Neuromuscular Fatigue and Workload differs in Competition and Training within Elite Cricketers.

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ABSTRACT

Purpose: To firstly, assess changes in neuromuscular function via alterations in the countermovement jump strategy, after training and two forms of competition. Secondly, to compare the relationship between workloads and fatigue in seam bowlers and non-seam bowlers. **Methods:** Twenty-two professional cricketers' neuromuscular function was assessed at baseline, immediately post and +24 h post-training, as well as after multi-day and one-day cricket events. In addition, perceptual (rating of perceived exertion; RPE and soreness) measures and external loads (Player Load^{TM}, number of sprints, total distance, overs) were monitored across all formats. **Results:** Seam bowlers covered more distance, completed more sprints and had a higher RPE in training ($P < 0.05$), without any difference in soreness compared to non-seam bowlers. Interestingly, compared to seam bowlers, the non-seam bowlers peak force decreased post-24 h compared to baseline only in one-day cricket (95% CI 2.1 –110.0 N; $P < 0.04$). There were no pre-post training or match differences in jump height or alterations in jump strategy ($P > 0.05$). Seam bowlers increased their peak jumping force from baseline to immediately post training or game (95% CI 28.8 – 132.4 N; $P < 0.01$) but decreased between post-cricket to +24 h (95% CI 48.89 – 148.0 N; $P < 0.001$). **Conclusion:** Seam bowlers were more accustomed to high workloads compared to non-seamers and, thus, more fatigue resistant. Changes in jump height or strategy do not appear to be effective methods of assessing fatigue in professional crickets. More common metrics, such as peak force, are more sensitive.

Keywords: Counter Movement Jump, GPS, Fast Bowling, Neuromuscular fatigue, Cricket.

INTRODUCTION

There are three formats of professional domestic cricket in the United Kingdom. Multi-day cricket is a minimum of 96 overs per day, for up to four days. One-day cricket is played in both a 50 over and 20 over competition. Alongside the demands of training, an in-season period can become clustered and immensely challenging for professional players, coaches and support staff. Therefore, necessitating frequent workload monitoring and assessing the readiness to train through an efficient and sensitive tool is an essential part of practice.

Research in cricket has typically reported external measures of workload (i.e. training doses) from global positioning system (GPS) tracking[1], time motion analysis (TMA)[2], number of overs bowled[3-5] whilst internal loads have been quantified using subjective measures, such as perception of effort[6]. Whilst these techniques can quantify the training dose-response and provide indirect measurements of an athlete's functional state, it is preferable to accompany these monitoring strategies with direct assessments of neuromuscular function. For example, vertical jump testing, 20 m sprint tests, and peak power assessment using a cycle ergometer are popular iso-inertial field tests of neuromuscular function[7]. Of these tests, perhaps the most commonly adopted is the counter-movement jump (CMJ), as assessed on a force plate. Analysis of kinetic variables during the vertical jump permits greater insight into the neuromuscular responses of athletes to training or match stressors[7,8]. Furthermore, CMJ testing has been demonstrated to be more sensitive to detecting changes in post-exercise neuromuscular function than other jump tests[8]. The superior sensitivity of this reliable and practical test makes the CMJ one of the most appropriate methods for the assessment of an athlete's neuromuscular status[7].

Analysis of jumping movements have typically focussed on traditional output variables, such as jump height, peak force and peak power[4]. However, these variables only report the output of the movement and, therefore, do not represent the movement strategy used to achieve this output. An alternative analysis technique has been described, which also examines movement strategy in jumping tasks[7]. It was reported that this alternative analysis was more sensitive to fatigue-induced changes during the secondary (delayed) stages of post-exercise fatigue [7]. Using this technique, it has been established that longitudinal changes in training load are associated with modifications in jumping strategy among elite athletes[8]. However, the association between acute load, fatigue and changes in jump strategy following different sporting activities, such as cricket, is yet to be investigated.

