during the downswing compared to skilled male batters. To facilitate the generation of hypotheses for future testing, additional whole-body kinematic differences between skilled male and female batters were also explored.

Methods

Participants

Fifteen male (age 21 ± 3 years; height 1.83 ± 0.05 m; mass 80.4 ± 9.3 kg) and fifteen female (age 20 ± 3 years; height 1.71 ± 0.05 m; mass 68.6 ± 7.4 kg) cricket batters participated in this study. Participants included university (male n = 5; female n = 5), professional county (male n = 7), and international (male n = 3; female n = 10) players. Data from the ten male county and international players were included in a previous investigation (Peploe et al., 2019). All participants were free from any injuries that may affect their participation and completed a health screen questionnaire before taking part. The testing procedures were explained in accordance with Loughborough University ethical guidelines, and each participant completed an informed consent form. All procedures were conducted according to the Declaration of Helsinki for studies involving human participants.

Data collection

All testing was conducted at the England & Wales Cricket Board National Cricket Performance Centre in Loughborough, UK, on an indoor standard-sized artificial cricket pitch. Kinematic data were recorded using an 18 camera Vicon Motion Analysis System (OMG Plc, Oxford, UK) operating at 250 Hz. All participants completed a self-selected warm-up and a series of familiarisation trials of the power hitting task under equivalent testing conditions immediately before data collection.

Forty-six retro-reflective markers were attached to each participant (Figure 1) over, or on padding adjacent to, bony landmarks in the same locations as a previous power hitting kinematics investigation (Peploe et al., 2019). Five additional markers were positioned on the bat (Figure 1) and five 15 × 15 mm patches of 3 M Scotch-Lite reflective tape were placed on the ball according to previous methods (Peploe, McErlain-Naylor, Harland, Yeadon et al., 2018).

Each participant performed a series of shots (male 14 ± 3; female 18 ± 4) against a bowling machine (BOLA Professional; male release speed 32.4 m·s^{-1}; female release speed 25.7 m·s^{-1}), aiming to hit the ball straight back over the bowling machine for maximum carry distance in a match-representative manner. Ball release speeds were selected by an international coach as

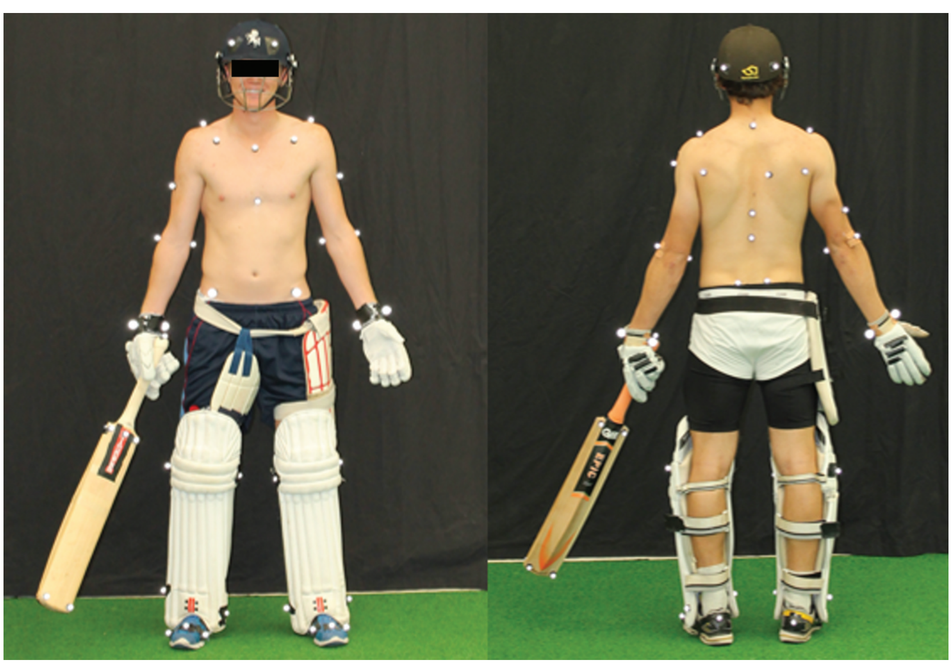

Figure 1. Retro-reflective marker positioning on player and bat.

representative of typical training conditions for each group (Felton et al., 2019). The bowling machine was directed towards a full length suitable for the power hitting task. Resultant incoming ball speed (after ball bounce) was 25.2 ± 1.2 m·s^{-1} and 20.1 ± 2.1 m·s^{-1} for male and female batters, respectively. Use of each participant's own bat avoided any effect of unfamiliar bat inertial properties on shot kinematics.

