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Research article

Accelerometery and Heart Rate Responses of Professional Fast-Medium Bowlers in One-Day and Multi-Day Cricket

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Abstract

The physical demands of fast-medium bowling are increasingly being recognised, yet comparative exploration of the differing demands between competitive formats (i.e. one-day [OD] versus multi-day [MD] matches) remain minimal. The aim of this study was to describe in-match physiological profiles of professional fast-medium bowlers from England across different versions of competitive matches using a multivariable wearable monitoring device. Seven professional cricket fast-medium bowlers wore the Bioharness™ monitoring device during matches, over three seasons (>80 hours in-match). Heart Rate (HR) and Accelerometry (ACC) was compared across match types (OD, MD) and different in-match activity states (Bowling, Between over bowling, Fielding). Peak acceleration during OD bowling was significantly higher in comparison to MD cricket ([OD vs. MD] 234.1 ± 57.9 vs 226.6 ± 32.9 ct·episode^{-1}, $p < 0.05$, ES = 0.11-0.30). Data for ACC were also higher during OD than MD fielding activities ($p < 0.01$, ES = 0.11-.30). OD bowling stimulated higher mean HR responses (143 ± 14 vs 137 ± 16 beats·min^{-1}, $p < 0.05$, ES = 0.21) when compared to MD matches. This increase in OD cricket was evident for both between over (129 ± 9 vs 120 ± 13 beats·min^{-1}, $p < 0.01$, ES = 0.11-0.50) and during fielding (115 ± 12 vs 106 ± 12 beats·min^{-1}, $p < 0.01$, ES = 0.36) activity. The increased HR and ACC evident in OD matches suggest greater acute physical loads than MD formats. Therefore, use of wearable technology and the findings provided give a valuable appreciation of the differences in match loads, and thus required physiological preparation and recovery in fast-medium bowlers.

Key words: Wearable monitoring, physiological profiles, in-match data, technology.

Introduction

Fast bowling is recognised as the most physically demanding role in cricket with these "pace" bowlers having the highest injury rates and shortest career spans within the sport (Orchard et al., 2016; Johnstone et al., 2014; Dennis et al., 2005). This group undertake high repetitive loading of the bowling action multiple times a day coupled with greater absolute distance (~22 km), the most distance per hour and highest number of sprints (>5.01 m.sec^{-1}) in comparison to other cricket players (Petersen et al., 2010; 2011). These movement demands placed on the fast-medium bowler are suggested to be exacerbated in One Day (OD) cricket compared to the Multi Day (MD) format with increased relative intensity in the shorter format (i.e. greater number of high intensity actions per hour). However, cricket specific evidence for strength and conditioning professionals is based on a limited range of data primarily from Australia therefore application to other countries is unclear (Petersen et al., 2009; 2010; 2011).

The limited physiological fast-medium bowling peer reviewed research from the previous 25 years identifies that evidence is derived primarily from simulated non-competitive bowling environments. Moreover there are inconsistent measures being noted (i.e. heart rate, blood lactate, run-up velocity etc.) limiting the generalisation of the data for exercise professionals who are seeking to apply the evidence to in-match situations. Fast-medium bowling research has seen a logical move towards understanding physical responses and movement during the actual bowling episode (Petersen et al., 2011; Duffield et al., 2009), providing more detailed information for the exercise professional. Critically though, data collections are often short (~6 overs) and are not match-specific, and thus differences between match formats (i.e. Twenty-Twenty [T20], One Day [OD], Multi Day [MD]) remain equivocal. In part, such lack of match-based understanding means the between bowling (or between-over) activity, i.e. where-by the bowler has time to recover between bowling successive overs, is another match-specific window that remains unexplored. In previous research this between over non-bowling episode is either standardised, ignored or hypothesised as to what the activity entails, and therefore how it would affect subsequent bowling performance.

