

Quantification of Bowling workload and Changes in Cognitive Function in Elite Fast Bowlers in Training compared with Twenty20 Cricket

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Abstract

BACKGROUND Bowling overs are the primary recorded measure for workloads in cricket for youth through to professionals. However, the validity of this measure has never been tested. Additionally, despite the cognitive component of cricket being suggested to be very high, changes in psychomotor processing speed has again not been explored. **METHODS** Eight professional English county cricket bowlers participated in the study. Participants wore global positioning systems with a tri-axial accelerometer during a Twenty20 match and training. Bowling overs were expressed relative to external forces. Additionally, cognitive function (as measured by psychomotor speed) was assessed pre and post Twenty20 game and training. **RESULTS** When expressed relative to high intensity running distance or external forces from the tri-axial accelerometer, the cost of each over (6 deliveries) was over 100% higher in a Twenty20 game compared to training. Psychomotor speed was unchanged although error within the cognitive task increased post Twenty20 (391 ± 82 to 547 ± 104 ms) and training (414 ± 110 to 561 ± 238 ms). This data suggests that reaction time is unchanged from cricket but the chance of making the correct decision is increased. **CONCLUSIONS** Movements in fielding should be quantified or bowling workloads adjusted to account for the high intensity fielding associated with Twenty20 cricket. Cognitive function was impaired following bowling, suggesting practitioners may also monitor psychomotor changes when assessing fatigue and allow appropriate time to mentally recover.

Key Words: Cognitive function, Workloads, Cricket, GPS

Introduction

Professional cricket in the UK is played in one of four different formats, which is differentiated by the length of the game. Up to 5 consecutive days are played in Test cricket (international teams only), whilst domestic level cricket requires performances of up to 4 days (County Championship), 1-day (50 over competition) or ~3 hours (Twenty20). Due to the shorter duration (~3 hrs), Twenty20, often draws greater interest from spectators and, as a result, has arguably become the most profitable form of the game for players ⁽¹⁾. In respect of this, there is a need for support staff to enable players to arrive in optimal condition, which often relies on accurate quantification of prior physical load and readiness to perform. Fast bowlers are associated with the highest risk of injury ⁽²⁾, which may be further exacerbated in Twenty20 cricket ⁽²⁾. Therefore, establishing and monitoring workloads is an essential tool in minimising the risk of injury. Currently, however, the physical demands and physiological stress associated with the shortest form of the game are poorly understood, particularly for fast bowlers⁽³⁾.

The number of 'overs' bowled in a match primarily determines physical workloads in cricket fast bowlers. An over consists of six deliveries, whereby the bowler completes a run-up (individual to each player) before releasing a straight-armed, over-arm throw towards the batsman stood 20 m away. The number of overs completed across games, weeks, months and careers has been linked to injury risk in fast bowlers ⁽⁴⁻⁶⁾. During a game of Twenty20 cricket, bowlers can bowl a maximum of four overs, which is markedly smaller than a multi-day, 50-over game or training session. Whilst the number of bowling overs is considered the primary contributor to the physical workload of fast bowlers, the multiple sprints that bowlers perform whilst fielding appears to be overlooked in respect of workload monitoring. Given the

significantly higher intensity (increase number of high intensity runs relative to the time period⁽⁷⁾) of Twenty20 cricket compared to other game formats ⁽⁷⁾, it seems essential that more aspects of the game are recorded when attempting to accurately quantify physical workload. Accurate workload quantification may be particularly useful in Twenty20 cricket, given the high incidence of muscle injuries in players taking part in this format of the game ⁽²⁾. Additionally, numerous other sports quantify workload through monitoring a wider selection of training and playing activities ^(8,9) and, as a result, it is surprising that workloads of fast bowlers are mainly quantified by bowling overs alone. Based on this reasoning, it is questionable whether the monitoring of number of bowling overs alone portrays an accurate representation of workload in fast bowlers during Twenty20 cricket.