Data analysis

Initially, bat and ball marker data for all trials were labelled within Vicon Nexus software (OMG Plc, Oxford, UK). The logarithmic curve fitting methodology of Peploe, McErlain-Naylor, Harland, Yeadon et al. (2018) was used to determine resultant instantaneous post-impact ball speed and vertical ball launch angle (calculated from vertical and anterior-posterior instantaneous post-impact ball velocities) for each trial. Ball carry distance was calculated from resultant instantaneous post-impact ball speed and vertical launch angle using a validated iterative ball flight model accounting for air resistance (Peploe, 2016). The best trial for each participant (*i.e.* greatest ball carry distance) was identified and used in all further investigation.

Whole-body marker data for the best trial per participant were labelled within Vicon Nexus. Trajectories were filtered using a recursive two-way Butterworth low-pass filter with a cut-off frequency of 15 Hz, determined via residual analysis (Winter, 2009). All whole-body kinematics were defined and processed according to Peploe et al. (2019). Local coordinate systems were defined in Visual 3D (C-Motion Inc., Germantown, MD, USA). Joint centres were defined as the midpoint of a pair of markers positioned across the joint (McErlain-Naylor et al., 2014; Ranson et al., 2009) except for the hip (Bell et al., 1989) and thorax (Worthington et al., 2013). Joint angles were calculated as Cardan angles using an x-y-z sequence, corresponding to flexion-extension, abduction-adduction, and longitudinal rotation, respectively. Pelvis and thorax rotations were calculated relative to the global coordinate system using a z-y-x Cardan sequence (Baker, 2001). Whole-body centre of mass was computed from segment geometry and relative masses (Hanavan, 1964).

As in previous research, events corresponding to the commencement of the downswing, forward stride end, and bat-ball impact were identified for each trial (Peploe et al., 2014, 2019). Likewise, twenty-six kinematic parameters were calculated for each trial (Table 1) following the methodology of Peploe et al. (2019). Kinematic parameters described elements of technique associated with an increased bat, racket, or clubhead speed in other hitting sports, or that were thought to be important by elite coaches. Maximum resultant speed of the bat distal end-point during the downswing was determined from the mid-point of the two distal bat blade markers.

Statistical analysis

All statistical analyses were performed within jamovi (Sydney, Australia) software version 1.2.2. Data were presented as mean ± standard deviation. General linear models were used to assess the effect of gender on each dependent variable, with height and body mass as covariates. This was performed for

Table 1. Comparison of male and female cricket batters for each parameter (mean ± SD), including parameter estimates for the fixed effect of gender (height and body mass as covariates).