With the on-going requirement of fast-medium bowlers to regularly play both the shorter (i.e. <1 day) and longer (i.e. >1 day) forms of cricket, understanding match-specific physical stresses is fundamental to permit exercise specialists plan evidence based appropriate training and recovery strategies. Advances in unobtrusive (wearable) physiological monitoring technology now permits the exercise professional to access more objective data from such competitive situations, potentially providing for applied exercise professionals new insights in to match loads of differing competitive formats (Johnstone et al., 2014; McNamara et al., 2015). Therefore, the aim of this study was to describe the in-match accelerometry and heart rate responses of English professional fast-

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medium bowlers between OD and MD competitive cricket using a multivariable wearable monitoring device.

Methods

General design

An observational research design was used to describe the in-match physiological and accelerometry responses of fast-medium bowlers. Data (Hours; MD 52.2, OD 29.6; Overs: MD 181, OD 85) were collected between May and July over three consecutive seasons, inclusive of 47 match files. Data were collected using the Bioharness^{TM} (Version1, Zephyr tech, Maryland, USA) which is a validated physiological multivariable mobile monitoring device measuring five simultaneous variables (Heart rate [HR], Breathing Frequency, Skin Temperature, Accelerometry [ACC] and Posture). The Bioharness^{TM} is worn against the skin by the participant via an elasticated strap attached around the chest. Version 1 of the Bioharness^{TM} monitoring device (weight 35 g, 80x40x15 mm) attaches to the front of the chest strap (50 g, 50 mm width), acts a data logger or transmitter, and has a memory of up to 480 hours and battery life of up to 10 hours in logging mode. Variables are measured simultaneously, time stamped and exportable to Excel. Based on earlier studies (Johnstone et al., 2012a; 2012b; 2012c) heart rate and accelerometry (dependent variable) were deemed the most precise and reliable variables (heart rate r = .91, CV <7.6%; Accelerometry r = .97, CV <14.7%) and were analysed relative to the match type and match state (independent variable). Heart rate data is captured through electrode sensors housed within the chest strap sampled at 250 Hz and reported as beats per minute (beat.min^{-1}). Tri axial accelerometry, using piezoelectric technology (i.e. cantilever beam set up) samples at 18 Hz and reports in counts per second (ct.sec^{-1}; 1 Hz). Acceleration data is measured in gravitational force (g) in a range of -3 to +3 g on each single axis or as Vector Magnitude Units (VMU) which is an integrated value over the previous 1 second epoch.

Participants

Following institutional ethics committee clearance (LS/3/2/09P(R1)), 7 English professional first-class cricketers (mean ± SD; age 24.8 ± 5.2 years; mass 89.7 ± 10.8 kg; stature 1.87 ± 0.08 m; sum of 8 skin fold 86.2 ± 19.6 mm) classified as right arm fast-medium paced bowlers (mean bowling speeds ranging 128–136 km·h^{-1}, recorded from televised matches) provided written informed consent. At the start of each season, participant's maximal aerobic capacity (VO_2max 52.3 ± 4.1 mL·kg^{-1}·min^{-1}; Multi-stage Shuttle Run (Ramsbottom et al., 1988) and linear speed (5m 1.1 ± 0.1; 10m; 1.8 ± 0.1; 20m 3.0 ± 0.1; Brower Timing TC system, USA) were measured.