Recently, a number of studies have investigated the movement demands of bowlers during Twenty20 games ^(7,10). Though these studies have provided some insight into the physical demands of cricket, none have focused on the mechanical load. With bowlers exposed to up to nine times their body weight during each delivery in fast bowling ^(11,12), it seems logical that forces, and not just distance covered and/or speed of movement, should be recorded in fast bowlers. Whether bowling overs reflect total match workloads (bowling and fielding) of fast bowlers has not been reported to date. Given that the number of bowling overs are currently used as the major units for monitoring workloads at the professional and amateur level ⁽³⁾, it seems prudent to investigate the legitimacy of this measure for accurately and reliably quantifying physical workload.

Alongside monitoring of the physical demands of Twenty20 games, the cognitive demands of this form of cricket are unknown. Given the nature of the game (short intense bursts of

activity interspersed with periods of inactivity i.e. fielding, combined with a highly skilled motor component i.e. bowling); it is fair to assume that players are presented with a cognitively taxing activity when training for and playing Twenty20 cricket. Indeed, perceptual cognitive skills have been a target in an attempt to improve performance, namely fielding skills, in elite cricket players⁽¹³⁾ and cricket-relevant abilities are impaired by cognitively challenging tasks⁽¹⁴⁾. To our knowledge, no study has investigated the relationship between load in cricket (bowling and fielding) and any associated impact on general cognitive function for the purpose of characterising overall physical and mental load placed upon a player. However, cognitive function has been used to monitor training load and diagnose overreaching or overtraining in other athletic⁽¹⁵⁾. Several of these studies have reported slower performance in various reaction time assessments following increased training loads in endurance athletes⁽¹⁵⁻¹⁹⁾. These findings provide support for the idea that reaction time-based tests and, in particular, psychomotor speed may be a useful tool to measure the effects of physical load and associated effects on cognitive function.

The current study investigated the efficacy of the number of bowling overs as a measure of workload in training and a Twenty20 game. In addition, this work attempted to characterise the relationship between bowling overs, internal load and cognitive function (as measured by psychomotor speed) in training for and playing Twenty20 cricket.

Materials and Methods

Subjects

Eight professional English county cricket bowlers (Mean \pm SD age, stature and mass were 22 \pm 3 years, 184.4 \pm 8.4 cm and 80.6 \pm 9.1 kg) volunteered to take part in the study. In terms of

speed, bowlers were classified as medium (<120 kph) to fast (<135 kph). All player participated in the training session and Twenty20 game. Ethical approval was granted prior to the start of the study through the University of Derby Ethics Committee and in accordance with Declaration of Helsinki ⁽²⁰⁾.

Design

Data was recorded during a single training session and fielding/bowling during a Twenty20 game. Training consisted solely of bowlers, bowling against batters in an outside net, whilst the Twenty20 game was a second XI competitive fixture. Only the fielding and bowling was included in the analysis to standardise time spent of the field. A counterbalanced design was used to eliminate the effects of any order bias. Both performances were preceded by a 24 h rest day during which participants were instructed to abstain from any strenuous physical activity. Additionally, participants were instructed to refrain from alcohol and caffeine consumption 24 h prior to the training and the Twenty20 game respectively. Participants also recorded a food diary for 24 h prior to training or the Twenty20 game and were instructed to replicate the diet for the second activity. In order to quantify physical load during each performance, movement was recorded using Global Positioning System (GPS) technology (StatSports, County Down, Ireland). All deliveries (balls bowled) were recorded during training and for the Twenty20 game. Cognitive function and subjective fatigue were taken and recorded 90 min before the start of activity and immediately post.

GPS

Movements were recorded by a Viper Metrics 10 Hz GPS pod (StatSports, County Down, Ireland). The units were switched on 10 min prior to performance. The GPS units were

housed in a specifically designed, fitted garment, located on the interscapula region of the thoracic spine. Each GPS unit contained a tri-axial accelerometer that sampled at 100 Hz. Both 10 Hz ⁽²¹⁾ and 100 Hz ⁽²²⁾ tri-axial accelerometer sampling rates are a reliable tool for assessing load in team sports. Data was analysed offline, using the software provided by the manufacturers (Viper System, StatSports, County Down, Ireland). In addition to the number of overs bowled, total distance covered and high intensity running (total distance completed above 5.5 m/s) were used in the statistical analysis for measures of load. Dynamic stress load (accumulation of forces exerted on the body above 2 g. [g is a measure of inertial stress on the body and is described as multiples of gravity, i.e. 2 g is equal to the force of 2 x gravity) was also used to give a measure of external load from the tri-axial accelerometer.