Parameter (° unless stated)	Male batters	Female batters	Estimate (95% CI)	SE	β	Interpretation	p
Ball launch speed (m·s^{-1})	33.5 ± 2.6	27.3 ± 2.8	5.35 (2.14, 8.58)	1.567	1.306	*Large*	0.002
Ball carry distance (m)	80.7 ± 10.0	57.7 ± 8.8	21.25 (10.03, 32.48)	5.459	1.429	*Large*	< 0.001
Maximum bat speed (m·s^{-1})	28.4 ± 2.5	22.6 ± 2.3	5.82 (3.00, 8.64)	1.371	1.542	*Large*	< 0.001
Bat angle DS	−167.4 ± 16.5	−164.0 ± 23.9	−4.97 (−30.30, 20.37)	12.325	−0.245	*Small*	0.690
Bat angle IMP	21.0 ± 7.0	16.8 ± 8.2	10.24 (1.59, 18.89)	4.210	1.311	*Large*	0.022
Bat angular rotation DS-IMP	188.4 ± 20.0	180.7 ± 25.0	15.21 (−12.29, 42.71)	13.378	0.674	*Moderate*	0.266
Bat CoM height DS (m)	1.24 ± 0.10	1.21 ± 0.13	−0.04 (−0.18, 0.10)	0.069	−0.340	*Small*	0.568
Wrist cocking angle DS	119.3 ± 11.8	118.7 ± 12.2	0.29 (−14.55, 15.13)	7.220	0.025	*Trivial*	0.968
Wrist cocking angle IMP	162.1 ± 8.5	168.9 ± 10.4	−4.00 (−15.33, 7.32)	5.508	−0.404	*Small*	0.474
Wrist uncocking min-IMP	**57.5 ± 14.7**	**61.9 ± 14.4**	**−2.00 (−19.85, 15.85)**	**8.683**	**−0.139**	***Trivial***	**0.819**
Lead elbow angle DS	121.2 ± 10.8	133.7 ± 27.5	−22.04 (−47.33, 3.24)	12.301	−1.025	*Moderate*	0.085
Lead elbow angle IMP	150.9 ± 13.7	130.8 ± 27.1	9.61 (−16.20, 35.41)	12.552	0.409	*Small*	0.451
Rear elbow angle DS	56.1 ± 8.1	65.4 ± 16.2	−2.35 (−17.77, 13.07)	7.501	−0.174	*Trivial*	0.757
Rear elbow angle IMP	126.3 ± 12.5	112.5 ± 10.6	13.80 (0.38, 27.23)	6.530	1.032	*Moderate*	0.044
Lead elbow extension DS-IMP	**29.7 ± 12.0**	**−3.0 ± 23.5**	**31.66 (9.16, 54.15)**	**10.944**	**1.280**	***Large***	**0.008**
Rear elbow extension DS-IMP	70.2 ± 13.4	47.1 ± 17.8	16.15 (−2.42, 34.72)	9.035	0.831	*Moderate*	0.086
Pelvis transverse angle IMP	−5.1 ± 8.6	−3.9 ± 10.1	5.51 (−4.86, 15.88)	5.045	0.596	*Small*	0.285
Thorax transverse angle IMP	−6.7 ± 13.5	−4.0 ± 12.5	8.37 (−6.57, 23.32)	7.271	0.651	*Moderate*	0.260
X-factor DS	**17.6 ± 8.3**	**12.4 ± 10.1**	**10.79 (1.16, 20.43)**	**4.688**	**1.141**	***Moderate***	**0.030**
X′-factor DS	22.3 ± 7.0	14.3 ± 8.5	7.60 (−1.85, 17.04)	4.596	0.879	*Moderate*	0.110
Max X-factor DS-IMP	24.9 ± 6.8	19.3 ± 7.6	7.25 (−1.30, 15.80)	4.158	0.947	*Moderate*	0.093
Max X′-factor DS-IMP	24.2 ± 8.1	16.2 ± 9.1	8.81 (−1.82, 19.44)	5.170	0.939	*Moderate*	0.100
X-factor stretch DS-max	7.2 ± 4.4	7.0 ± 5.3	−3.54 (−8.38, 1.30)	2.353	−0.743	*Moderate*	0.144
X-factor reduction max-IMP	23.3 ± 7.2	19.6 ± 8.3	9.40 (0.28, 18.52)	4.435	1.197	*Moderate*	0.044
X′-factor reduction max-IMP	19.3 ± 6.8	17.4 ± 7.2	3.71 (−4.43, 11.86)	3.964	0.538	*Small*	0.357
CoM A-P displacement min-IMP (m)	0.37 ± 0.11	0.46 ± 0.23	−0.17 (−0.38, 0.04)	0.102	−0.928	*Moderate*	0.113
Lead knee angle IMP	141.6 ± 14.1	146.1 ± 14.6	−8.47 (−26.10, 9.17)	8.579	−0.592	*Small*	0.333
Lead knee extension SEnd-IMP	−4.1 ± 12.0	−0.1 ± 9.7	−0.46 (−13.79, 12.87)	6.483	−0.042	*Trivial*	0.944
Base length IMP (m)	0.81 ± 0.10	0.82 ± 0.10	−0.06 (−0.18, 0.07)	0.059	−0.556	*Small*	0.360