In conjunction with further exploring the alterations in jump strategy associated with changing neuromuscular function, the suitability of one test to assess neuromuscular function within a team has not been fully explored. Previous research demonstrates that there appears to be a task specificity to assessing neuromuscular function[9,10]. Given the multitude of different biomechanical and physiological requirements in cricket[11] it may be the case a single test will not capture the neuromuscular demands of each position and consequently not be a suitable to detect changes in fatigue.

Physical workloads of bowlers are often measured by the number of balls delivered, overs completed or even specific micro-technology markers for greater accuracy[12]. It has been suggested that to minimise injury risk, elite bowlers should deliver 123-188 balls per week [13] although this can be exceeded with 50 plus overs being bowled in a 5-day match[5]. This approach is based on the established relationship with injury risk[3,14], despite it failing to account for other activities during play. Seam bowlers have demonstrated higher workloads during competition[15,16] and during training[4,6] compared with non-seam bowlers; however, the relationship with changes in neuromuscular function has not been investigated. Understanding the relationships between training and match load and neuromuscular function will help to inform the periodization and planning of training in practice.

The primary purpose of this study was to assess neuromuscular function in different cricket positions, through both traditional and alternative analyses of the CMJ, following cricket performance in training and competition among elite players. The secondary purpose was to assess internal workload after different cricket formats and to compare seam bowlers and non-seam bowlers' workloads.

METHODS

Participants

Twenty-two professional English County cricket players (mean ± SD age 24 ± 9 yrs, 182 ± 7 cm, 81 ± 3 kg) volunteered to take part in the study. Participants were assigned to either the Seam bowlers' group or non-Seam bowlers' group, based on their role in the team. Seam bowlers were categorised as players who bowl fast, medium-fast or medium pace, whereas non-seam bowlers, were wicket-keepers, specialist batsmen or spin bowlers[5]. Players who both bat and bowl were designated based upon their bowling style. For example, spin bowlers were categorised as non-seam bowlers' and medium to fast bowling all-rounders as seam bowlers. Ethical approval was granted prior to the start of data collection through the University of Derby Life and Sciences Ethics Committee and the study was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants give informed consent before the commencement of the study.

Procedures

Data were collected from training sessions, multi-day and 50 over matches during the 2016 English professional domestic cricket season. Training sessions were defined as any outdoor nets sessions during which seam bowlers were required to bowl a minimum of 10 overs per session. In total, data was collected from six training sessions, four multi-day and two 50 over matches.

Measurements of neuromuscular function were made prior to performance (baseline), immediately post (+ 0 h) and 24 h post (+ 24 h). Data collection for the +24 h testing session occurred at the same time of day as the baseline testing session from the day before. Participants completed a self-paced warm-up consisting of light jogging (~10 min), dynamic stretching and running activities of increasing speed (~5 min). Participants performed four CMJ trials. During each CMJ, participants held a wooden dowel across their back similar to a back-squat position. All jumps were strictly vertical, in that take-off and landing were performed within the area of the force plate (400 Series Force Plate, Fitech, Skye, Australia). Trials were sampled at 600 Hz using Ballistic Measurement System and software (BMS, Fitness Technology, Adelaide, Australia, Version) and participants were instructed to perform the CMJ “as they normally would” using a self-selected depth and “as maximally as they can”. This instruction provided opportunity to investigate changes in adopted jump strategy[7].

In each session, external workload was measured in two ways. Firstly, participants were fitted with a single wearable tracking device (MinimaxX S5, Catapult Innovations, Australia), sampling at 10-Hz. The wearable device contained a 100 Hz tri-axial accelerometer and was securely fitted below the neck, in the interscapula region of the thoracic spine using a manufacturer-supplied sports vest. Familiarisation with this device occurred in pre-season training sessions. Speed zones of 15-20 $km \cdot h^{-1}$ (jogging), 20-25 $km \cdot h^{-1}$ (high speed running) and 25 $km \cdot h^{-1}$+ (sprinting) were set, as per manufacture guidelines. Secondly, the number of balls bowled during performance was also recorded as a measure of external workload. Internal workloads were prescribed by the coach and reported daily in the form of rate of perceived exertion for the activity and the perceived soreness on a 10-point ratio scale.