Psychomotor Speed

Cognitive function was measured using the Axon Sports Cognitive Priming application (ASCPA, Axon Sports, AZ). The ASCPA is a short (~90 s), tablet-based, neurocognitive test of an individual's fundamental cognitive processing. The test has been developed as a tool for the assessment of fundamental cognitive processing in mobile environments and athletic populations. The application delivers tasks that measure cognitive domains that are sensitive to change, including attention and psychomotor speed. For this study, tasks were delivered in a fixed order; a simple reaction time task, followed by one other task, selected from three possible options and measuring attention. The simple reaction time task involved detection of a visual stimulus in a fixed location on the tablet screen and initiation of a corresponding motor output. This task is a measure of psychomotor speed and the main outcome variables were response time (ms) and error corrected response time (ms).

Error corrected response time is equal to response time with the addition of any penalty incurred. Initial data measuring psychomotor speed using the ASCPA and the Cogstate (Cogstate Ltd., Melbourne Australia) Computerised Cognitive Assessment Tool (CCAT – a neuropsychological assessment of cognitive function, sensitive to change in cognitive function⁽²³⁻²⁵⁾) demonstrated a significant and positive correlation ($r = 0.80, p = 0.03$) (unpublished data). Psychomotor speed has displayed sensitivity to physical activity in endurance athletes, that is, a slowing of reaction time with increased training load^(15,17,18).

The tablet with the ASCPA was placed on a table in a quiet room where participants were free from distraction. Participants were instructed to use their dominant hand for the psychomotor speed task and both hands for the attention tests if required. Participants included in this study regularly use the ASCPA as a monitoring tool so were fully familiarised with the test.

Visual Analogue Scale (VAS)

To quantify changes in perceptual fatigue, a 100mm VAS was used. At the left hand of the scale the words “No Fatigue” were written, whilst “Severely Fatigued” was written on the right side. The VAS was scored 0 to 100 with the percentage change calculated from pre and post training and the Twenty20 game. Participants could not see their previous scores.

Statistical analyses

All data are presented as mean \pm SD. Paired samples *t*-tests were used to identify differences in distance covered, high intensity running distance, accumulative dynamic stress load and bowling overs between training and Twenty20 overs. High intensity running and dynamic

stress load was also expressed relative to overs bowled in training and Twenty20 performances.

A two-way, repeated measures ANOVA was used to detect differences in perceptual fatigue, reaction time and error corrected reaction time pre and post training and the Twenty20 game. If significance was found, an LSD *post-hoc* was used for pairwise comparisons, with 95% confidence intervals (CI) to assess the magnitude of change. Effect sizes (ES) were also used to detect changes between Twenty20 and training or pre to post. ES were evaluated based on Cohen (26) work as; trivial = 0-0.19; small = 0.20-0.49; medium = 0.50-0.79; large > 0.80. Pearson's correlation coefficient was used to identify relationships between bowling overs, GPS variables, stress responses and psychomotor speed. Statistical analyses were performed using GraphPad Prism (v5, San Diego, CA).

Results

Table 1 describes the movement demands of fast bowlers during the training session and Twenty20 game. Participants bowled significantly more overs during training compared to Twenty20 ($t_{(7)} = 4.4$; mean difference 4.5; 95% CI 2.1 – 6.9 Overs: $P < 0.05$; ES = 2.2), this was despite no significant difference ($P > 0.05$) in total distance, high intensity running and dynamic stress load.

Figure 1 and 2 shows individual and mean responses for high intensity running and dynamic stress load respectively when expressed relative to overs bowled in training and Twenty20.

Both high intensity running ($t_{(7)} = 3.5$; 95% CI 7.4 – 37.6: $P < 0.05$) and dynamic stress ($t_{(7)} =$

3.4; 95% CI 20.1 – 110.7; $P < 0.001$) load relative to overs bowled were significantly higher in Twenty20 cricket compared to training.