Note: CI: confidence interval; SE: standard error; DS: commencement of downswing; IMP: impact; CoM: centre of mass; X-factor: transverse plane pelvis-thorax separation angle; X′-factor: frontal plane pelvis-thorax separation angle; A-P: anterior-posterior; SEnd: stride end; base length: the resultant distance between feet CoM; bold text: hypotheses identified a priori, all other tests were exploratory.

each of the three *a priori* hypotheses (separation between the pelvis and thorax segments in the transverse plane at the commencement of the downswing, lead elbow extension during the downswing, and wrist uncocking from minimum angle to impact), as well as for each of the other parameters explored (Table 1). The "effect of gender" was used to represent the combined organismic (other than height and body mass), environmental, and task constraints which potentially differ between genders. Effects were considered statistically significant at $p < 0.05$. Parameter estimates for the fixed effect of gender (with 95% confidence intervals: Harrison et al., 2020) were reported, as was the standard error (SE) and the standardised effect size estimate (β). Effect sizes were interpreted as: *trivial* < 0.2; 0.2 ≤ *small* < 0.6; 0.6 ≤ *moderate* < 1.2; 1.2 ≤ *large* < 2.0; *very large* ≥ 2.0 (Hopkins et al., 2009). Normality of the residuals was checked for all models (0.196 ≤ Kolmogorov-Smirnov *p*-value ≤ 0.993).

Results

Performance outcomes

The effect of gender was significant (male batters > female batters) for each of maximum bat speed (28.4 ± 2.5 *vs* 22.6 ± 2.3 $m{\cdot}s^{-1}$; β = 1.54, *large*; SE = 1.37; $p < 0.001$), ball launch speed (33.5 ± 2.6 *vs* 27.3 ± 2.8 $m{\cdot}s^{-1}$; β = 1.31, *large*; SE = 1.57; $p = 0.002$), and ball carry distance (80.7 ± 10.0 *vs* 57.7 ± 8.8 m; β = 1.43, *large*; SE = 5.46; $p < 0.001$) (Table 1, Figure 2).

Hypothesised effects

The effect of gender was significant (male batters > female batters) for pelvis-thorax transverse plane separation at the commencement of the downswing (17.6 ± 8.3 *vs* 12.4 ± 10.1°; β = 1.14, *moderate*; SE = 4.69; $p = 0.030$) and lead elbow extension during the downswing (29.7 ± 12.0 *vs* −3.0 ± 23.5°; β = 1.28, *large*; SE = 10.94; $p = 0.008$), but not for wrist uncocking from minimum angle to impact (57.5 ± 14.7 *vs* 61.9 ± 14.4°; β = −0.14, *trivial*; SE = 8.68; $p = 0.819$) (Table 1, Figure 3).

Exploratory effects

The effect of gender was significant (male batters > female batters) for each of bat angle about the global medio-lateral axis at impact (21.0 ± 7.0 *vs* 16.8 ± 8.2°; β = 1.31, *large*; SE = 4.21; $p = 0.022$), rear elbow angle at impact (126.3 ± 12.5 *vs* 112.5 ± 10.6°; β = 1.03, *moderate*; SE = 6.53; $p = 0.044$), and X-factor reduction from maximum separation to impact (23.3 ± 7.2 *vs* 19.6 ± 8.3°; β = 1.197, *moderate*; SE = 4.44; $p = 0.044$) (Table 1, Figure 4). For all other kinematic parameters, the effect of gender was not significant (Table 1).

Discussion

Skilled male cricket batters generated greater maximum bat speeds, ball launch speeds, and ball carry distances than their female counterparts. After controlling for the effects of body mass and height, male batters had greater pelvis-thorax separation in the transverse plane at the commencement of the downswing and extended their lead elbows during the downswing more than female batters. These two *a priori* kinematic hypotheses were therefore supported. However, there was no effect of gender on the magnitude of wrist uncocking during the downswing.