Data Analysis

Jump height was calculated using the time in air method[17]. 'Typically derived' CMJ variables (CMJ-TYP) and time-based CMJ variables were calculated using a jump-start threshold based on a > 5% decrease in body weight. 'Alternative' CMJ variables (CMJ-ALT) variables were calculated by extraction of raw CMJ data from the BMS software and analysis using a custom written Matlab script. Descriptions of all variables can be found in supplementary table 1.

For all vertical jump tests, the three most consistent were selected to best represent the athlete's typical performance. The three most consistent trials were identified as those which were closest to the overall participant mean for the CMJ-ALT variable mean eccentric and concentric power over time (MEccConP)[7].

Statistical Analysis

Data were analysed using SPSS (version 22.0, Chicago, Illinois, USA) and data are presented as mean ± standard deviation (SD). To detect differences in the force platform variables across time (baseline, + 0 h and + 24 h. post), between positions (seam bowlers and non-seam bowlers) and game formats (training, multi-day and one-day), a three-way ANOVA was conducted. Data was screened to ensure all assumptions were met before performing the ANOVA. Univariate analysis of variance was used to assess differences in game formats and positions for soreness, RPE and all GPS variables. In both tests, the alpha level was set at 0.05. If significance interactions were detected, a Bonferroni post hoc test was used for pairwise comparisons. Additionally, 95% confidence intervals (CI) were used.

RESULTS

For both CMJ-ALT and jump height there was no significant difference ($P > 0.05$) in jump height across time, position and format (Table 1). However, there was a TIME X POSITION X FORMAT interaction ($F_{(2, 84)} = 2.5$; $P = 0.047$) for peak force. In training and multi-day games, the seam bowlers increased peak force from baseline to +0 h (Training - 95% CI 20.5–163.0N; $P < 0.01$; Multi-day - 95% CI 23.7–182.1N; $P < 0.01$) but decreased from +0 h to +24 h (Training - 95% CI 3.1–154.6N; $P = 0.04$; Multiday - 95% CI 97.5–266.9N; $P < 0.001$). Conversely, during one-day cricket, non-seam bowlers produced significantly greater magnitudes of peak force during baseline (95% CI 11.2 – 128.1N; $P = 0.03$) and +0 h (95% CI 20.0 – 234.0N; $P = 0.02$) conditions compared to + 24 h (Table 1). Furthermore, peak power changed across time ($F_{(2, 84)} = 13.7$; $P < 0.001$); pairwise comparison demonstrated increases from baseline to +0 h (95% CI 73.9 – 432.5.1W; $P < 0.01$) and subsequent decreases from +0 h to +24 h (95% CI 106.5–589.5W; $P < 0.01$).

There was no difference in soreness for seam bowlers and non-seam bowlers for training, multi-day and one-day cricket (Fig.1). However, RPE showed a FORMAT X GROUP interaction ($F_{(2, 38)} = 4.6$; $P = 0.02$). The *post hoc* analysis showed that seam bowlers perceived training harder than non-seam bowlers (95% CI 0.6 – 4.0AU; $P = 0.01$).

The GPS variables for the different formats are shown in supplementary table 2 Total distance was different between groups ($F_{(1, 44)} = 8.5$; $P < 0.01$) and formats ($F_{(1, 38)} = 6.1$; $P < 0.01$). Overall (training, multi-day and one-day), non-seam bowlers covered less distance compared to seam bowlers (95% CI 1018–5602m; $P < 0.01$) and a greater distance was covered in one-day cricket compared to training (95% CI 1383–8542m; $P < 0.01$). Seam bowlers performed more sprints (95% CI 16.0 – 49.0; $P < 0.001$), covered a greater distance between 15-20 $km \cdot h^{-1}$ (95% CI 318.8 – 820.4; $P < 0.001$) and 20-25 $km \cdot h^{-1}$ (95% CI 104.8 – 554.7; $P < 0.01$) but no statistically significant differences above 25 $km \cdot h^{-1}$. There were also no statistically significant differences ($P > 0.05$) in player load and player load per minutes.