The results from figure 3 show a significant correlation between overs bowled in training and dynamic stress load (95% CI $r^2 = 0.72 - 0.99$; $P < 0.05$) but not during Twenty20 cricket ($P > 0.05$). Similarly, there was a significant correlation between overs bowled and high intensity running distance in training (95% CI $r^2 = 0.18 - 0.96$; $P < 0.05$) but not during Twenty20 cricket ($P > 0.05$) (figure 4).

Simple reaction time and error adjusted reaction time pre and post training and the Twenty20 game can be seen in figure 5. The ANOVA revealed a significant main effect of time ($F_{(1,12)} = 20.4$; $P < 0.05$). *Post hoc* analysis showed a significant increase in error adjusted reaction time post training (95% CI 28 - 267; $P < 0.05$; ES = 0.8) and a Twenty20 game (95% CI 37 - 274; $P < 0.05$; ES = 1.8). There were no significant differences between the Twenty20 game and training. Subjective fatigue increased across time ($F_{(1,12)} = 32.7$; $P < 0.05$) with an increase in self-rated fatigue post training (95% CI 9.8 - 44.9; $P < 0.05$; ES = 1.3) and Twenty20 (95% CI 11.7 - 46.8; $P < 0.05$; ES = 2.3). However, there was no difference in subjective fatigue between Twenty20 and training ($P > 0.05$).

Discussion

The main results from this study were that; 1) during a Twenty20 game, the cost of each over relative to high intensity running and dynamic stress load was over 100% higher compared to bowling overs during training; 2) both subjective fatigue and error corrected response time showed increases post training and Twenty20; however, these changes were not associated

with differing workloads in Twenty20 or training and 3) the number of bowling overs were correlated to high intensity running distance and cumulative dynamic stress load during training but not a Twenty20 game.

The results from this study add to the limited research ^(7,10) reporting distances covered by fast bowlers during a Twenty20 game. On average, the fast bowlers covered 5247 m, 325 m of which were sprinted. Results from Petersen *et al.* ⁽⁷⁾ reported total distances of 5500 m and sprinting distance of 406 m; however, work from the same group has also reported higher distances of 8489 m total and 723 m sprinting ⁽¹⁾. Several factors may influence the disparity in results including, such as; fielding position, number of overs bowled, bowling run up speed, size of field and total runs scored in the game. The movement analysis performed in this study should further help sport scientists and strength and conditioning coaches characterise workloads and subsequently prescription of training stimuli to prepare fast bowlers for Twenty20 cricket.

More recently, professional teams have moved toward the use of tri-axial accelerometry, in addition to GPS measures, for monitoring player load ⁽²⁷⁾. However, to our knowledge, this is the first study to use tri-axial accelerometry data in a cricket match or training. Given that the lumbar spine and lower body is exposed to up to nine times body mass during bowling ^(11,12), it seems logical that tri-axial accelerometry data should be a major component of physical workload monitoring. Previous studies have shown tri-axial accelerometry to be a reliable assessment tool for quantifying physical load ^(21,28). In addition, it has been shown that players exposed to the highest load also ran the greatest distance during games ⁽²⁹⁾. In cricket, fast bowling load is quantified using the number of overs bowled. Our study demonstrated a

strong correlation ($r^2 = 0.89$) between dynamic stress load and bowling overs. Training in this study consisted solely of a practice session, with bowlers performing no other strenuous activities in addition to the recorded bowling overs. During training, it can therefore be concluded that the recording of bowling overs reflects the external load the bowlers are exposed to during a net session. However, during a Twenty20 game there was no correlation between dynamic stress load and bowling overs, suggesting the number of overs does not accurately reflect the amount of external forces the players are exposed to in a game.

Total overs ⁽⁴⁻⁶⁾ and rapid increases in overs across a short period of time ⁽³⁾ are considered to increase the injury risk of fast bowlers. As bowlers can only bowl a maximum of 4 overs during a Twenty20 game, multiple games of Twenty20 could be interpreted as a 'low load week'. These 'lower load' weeks during Twenty20 period have been suggested to be the cause of injuries in fast bowlers during or following a Twenty20 series of games ^(2, 5).