The confluence of organismic, environmental, and task constraints during the power hitting task resulted in kinematic differences between skilled male and female cricket batters. The earliest and most proximal of these differences involved transverse plane pelvis-thorax separation at the commencement of the downswing as hypothesised. Despite no differences in lower-body kinematics and no other differences before the downswing (Table 1), male batters exhibited moderately greater pelvis-thorax separation compared to female

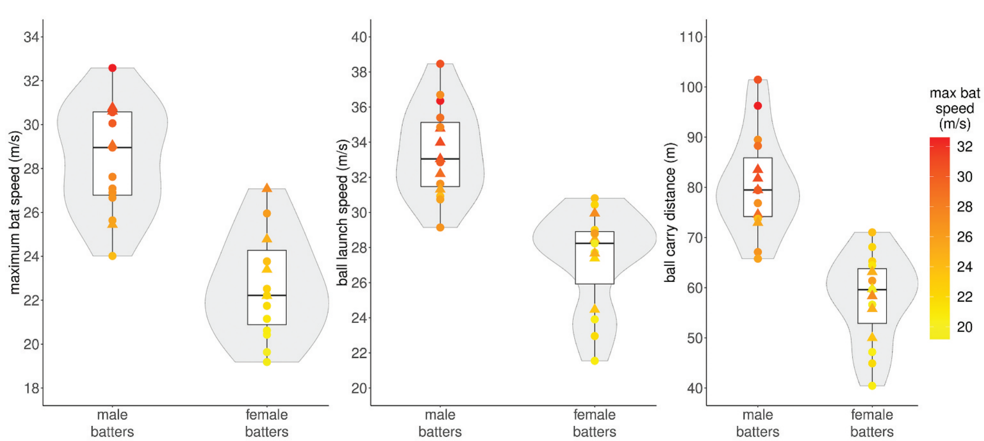

Figure 2. Performance outcomes: maximum bat speed (left), ball launch speed (middle), and ball carry distance (right) for university (triangle) and county to international (circle) male and female cricket batters. Colour-scale indicates maximum bat speed for each participant. Box and whisker plot indicates the median and interquartile range. Shaded density illustrates the distribution of data points.

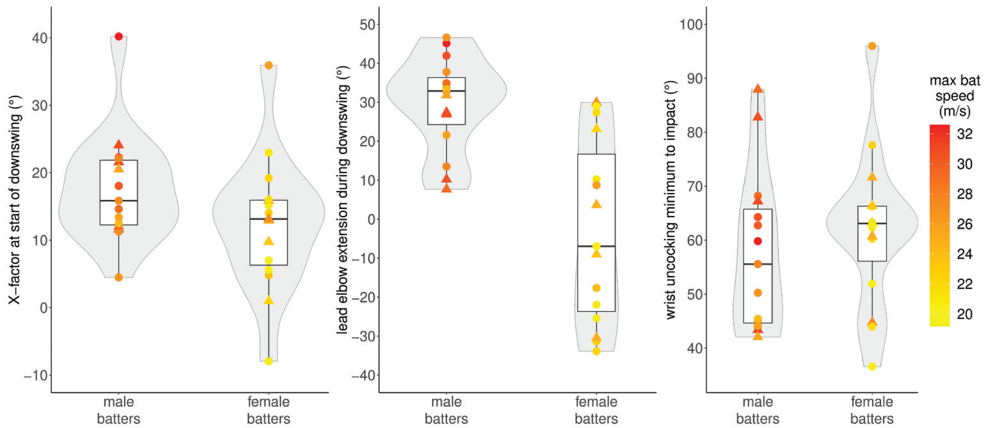

Figure 3. Hypothesised effects: X-factor at the start of the downswing (left), lead elbow extension during the downswing (middle), and wrist uncocking from minimum to impact (right) for university (triangle) and county to international (circle) male and female cricket batters. Colour-scale indicates maximum bat speed for each participant. Box and whisker plot indicates the median and interquartile range. Shaded density illustrates the distribution of data points.