DISCUSSION

The current study is the first to examine changes in neuromuscular fatigue in the different formats of cricket and training in elite senior crickets. It is also the first to investigate neuromuscular function in elite cricketers through both traditional-based and alternative analyses of the CMJ. The main findings were that, despite a constant higher workload across performance conditions, seam bowlers jump height, peak force and jump strategy did not change from baseline to +24 h. In addition, non-seam bowlers suffer a greater amount of fatigue compared to seam bowlers following 50-over cricket.

The results of studies investigating pre-post exercise jump height changes are equivocal[18-20]. The discrepant reports may be related to methodological differences between studies, with inconsistencies in the time taken between exercise cessation and testing, changes in the load placed on the individual and, importantly, differences in the modes of exercise under investigation. Of interest, the insensitivity of jump height to training and matches in our study supports the only other paper investigating neuromuscular fatigue in cricket[4].

It was anticipated that different movement strategies would have been used by both groups in the +0 h and +24 h conditions[7]. However, no significant differences across time, group or format were identified. This may be linked to the specificity of fatigue. For example, following exercise that heavily utilises the stretch shortening cycle (SSC), such as endurance running, reductions in drop jump, but not CMJ height, have been reported[9]. Additionally, fatigue-induced changes in CMJ height are correlated with the back-squat load but not any other mechanically dissimilar exercises[10]. The two wicket keepers in the study showed a relatively large change of 10% CMJ height. This is unsurprising as they performed a lot of bodyweight squats as part of their positional roles. Alternatively, seam bowling requires a large elastic energy production during the delivery[11] and an increase use of the SSC in the delivery run-up compared to other cricket positions, which might explain the lack of change in our data. Therefore, the CMJ may not be mechanically specific enough to detect fatigue in some cricket players, such as seam bowlers. Consequently, it appears that fatigue tests may be more sensitive around similar movement demands that dynamically correspond to the sport or positions.

Given the differing demands of the game formats and positions in cricket [16], it is unsurprising our study found differences in neuromuscular function post competition for the different cricket formats and positions. Non-seam bowlers demonstrated a reduction in peak force +24 h compared to baseline during one-day cricket. The reduced ability to produce peak force at +24 h indicated the presence of fatigue in non-seam bowlers in one-day cricket. In combination with the lower distance covered by the non-seamers compared to seamers across training and cricket formats, our data could suggest that non-seamers are less physically prepared for the match demands of 50 over cricket. Alternatively, the type of load experienced during batting may have impacted upon peak concentric force production, as opposed to the alternative measures, such as the force produced at the transition point of the jump[7]. It is our suggestion that task specificity should be considered whilst testing an athletes neuromuscular status[9] and that monitoring tests should be position or demand specific. Therefore, a test such as the reactive strength index may be more sensitive to fatigue in cricket, particularly with seam bowlers', due to larger elastic competent of seam bowling and greater use of the SSC.

Seam bowlers demonstrated greater peak force post activity across formats and training, compared to non-seam bowlers. This supports previous research, which has suggested that a potentiation effect occurs following lower levels of prior exercise[21]. Our data also adds to the literature that suggesting that post activation potentiation may not be task specific and consequently may be more neutrally supraspinal and/or spinal mediated[22,23] as opposed to being only due to biomechanical alterations a muscle level[24]. A potentiation effect was also evident with peak power from baseline to immediately post performance condition. Whilst this seemingly conflicts with reports from sports, where no change[20,25,26] or lower peak power values [27] have previously been reported following match performance, these results were found in collision team sports, where the demands and subsequent manifestation of fatigue is different. However, it has to be noted that there was no change in jump height or peak power. Consequently, whether a potentiation effect has occurred is speculative.