Procedures

Prior to all matches, players followed a prescribed pre-match routine; no alcohol (24 hrs), avoiding caffeine (2 hrs), maintaining a well-rested and hydrated state. Pre-match hydration status was measured by urine osmolality (Osmocheck, Vitech Scientific, UK) with pre-match exclusion threshold set at ≥800 mOsmo (Armstrong et al., 1998). Participants' pre-match mean hydration status was 541.7 ± 227.1 mOsmols which was within the set threshold. To further control the data collection, environmental temperature was monitored (Portable Weather Station; Oregon Scientific, UK; Online reports, The Met Office, UK) and if ≥ 27^{o}C (Sawaka et al., 2006) and/or the match was interrupted by rain, data were retrospectively removed from the analysis. Eleven files were not included due to environmental or technical issues (i.e. software error). Therefore, 36 match files entered the analysis (5.1 ± 2.0 files per player). An individual Bioharness^{TM} device was assigned to each participant, synchronised to the official match scorer (laptop M750, Toshiba Portege) and was fitted after the warm up by the same researcher 15 minutes prior to the match commencing to record pre-match baseline heart rate. At set breaks during the match (i.e. lunch), devices remained on players but this data was removed retrospectively from analysis. Matches were classified as multi-day (MD) lasting 3 or 4 days or one-day (OD) 50 over cricket. Match activity periods, or episodes (bowling, between over and fielding) were determined through the use of the official match scorer and accelerometry data captured by the Bioharness^{TM}. Additional information on bowlers' run-up characteristics were recorded (length [m] 20.1 ± 2.7; time [sec^{-1}] 3.6 ± 0.5; velocity [Km·h^{-1}] 19.9 ± 1.6) and subsequently the bowling episodes were defined as 10 seconds prior to the first delivery in the over and ending 10 seconds after the last delivery of the over. By outlining the bowling episodes, the between-over and fielding episodes became self-defining.

Statistical analysis

An automated batch processing method (R Version 3.0.0, http://www.R-project.org/) (Wand, 2013) was used to generate match outputs required (Figure 1). A cross-validation of this process identified 3% error rate from 1596 deliveries (n = 36 files) which were then corrected manually based off information gleaned from official scorers match cards.

A variety of measures were available from the accelerometry variable (count [ct] ·episode^{-1}); a combined activity metric Vector Magnitude Units (VMU) would present a quantifiable physical activity measure (Chen and Bassett, 2005), peak acceleration (max 3-axis magnitude during previous 1 second), and individual axes were analysed (vertical; lateral, sagittal). When reviewing the acceleration data from the vertical axis, peak values for both upward (negative) and downward (positive) directions presented only upward (negative) values. Therefore values for the downward acceleration were removed from the analysis as they provided little useful information.

Recorded heart rate measured during different match periods included absolute (beats.min^{-1}) and relative values (i.e. age related or from non-active baseline heart rate) which have been documented in previous studies (Lambert and Borresen, 2006; Barbero-Alvarez et al., 2008). Heart rate (HR) recovery values 10 seconds pre (HR_{10}) and 60 seconds post (HR_{60}) bowling episodes were also captured. During some high intensity bowling episodes artefacts (< 50 or > 200 beat·min^{-1}) in the heart rate data were identified so Polynominal smoothing was implemented (Ruppert et al., 1995; Zakeri et al., 2008).

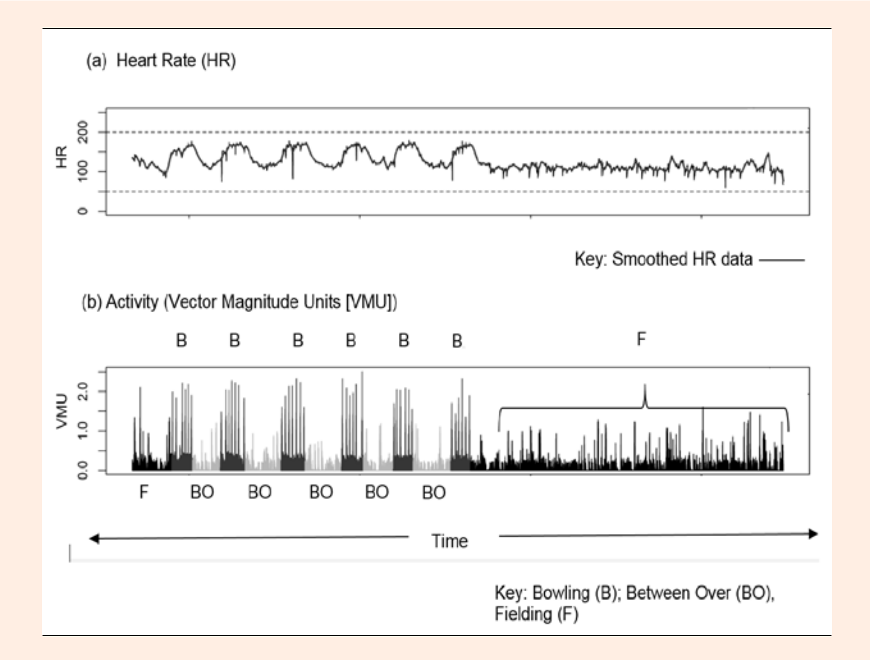

Figure 1. **An example screen shot of 120 min of processed OD match data which included a 6 over bowling episode from one participant with (a) Heart rate (beats.min^{-1}) and (b) Activity VMU ct.episode^{-1} measured simultaneously.**