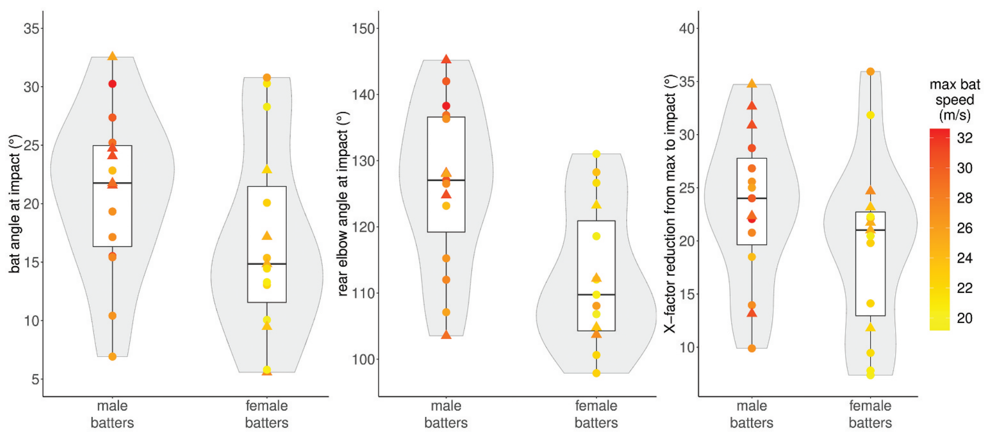

Figure 4. Exploratory effects identified: bat angle at impact (left), rear elbow angle at impact (middle), and X-factor reduction from maximum to impact (right) for university (triangle) and county to international (circle) male and female cricket batters. Colour-scale indicates maximum bat speed for each participant. Box and whisker plot indicates the median and interquartile range. Shaded density illustrates the distribution of data points.

batters (Figure 3). Greater separation, or "X-factor", may enable batters to make more effective use of the stretch-shortening cycle (Ettema, 2001; Komi, 1984, 2000), leading to faster uncoiling during the downswing (Myers et al., 2008). Indeed, exploratory analyses revealed that male batters subsequently exhibited a moderately greater reduction or "recoil" in pelvis-thorax separation during the downswing compared to female batters (Figure 4). Although the causes of these differences are unclear, it has been suggested that greater anticipation of incoming ball trajectory characteristics may facilitate greater torso axial rotations (McErlain-Naylor et al., 2020; Peploe et al., 2019). It may therefore be posited that the reported effects of gender reflect differences in anticipatory skill level. However, there was no clear difference in these torso rotational parameters between batters of different playing levels (university or international batters: Figures 3 and 4). Future research investigating individual-specific relationships between anticipation and torso rotations under varying task and environmental constraints may advance understanding in this area. This relationship will be further affected by the choice of (and experience with) ball speed and delivery method, with a bowling machine (used in the present study to control incoming ball trajectory) limiting the availability of pre-release visual cues and therefore acting as an additional constraint to influence emergent movement solutions (McErlain-Naylor et al., 2020; Peploe et al., 2014; Pinder et al., 2009, 2011).

Later in the proximal-to-distal kinetic chain, male batters exhibited greater lead elbow extension during the downswing (large effect size; Figure 3) and a moderately greater rear elbow angle at impact (Figure 4). There appears to be a difference on average in the emergent movement solution of male and female cricket batters at the elbow joint during this power hitting task. Male batters extended their lead elbow by 30 ± 12° whereas female batters flexed theirs on average by 3 ± 24°. This resembles the previous observation that experienced male golfers extend their lead elbow during the downswing by 10° on average, whilst experienced female golfers flex theirs by 24° (Egret et al., 2006). Eight female batters in the present study (range: −7 to −34°), but no male batters, flexed their lead elbow during the downswing (Figure 3). The nine greatest lead elbow extension magnitudes were all observed in male batters and the nine lowest (or most negative) extension magnitudes were all observed in female batters (Figure 3). These differences at the elbow joint perhaps reflect female batters using more of a traditional "checked drive" movement solution on average rather than a specific power hitting solution as used by male batters on average. A large difference in bat angle at impact was consequently reported – with male batters rotating their bat further forward beyond the vertical. Theoretically, greater lead elbow extension would provide a greater range through which to accelerate the forearm segment, and simultaneously increase the length of the bat-arm system at impact (Peploe et al., 2019). Lead elbow extension of up to 30° (Figure 3) suggests that power hitting solutions involving elbow extension are possible for female batters. Likewise, the lead elbow flexion observed by Egret et al. (2006) in female golfers was not replicated in greater skilled professional female golfers (Zheng et al., 2008). Indeed, the control of movement may differ more between male and female athletes at lower rather than higher skill levels (Lawrence et al., 2017). The effect of gender in the present study was present after controlling for the effects of body mass and height (i.e., the differences were not caused by players adapting to differences in body height). Observed differences are therefore likely a result of the specific organismic, environmental, and task constraints present for male and female batters, as well as their specific training experience and coaching histories.