The current study adds to limited existing knowledge of training loads for professional cricketers. As with previous literature, the seam bowlers group were subjected to greater workloads than the non-seam bowlers in training[4] and competition[1,16]. Seam Bowlers are thought to demonstrate higher workloads as they take part in all aspects of training[4]. The current study supports this, as the seam bowlers took part in fielding, bowling and batting practices during training, whereas members of the non-seam bowling group only took part in batting and fielding practices. Competition workloads were also higher for seam bowlers than non-seam bowlers, which supports previous literature[15,16]. The wellness scores indicated that seam bowlers found training more difficult, this is to be expected given the larger external workloads experienced. Interestingly, despite seam bowlers finding training difficult and performing at higher workloads, only the non-seam bowlers showed any evidence of fatigue. Whether this is due to higher fitness levels is unclear but increasing the workloads of non-seam bowlers in training may have reduced the fatigue levels associated with one-day cricket. It was beyond the score of this paper, however given the popularity of Twenty20 cricket around the word, future research should focus on the demands and neuromuscular fatigue within this shorter format.

CONCLUISIONS

Jump height might not be an appropriate assessment of neuromuscular fatigue in elite cricketers. Additionally, changes in jump strategy were also insensitive to fatigue. We suggest that the CMJ lacks the task specificity to detect fatigue following cricket performance. However, variables such as peak force or peak power appear to be more sensitive to change and, therefore, more applicable for the assessment of readiness to train. Our data also show that, despite seam bowlers covering greater distances in training and competition, there was no difference in muscle soreness +24 h after activity compared to non-bowlers. In addition, non-seamers bowlers showed a greater evidence of fatigue despite lower workloads.

PRACTICAL IMPLICATONS

- Non-seamers bowlers suffer greater fatigue from 50-over match play compared to seam bowlers. Consequently, the recovery process of practisers should meet this needs.
- Jump height and an alternative jump strategy analysis may not detect the fatigue induced following cricket performance.
- Typical measures, such as peak force appear to be more sensitive to fatigue in the +24h post cricket performance and, thus, practitioners should use this variable to assess readiness to train.
- Fatigue tests should be mechanically similar to the sport.