However, our data show that when dynamic stress load is expressed relative to each over bowled in Twenty20 cricket, the cost of each over was over 100% higher compared to training. As a result, we suggest that if bowling overs are being used to quantify physical load, overs bowled in Twenty20 cricket should be doubled in order to reflect the higher physical loads present in this form of the game. This would, therefore, include the fielding element and may partly explain the increase in thigh and hamstring injuries from Twenty20 cricket ⁽²⁾ using current monitoring practices. Similarly, high intensity running distance and bowling overs showed a strong correlation ($r^2 = 0.62$) during training, but no correlation during a Twenty20 game. This information demonstrates that, if possible, high intensity running should be monitored independent of bowling overs. It is hoped that this data will help

coaches and applied scientists to better understand workloads during Twenty20 cricket and ultimately optimise performance.

In a novel approach, the current study also measured cognitive function following training and a Twenty20 game. Top level cricket performance requires the use of perceptual cognitive skills ⁽³⁰⁾ and these cognitive skills have been a target for performance improvement ⁽¹³⁾.

Many of the cognitive components involved in elite cricket performance involve processing of environmental stimuli and eliciting the appropriate response. As such, the study of simple reaction time or psychomotor speed and how this simple cognitive construct is affected by physical load could be informative as to the impact of load on cricket performance in general.

To date, researchers have used cognitive function in an effort to monitor training load and diagnose overreaching or overtraining in endurance athletes with reports of slower performance in reaction time assessments following increased training loads ⁽¹⁵⁻¹⁹⁾. To the

authors knowledge, the current study is the first to investigate the utility of psychomotor speed as a tool to characterise the effects of physical load on cognitive function in a field sport, namely Twenty20 cricket. Our findings report no difference in response time but a

significant increase in errors corrected response time following training and a Twenty20

game. In addition, contrary to the physical load data reported above, response time showed

no difference between training and a Twenty20 game, therefore suggesting the cognitive load is similar in both.

The increase in error count from pre to post training and Twenty20 game is surprising given previous literature investigating the effects of exercise induced arousal on cognitive

function⁽³¹⁾ where positive effects on various domains of cognition, including reaction time

have been reported. However, the studies outlined in this meta-regression analysis were laboratory-based and conducted using either cycling or running and their direct relevance to cricket performance is questionable. It could be the case that an increased mental load from bowling and fielding during cricket training and game play comes at a higher cost than monostructural activities such as running and cycling. This increased cost could lead to an inability to attribute sufficient cognitive resource to respond to the stimuli as instructed, due to fatigue. Indeed, a recent study demonstrated that 30-min of cognitively challenging tasks impaired performance in cricket-relevant tasks ⁽¹⁴⁾. These findings are supported by our reported increase in subjective fatigue after both training and the Twenty20 game, indicating that the mental load, rather than physical demand, might determine the observed psychomotor speed decline. In further support of this, both reaction time and subjective fatigue were not different between training and the Twenty20 game, despite a significant increase in physical load between the two. This result could also be attributed to the temporal sensitivity of each marker, where continued cognitive monitoring (i.e. reaction time assessment) and subjective questioning in the days following the training bout and Twenty20 game may report differing recovery profiles. As this is the first study to investigate these variables in this manner, further work is needed to elucidate the mechanism behind these findings.

Conclusion

The relative cost (high intensity running and dynamic stress load) of each over is ~100% greater in a Twenty20 game compared to training, therefore where financially viable, both GPS and tri-axial accelerometers should be used to monitor the exact physical exertions of fast bowlers. If the purchasing of GPS systems is not practical, correction factors could be applied to bowling overs to account for which environment the overs were bowled (i.e.

training or match). Cognitive function was partly impaired post Twenty20 game and training. As psychomotor factors are largely overlooked as a measure of readiness to train or play, our research offers new insight suggesting psychomotor speed may be a useful tool to monitor aspects of cognitive fatigue in field sports, though more research in this area is needed.

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Conflict of Interest – No conflicts of interest

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Table 1. Physical demands of fast bowlers in training and during a Twenty20 game

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Figure 1. Individual (A) and mean (B) responses for high intensity running relative to overs for training and Twenty20 cricket. * denotes significantly different from training.

Figure 2. Individual (A) and mean (B) responses for dynamic stress load relative to overs for training and Twenty20 cricket. * denotes significantly different from training.