One important organismic constraint is the absolute muscular strength of the batter. The greater body mass of the male batters (controlled for in the present study) is presumably associated with a greater absolute physiological cross-sectional area of muscle (Abe et al., 2003) (only partially controlled for via body mass), which would likely facilitate greater force production and body segment acceleration compared with female batters attempting to execute the same movement (Lieber & Fridén, 2000). Absolute strength affordances may therefore contribute to the selection by skilled female batters of a movement solution involving less elbow extension compared with the male batters, as may various other factors relating to equipment and the task itself. It is also possible that some female batters have not been coached to utilise a specific power hitting technique like that of the male batters. The purpose of the present study is not to fully explain the causal relationships underlying these differences but to identify the combined effects of organismic, environmental and task constraints for further exploration.

Environmental constraints include the interactions between human system and external equipment. Any influence of strength constraints on the emergent movement patterns would likely be relative to bat moment of inertia (Koenig et al., 2004). Using a bat with a larger relative moment of inertia not only slows the swing but leads to a reorganisation of the movement pattern (Southard & Groomer, 2003). In baseball, a lack of velocity transfer from the leading elbow to leading wrist is the most noticeable effect of increased bat inertia during warm-up on subsequent batting kinematics (Southard & Groomer, 2003). Qualitatively, the lead arm appeared to control and stabilise the swing rather than increasing bat velocity (*e.g.*, through elbow extension). This is the same pattern observed on average in the present study's female batters, suggesting that their bat moment of inertia may not be particularly well scaled to their absolute strength constraints. The relationship between equipment scaling (e.g., bat mass and length) and self-organisation of movement solutions within cricket batting tasks is an important area for subsequent research, with potential applications for the design of both equipment and coaching practices.

Task constraints such as the playing area boundary size differ between male and female cricket (ICC, 2020a, 2020b). If a female batter is able to clear the smaller boundary whilst flexing the lead elbow and utilising relatively little pelvis-thorax separation then there may be little stimulus or benefit to exploring alternative techniques. It remains possible that the reduced boundary size allows some batters to prioritise accuracy of bat-ball impact location and subsequent shot direction over bat speed (Peploe, McErlain-Naylor, Harland, King et al., 2018). Factors such as the margin for error in swing timing (i.e., reduced risk) and the ability to adapt to various types of ball delivery may also lead to the adoption of a particular technique under these female-specific task constraints where the impetus for even greater ball carry distances is removed.

This study has identified the greatest differences in power hitting kinematics between skilled male and female cricket batters. The causes of these differences are likely to be multifactorial, involving aspects relating to the individual players, their equipment, the task of power hitting in male or female cricket, and the history of training experience and coaching practices. Future research is necessary to determine the relationships between strength characteristics, bat moment of inertia, and cricket power hitting kinematics, particularly within female batters. Likewise, the relationship between anticipatory skills and axial torso rotations during cricket batting warrants further exploration. Players, coaches, and strength and conditioning practitioners should recognise the differences in predominantly elbow kinematics currently used by skilled male and female cricket batters to solve their relative power hitting tasks. Stakeholders should acknowledge and continue to investigate the roles of various constraints on the development of cricket batting technique within individuals and specific cohorts. Longitudinal interventions focusing on technical coaching and/or strength and conditioning are particularly important. Although a single best trial per player was used to represent individual-specific maximal performance in the present study, the effects of various constraints on intra-individual movement variability across multiple trials should also be explored in the future.

Conclusion

Skilled male cricket batters generated greater maximum bat speeds, ball launch speeds, and ball carry distances than skilled female batters. After controlling for the effects of body mass and height, male batters had greater pelvis-thorax separation in the transverse plane at the commencement of the downswing and extended their lead elbows during the downswing more than female batters. Eight female batters, but no male batters, flexed their lead elbow during the downswing. The hypothesised effect of gender on the magnitude of wrist uncocking during the downswing was not observed. The causes of these differences are likely to be multi-factorial, involving aspects relating to the individual players, their equipment, the task of power hitting in male or female cricket, and the history of training experience and coaching practices. Stakeholders should acknowledge and continue to investigate the roles of various constraints on the development of cricket batting technique within individuals and specific cohorts.

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