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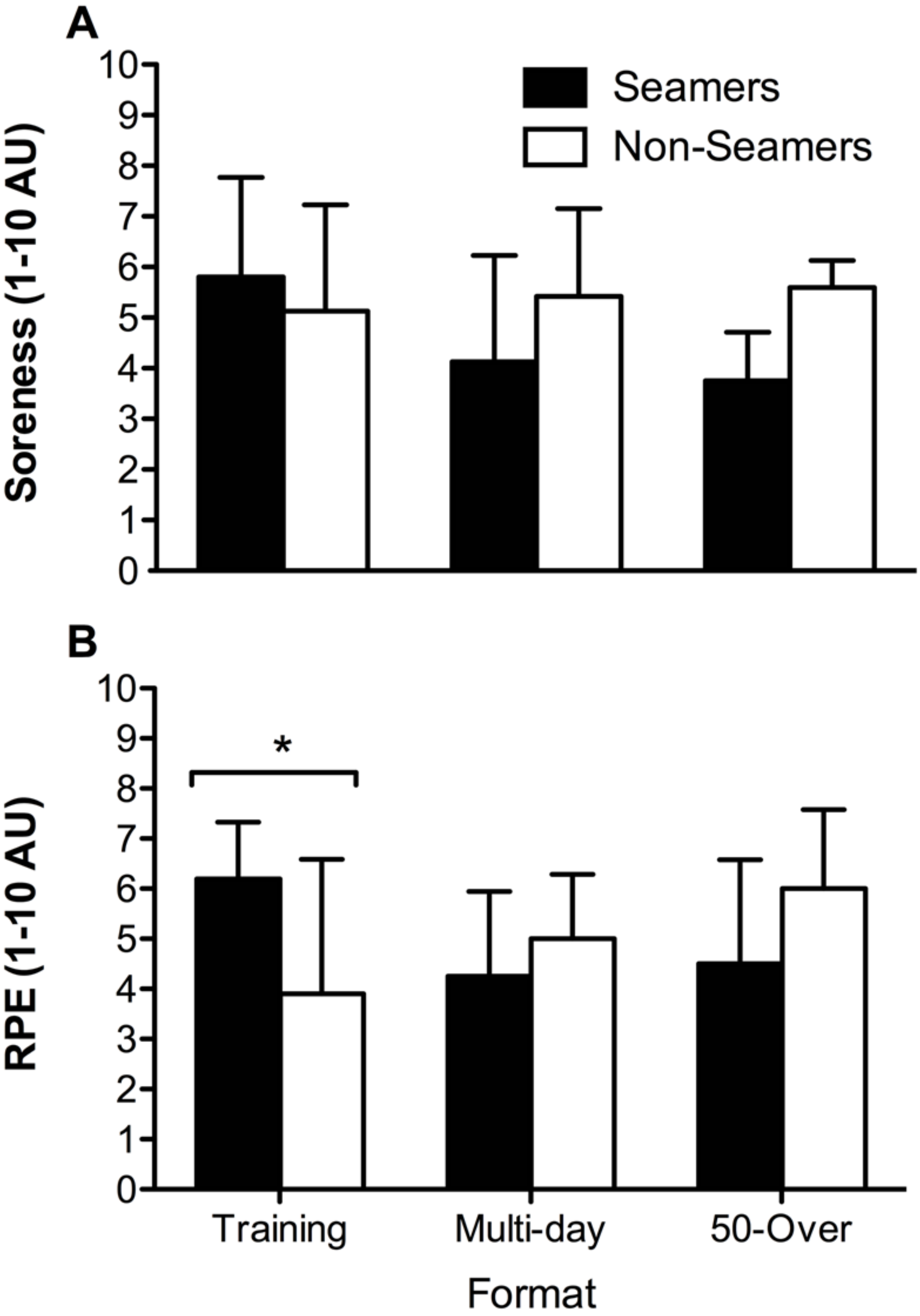
TITLES OF FIGURES

Figure 1. Reported RPE (**A**) and soreness (**B**) following training, multi-day and one-day cricket in seam bowlers and non-seam bowlers.

Figure 2. Representative CMJ seam bowler trace for force (**A**) and power (**B**) pre, immediately post and 24 h post training.


A
Seamers
Non-Seamers
Soreness (1-10 AU)
0
1
2
3
4
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6
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8
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10
B
*
RPE (1-10 AU)
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1
2
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6
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8
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Training
Multi-day
50-Over
Format