Figure 3. Correlation between dynamic stress load and bowling overs during (A) training (B) and a Twenty20 game.

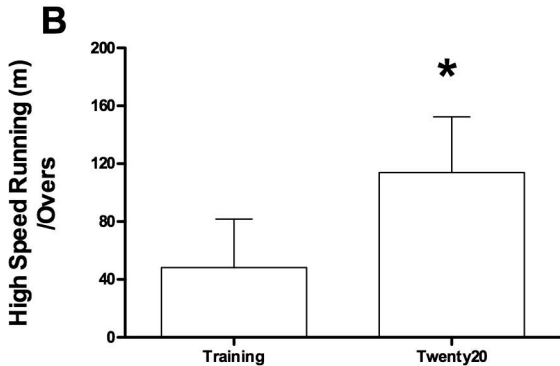
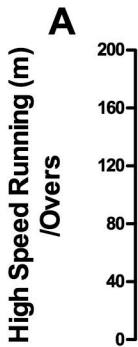
Figure 4. Correlation between high intensity running and bowling overs during (A) training (B) and a Twenty20 game.

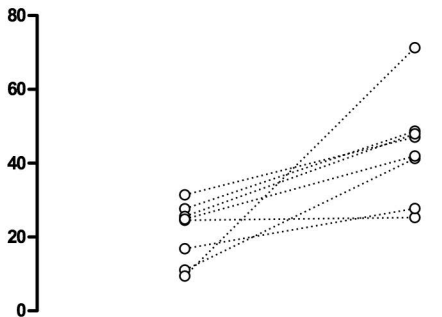
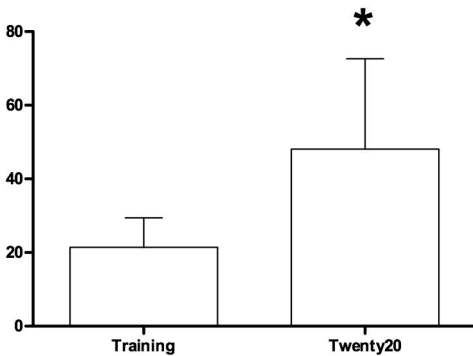
Figure 5. Reaction time pre and post Twenty20 and training (A) Error corrected reaction time pre and post Twenty20 and training (B) * denotes significantly different from pre.