Data were exported (Excel Microsoft Windows) from the Bioharness[TM] device to statistical software package (SPSS v20) for analysis. Data was assessed for distribution using Kolmogorov-Smirnov test and where appropriate parametric independent statistical tests (T-test) and non-parametric alternatives (Mann-Whitney U) were chosen as data are not directly paired. Further, the magnitude of difference between match formats was determined from the standardised effect sizes (ES; Cohen's d)) (*d*= 0.10 classed as small effect, *d*= 0.30 medium effect and *d* = 0.50 a large effect) which were also reported to provide additional understanding of the significance of the outcome (Field and Miles, 2010; O'Donoghue, 2012).

Results

Descriptive data for OD matches bowling episodes (208.2 ± 25.6 sec^{-1}) and between over episodes (346.6 ± 73.9 sec^{-1}) were completed in a faster time in comparison to MD matches bowling (235.2 ± 38.2 sec^{-1}) and between over episodes (359.6 ± 52.1 sec^{-1}). Further, scoring rate (runs per over [r.p.o]) off respective bowling periods was significantly higher in OD matches (4.00 ± 3.04 r.p.o.) in comparison to MD (3.1 ± 3.2 r.p.o.) ($p < 0.05$, ES = 0.17).

During bowling (Table 1), a significantly ($p < 0.05$) higher cumulative peak acceleration (ES = 0.12) and lateral right (ES = 0.13) activity were recorded in OD compared to MD matches. However, lateral left axis values recorded were significantly higher in MD cricket, despite small ES between formats ($p < 0.05$, ES = 0.17). Between over, lateral left axis presented as significantly ($p < 0.05$, ES = 0.20) higher values in MD cricket, but with the exception of the sagittal posterior axis, a trend for higher values were noted in OD format compared to MD. During fielding activities all accelerometry data presented significantly ($p < 0.05$, ES = 0.24 - 0.32) higher values for OD matches with small to medium ES compared to MD.

Except for $HR_{60r,}$ in comparison to the MD format, heart rate values were significantly ($p < 0.05$) higher with small to medium ES during OD bowling were noted (HR ES = 0.21, HR_{age} ES = 0.17, HR_{max} ES = 0.12, HR_{min} ES =0.41, HR_{minage} ES = 0.33) (Table 2). There was no significant difference ($p > 0.05$) between the two match formats reported for HR_{10r}, HR_{60r} and HR_{maxage}.

Table 1. **Change (Ch ±) of cumulative ACC data (ct·episode^{-1}) during different match states in OD and MD matches. Data are Mdn (± IQR).**

	Bowling			Between Over			Fielding		
	One Day	**Multi Day**	**Ch ±**	**One Day**	**Multi Day**	**Ch ±**	**One Day**	**Multi Day**	**Ch ±**
VMU	115.4 (143.4)	113.7 (16.5)	-1.7	63.3 (16.6)	62.5 (22.1)	-0.8	448.5 (883.6)	144.8 (445.7)	-303.7[b c]
Peak accel	234.1 (57.9)	226.6 (32.9)	-7.5[a c]	136.4 (46.0)	126.5 (47.4)	-9.9	1349.9 (2607.4)	356.1 (1097.5)	-993.8[b c]
Vertical	-374.5 (71.3)	-375.0 (56.9)	0.5	-365.3 (104.7)	-363.0 (80.2)	-2.3	-2634.4 (4986.4)	-770.8 (2690.2)	-1863.6[b c]
Lateral left	115.4 (26.4)	122.6 (35.3)	7.2[a c]	52.5 (24.3)	66.4 (32.7)	13.8[a c]	496.4 (656.1)	148.7 (433.4)	-347.7[b c]
Lateral right	-99.5 (24.3)	-93.5 (20.4)	-6.0[a c]	-57.6 (20.8)	-54.6 (28.2)	-3.0	-374.3 (875.8)	-141.9 (442.6)	-232.4[b c]
Sagittal ant	53.0 (16.9)	51.2 (21.2)	-1.8	54.1 (31.9)	50.4 (29.7)	-3.7	172.7 (768.3)	222.5 (431.9)	49.8[a c]
Sagittal post	-154.1 (31.1)	-153.1 (33.1)	-1.0	-59.4 (44.9)	-64.2 (33.8)	4.8	-473.0 (919.4)	-119.3 (319.5)	-353.7[b c]