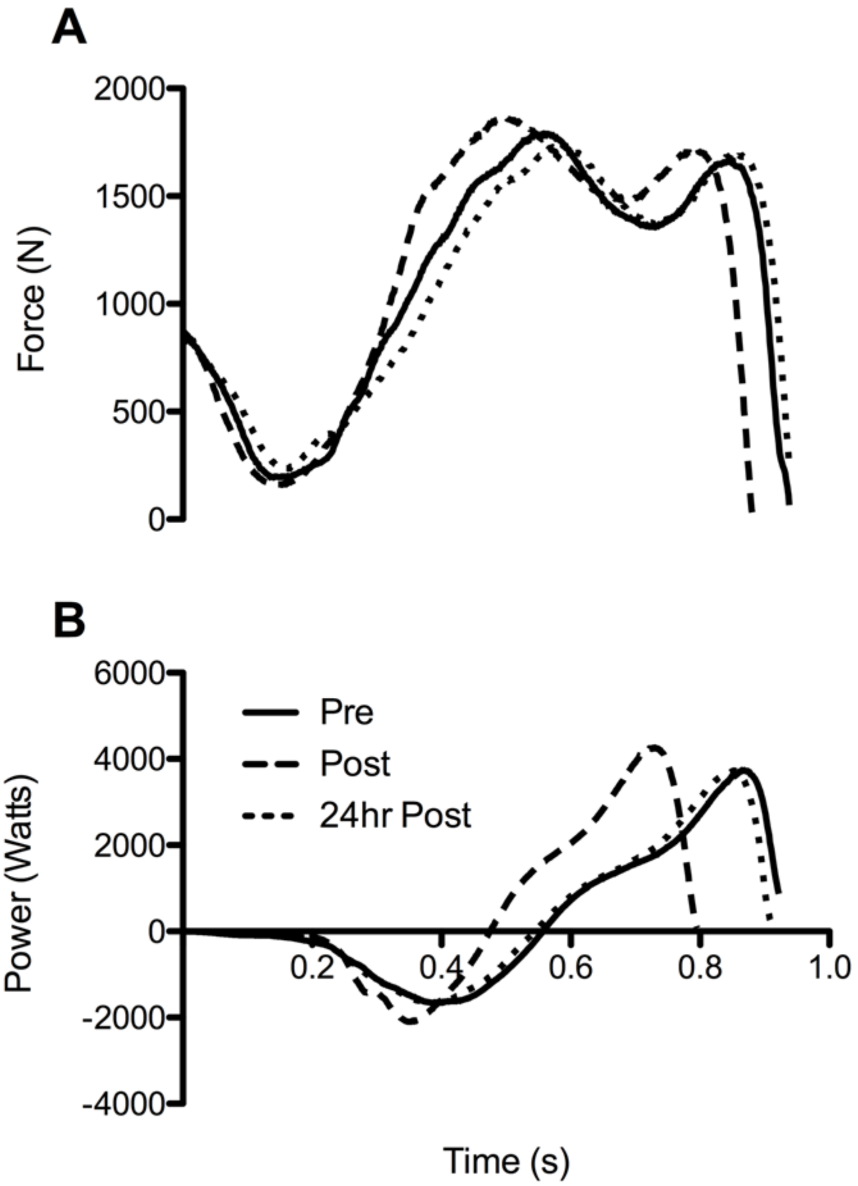
A
Force (N)
2000
1500
1000
500
0
B
Power (Watts)
6000
4000
2000
0
-2000
-4000
0.2
0.4
0.6
0.8
1.0
Pre
Post
24hr Post
Time (s)

Table 1. Changes in typical and alternative jump variables in seamers and non-seamers across training, multiday and 50-over cricket.