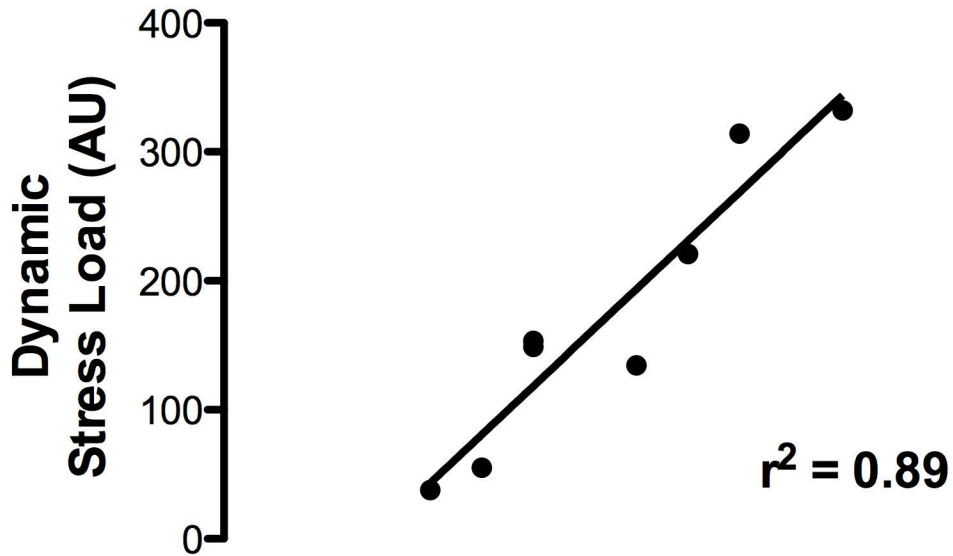
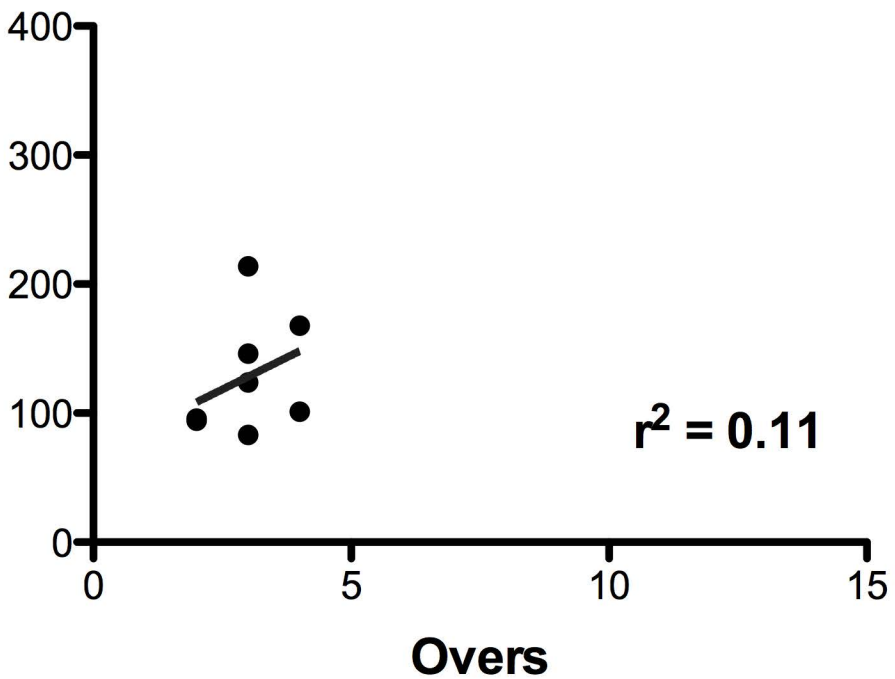
Table 1. Physical demands of fast bowlers in training and during a Twenty20 game

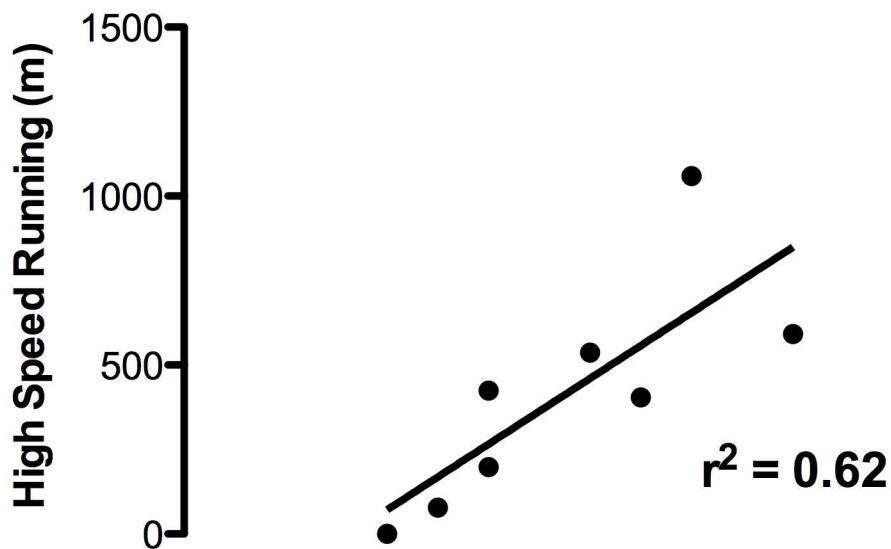
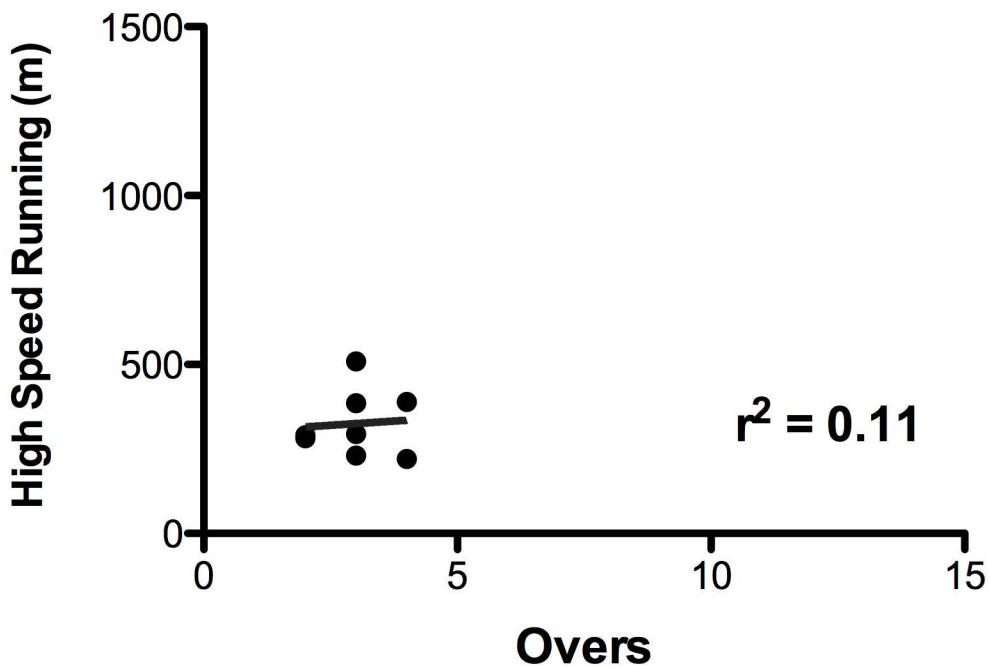
	Overs	Total Distance (m)	Sprinting (> 5.5m/s)	Dynamic Stress Load
Training	7.5 ± 2.73*	5542 ± 1769	411.8 ± 336.7	174.6 ± 108.3
Twenty20	3.00 ± 0.76	5247 ± 659.5	325.25 ± 97.0	140.8 ± 75.7