Tabular report: VMU = Vector Magnitude Units, Change (Ch ±) = difference from OD to MD, "-" (negative) = higher OD value, ACC units counts per episode (ct·episode^{-1}). Significant difference: [a] $p < 0.05$, [b] $p < 0.01$. Effect Size: [c] ES classed small to medium r = 0.11 - 0.30, [d] ES classed as medium to large r = 0.30 to 0.50

Table 2. Descriptive statistics for absolute (beat.min^{-1}) and relative (% of age) heart rate (HR) data in OD and MD matches during bowling, between and fielding activity. Data are means(±SD).

	Bowling			Between Over			Fielding		
	One Day	Multi Day	Ch ±	One Day	Multi Day	Ch ±	One Day	Multi Day	Ch ±
HR	143 (14)	137 ± 16	-6 [a c]	129 ± 9	120 ± 13	-9 [b d]	115 ± 12	106 ± 12	-10 [b d]
HR_{age}	73 (15)	71 ± 14	-2 [a c]	66 ± 5	62 ± 7	-4 [b c]	59 ± 6	55 ± 6	-4 [b d]
HR_{max}	151 (14)	149 ± 18	2 [a]	151 ± 16	146 ± 20	-5	147 ± 17	137 ± 19	-10 [b c]
HR_{maxage}	77 (8)	77 ± 10	0	77 ± 9	76 ± 11	-1	75 ± 9	71 ± 10	-4 [b c]
HR_{min}	126 (12)	116 ± 13	-10 [a d]	118 ± 9	104 ± 12	-14 [b d]	99 ± 13	87 ± 11	-12 [b d]
HR_{minage}	66 (9)	60 ± 7	-6 [a d]	61 ± 6	55 ± 6	-6 [b c]	51 ± 8	45 ± 6	-6 [b d]
HR_{60r}	41 (17)	45 ± 17	4	-	-	-	-	-	-
HR_{10r}	28 (15)	28 ± 13	0	-	-	-	-	-	-

Tabular report: Units absolute heart rate (HR) beats per min (beat·min^{-1}) or relative percent (%) of age. Change (Ch ±) = difference from OD to MD, "-" (negative) = higher OD value, ACC units counts per episode (ct·episode^{-1}).Significant difference: [a] $p < 0.05$, [b] $p < 0.01$. Effect Size: [c] ES classed small to medium r = 0.11 - 0.30, [d] ES classed as medium to large r = 0.30 to 0.50

Between overs analysis (Table 2) noted significantly higher HR values occurring in the OD cricket format ($p < 0.05$) with medium to large ES for HR (ES = 0.35), HR_{age} (ES = 0.27), HR_{min} (ES = 0.45) and HR_{minage} (ES = 0.27). No significant ($p > 0.05$) differences were evident between match formats for HR_{max} and HR_{maxage}. For fielding activities, in comparison to MD cricket, all HR measures were significantly higher ($p < 0.05$) in the OD format with medium to large ES (Table 2).