	Training					
	Seamers			Non-Seamers		
	Pre	**Post**	**24hr post**	**Pre**	**Post**	**24hr post**
JH (m)	0.33± 0.03	0.33± 0.03	0.33±0.03	0.38 ± 0.07	0.39 ± 0.08	0.38 ± 0.08
PP (W)	7825± 675	8330 ±844	8018 ±744	8422 ± 974	8397 ± 931	8353 ± 846
PF (N)	1799 ± 196	1890 ± 169 *	1811 ± 175	1878 ± 259	1842 ± 214	1851 ± 234
EccDur (s)	0.57 ± 0.07	0.53 ± 0.04	0.57 ± 0.05	0.53 ± 0.04	0.54 ± 0.06	0.53 ± 0.06
ConDur (s)	0.33 ± 0.04	0.32 ± 0.03	0.33 ± 0.04	0.32 ± 0.03	0.31 ± 0.03	0.32 ± 0.04
FT: TotDur	0.58 ± 0.09	0.62 ± 0.07	0.58 ± 0.07	0.66 ± 0.08	0.66 ± 0.09	0.66 ± 0.09
F@Trans (NKg^{-1})	19.89 ± 2.49	19.54 ± 2.31	19.02 ±2.21	20.97 ± 1.42	21.01 ± 2.26	21.18 ± 1.47
MEccConP (Ws^{-1})	10.51 ± 3.67	11.80 ± 2.25	10.38 ± 2.47	13.05 ± 2.55	13.17 ± 3.60	13.04 ±2.99
	Multiday					
	Seamers			**Non-Seamers**		
	Pre	**Post**	**24hr post**	**Pre**	**Post**	**24hr post**
JH (m)	0.32 ± 0.03	0.31 ± 0.04	0.31 ± 0.03	0.38 ± 0.08	0.38 ± 0.08	0.35 ± 0.07
PP (W)	7879 ± 690	8050 ± 1000	7451 ± 613	8211 ± 1031	8545 ± 1271	8262 ± 1253
PF (N)	1790 ± 205	1898 ± 193*	1716 ± 136	1844 ± 238	1850 ± 242	1829 ± 285
EccDur (s)	0.57± 0.07	0.54± 0.08	0.59 ± 0.09	0.53 ± 0.04	0.54 ± 0.06	0.53 ± 0.06
ConDur (s)	0.34 ± 0.04	0.32 ± 0.05	0.35 ± 0.04	0.31 ± 0.03	0.29 ± 0.04	0.33 ± 0.05
FT: TotDur	0.58 ± 0.10	0.61 ± 0.13	0.55 ± 0.10	0.66 ± 0.09	0.68 ± 0.10	0.62 ± 0.07
F@Trans (NKg^{-1})	19.54 ± 2.39	19.55 ± 2.45	18.37 ± 2.27	21.11 ± 1.49	20.99 ± 1.30	19.32 ± 2.37
MEccConP (Ws^{-1})	10.67 ± 3.87	11.76 ± 4.60	9.73 ± 3.23	13.25± 2.80	13.99 ± 3.43	13.61± 5.04
	50-over					
	Seamers			**Non-Seamers**		
	Pre	**Post**	**24hr post**	**Pre**	**Post**	**24hr post**
JH (m)	0.32 ± 0.03	0.30 ± 0.02	0.30 ± 0.03	0.37 ± 0.07	0.38 ± 0.09	0.36 ± 0.07
PP (W)	7558 ± 718	7386 ± 570	7187 ± 565	8387 ±1264	8640 ± 1331	7961 ± 1336
PF (N)	1672 ± 124	1703 ± 138	1655 ± 95	1936 ± 255	1935 ± 228	1808 ± 229*ƚ
EccDur (s)	0.58 ± 0.04	0.57 ± 0.04	0.55 ± 0.04	0.52 ± 0.05	0.53 ± 0.06	0.52 ± 0.04
ConDur (s)	0.35 ± 0.02	0.34 ± 0.02	0.34 ± 0.04	0.28 ± 0.02	0.28 ± 0.02	0.28 ± 0.03
FT: TotDur	0.55 ± 0.05	0.55 ± 0.04	0.56 ± 0.06	0.69 ± 0.10	0.70 ± 0.10	0.68 ± 0.10
F@Trans (NKg^{-1})	19.04 ± 1.23	18.31 ± 1.24	18.58 ± 1.24	22.13 ± 1.30	22.03 ± 0.94	21.94 ±1.41
MEccConP (Ws^{-1})	9.73 ± 1.50	9.85 ± 1.43	10.40 ± 2.21	14.52 ± 3.44	14.79 ± 4.09	14.30 ± 3.07

*Significantly different from pre; ƚsignificantly from post

Abbreviations: JH, Jump Height; PP, Peak Power; PF, Peak Force; EccDur, Eccentric Duration; ConDur, Concentric Duration; FT:TotDur, Flight Time: Total Duration; F@Trans, Force at Transition; MEccConP, Mean Eccentic Concentric Power