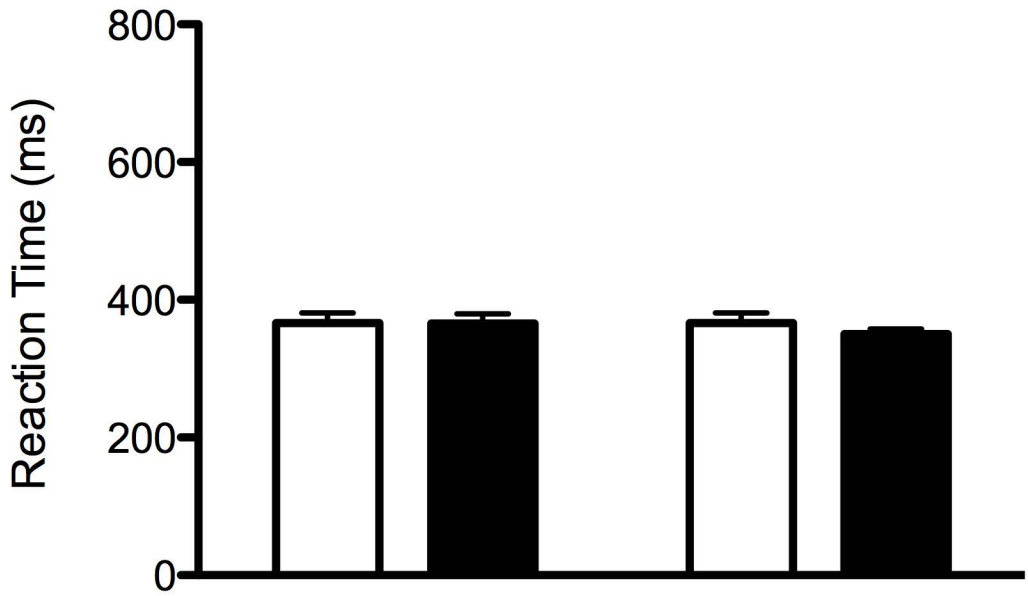
*Denotes significantly different ($P < 0.01$) from Twenty20



A**Dynamic
Stress Load/Overs****B****Dynamic
Stress Load/Overs**

A**B**

A**B**

A**B**