Discussion

This research successfully identified an in-match physiological profile of professional fast-medium bowlers during different activities (i.e. bowling, between over, and fielding) between respective OD and MD formats of cricket using a wearable multivariable monitoring device. The data from this study indicate OD cricket is a more physically demanding format for fast-medium bowlers. With the limited research in this area and an increasingly overcrowded fixture schedules requiring players to switch between MD and OD matches, understanding the physical stress performers experience during different formats is critical if strength and conditioning professionals are to plan to maintain optimal performance in their players.

During bowling, peak acceleration and lateral right axis accelerometry values were greater in OD cricket format. However, the combined tri-axial activity count (VMUs), reported non-significant differences for bowling episodes in the two forms of cricket which appears to contrast with available research identifying increased physical work (i.e. higher number of sprints, distance per hour) during the shorter format (Petersen et al., 2009; 2010; 2011). The similarity of VMU data between formats in the current study may be explained by the consistent repetitive rhythmical bowling action deemed important to bowling success (Woolmer et al., 2008). Stable accelerometry derived Playerload data has been noted elsewhere during bowling in national level fast bowlers (McNamara et al., 2015) further supporting the notion that the activity associated with bowling is consistent over to over. The higher peak acceleration value noted in OD bowling, based on the previous argument, is probably not attributed to faster run up velocities in OD matches though this cannot be ruled out completely as this research did not substantiate this either way.

A measurement of interest relates to accelerations in the lateral axis (Table 1). Left axis acceleration was significantly higher for bowling in OD in comparison to MD cricket. Comparatively, higher forces are evident in the left than right directions during (right-handed) bowling due to left lateral flexion during bowling delivery (Davies and Collins, 2012; Woolmer et al., 2008). Less intuitive, the right axis was significantly higher in OD cricket, which is more difficult to explain. With small participant numbers some anomalies in data can occur. When considering the participants, all bowlers were right handed, well trained in completing the same task, albeit with technical differences. There is no evidence that bowlers change their bowling style in different formats of the game. The bowling action is a complex series of extensions, rotations and flexion's of the trunk therefore creating different forces and accelerometry values throughout (Bartlett et al., 1996; Woolmer et al., 2008). With improving wearable technology and the ability to collate a large data set, accelerometry devices can provide new information for the coach linked to technique and workload and this area warrants further investigation with a wider cohort of bowlers. Future studies with advanced technology may provide clarity on this point.

The bowling related heart rate data (Table 2) shows OD cricket stimulating higher absolute and relative values (mean and min) in comparison to MD. Considering accelerometry data trends, in-match timings and previous GPS research, this appears to be in line with the sparse in-match data published previously (Johnstone et al., 2014; Petersen et al., 2011). The values in both OD and MD formats are lower than have been reported in simulated bowling research (154–163 beats·min^{-1}) (Duffield et al., 2009; Johnstone et al., 2014). Differences in heart rate values between this competitive and simulated bowling event could be linked to a number of reasons. Firstly, simulated match environments are ecologically weak given the diverse and distinct match formats (MD, OD, T20) (Petersen et al., 2009; 2010; 2011). Moreover, methodological agreement in describing the occurrences of bowling and non-bowling episodes remains undefined. Thus, any response to a period of bowling is a consequence of what occurred prior, and to date this information is limited. The evidence from this bowling data suggests there is a trend of increased activity, shorter recovery time and potentially higher cardio-vascular workload for fast-medium bowlers in OD cricket. This information could be useful for strength and conditioning specialists to better understand bowling workload and assist in managing the demands between different formats of the game.

This in-match analysis provides a first insight in to the between-over period, an often ignored period of play that may provide further understanding in to the physiological state of performer's prior to bowling. Specifically, between-over accelerometry data (Table 1) did not present a consistent picture of statistically significant higher values within OD cricket. Lateral left data was greater in MD format which mirrors the finding during bowling which may be linked to a fielding activity or bowlers specific pre-bowling activity, though as this was not monitored in this study can only be hypothesised. Across match formats, relative and absolute values for minimum heart rate during the between-over period present significantly higher values in OD cricket. The OD match timings in this research and data from Petersen et al. (2010; 2011) reports that fast-medium bowlers have a reduced recovery period supporting the notion of increased cardiovascular stress due to a shorter time between bowling episodes in the OD format of cricket. Between-over activity has only been acknowledged by Duffield et al. (2009) within wider simulated bowling research and also by Petersen et al. who intimated from GPS data collected in-match, the between-over episode was not a standardised activity period, describing sprints or clusters of sprints occurring. With initial in-match evidence identified in this research, relative to the bowling episodes, the data confirms that less activity occurs in the between-over periods thus potentially providing an opportunity for cardiovascular recovery. This current research now provides some initial evidence for replication and investigation by others to assess if there is a valuable marker (i.e. HR minimum or HR delta) for coaches to monitor and shape match-tactics on prior to bowling.

In comparison to the other match states, fielding data presented the highest accumulated accelerometry counts per episode due to the extended period (>90 $mins^{-1}$) performers were completing that specific task. This match state reported the lowest heart rate responses corroborating previous evidence that fielding is a predominately low intensity activity interspersed with high intensity efforts. Clearly the latter activity profile is determined by the position in the field (i.e. static close catching or in a more dynamic outfield position) which would provide further insight to the physical cost or potential for recovery associated with this part of the game (Petersen et al., 2010; 2011; Woolmer et al., 2008). With the exception of sagittal anterior axis, accelerometry data (Table 1) presents an overriding trend of statistically significant higher values within the OD format which is more interesting considering the OD match occurs over a shorter duration. It is unclear why sagittal anterior axis presents higher counts in the MD format though due to the wide variety of roles and movement patterns that occur within fielding over long periods along with small participant numbers, this may be an anomaly. Large inter-quartile ranges associated with this data suggest that there is a high variation of fielding activity occurring which is consistent similar in-match GPS data (Petersen et al., 2010; 2011). In summary, this current study provides an insight in to the fielding role completed by fast-medium bowlers with seemingly a greater physical workload for the performer in OD cricket. Future research may seek to relate total fielding activity, activity per minute, fielding position and subsequent bowling performance.

As with any field based study, the benefit of a real-life data set is accompanied by some limitations of working in a less controlled environment. Though the multi-variable Bioharness™ provided a unique data capture it is acknowledged that 18 Hz accelerometer did not meet the Nyquist criterion (Chen and Bassett, 2005) therefore a comprehensive capture of the bowling activity was restricted. Recent developments within this area now have accelerometry devices capturing data at 100 Hz which would provide more comprehensive picture of performance. Bowling related heart rate values reported adopted polynomial smoothing to remove artefacts which occurred intermittently during the bowling action, a process which could have influenced the data collected. Although matching participant numbers for other studies using first-class performers (Duffield et al., 2009; McNamara et al., 2015), the small sample size could present statistical anomalies so application to wider populations should be completed with caution. Future research should present accelerometry data as both absolute counts ($ct.episode^{-1}$) and time relative ($ct.min^{-1}$) to provide additional inter and intra level analysis. Finally, for comparative purposes, future in-match research within bowling should agree the criteria for defining different timings of match episodes, a blueprint has been created within this research.

Conclusion

To conclude, this research is one of the first to report on fast-medium bowlers' physical data across two competitive formats of English performance cricket reporting previously unseen data on different match states. It is clear mobile or wearable monitoring technology now allows more ecologically valid field based data which is in line with the needs of the exercise specialist and coach. This presents an exciting opportunity for exercise professionals and coaches to make sure the physical demands of training matches the demands of the game. Additionally, coaches can work with sport science support teams to log in-match physical stress (i.e. a composite of heart rate and accelerometry measure) between match formats which will further improve conditioning and recovery for the individual performer, potentially reducing risk of injury leading to optimal performance.

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Key points

- One Day cricket has a greater overall physical strain on fast-medium bowlers providing shorter time for recovery between bowling episodes in comparison to Multi Day format.
- Wearable physiological monitoring technology can provide enhanced in-match workload monitoring replacing the need for simulated match-play environments.
- Adopting a standard global approach when defining bowling and between over episodes has been provided permitting comparative analysis to occur between teams/players enhancing coaches understanding of performance.

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