Movement patterns and physical strain during a novel, simulated cricket batting innings (BATEX)

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Abstract
A simulated cricket batting innings was developed to replicate the physical demands of scoring a century during One-Day International cricket. The simulated innings requires running-between-the-wickets across six 5-over stages, each of 21 min duration. To validate whether the simulated batting innings is reflective of One-Day International batting, movement patterns were collected using a global positioning system (GPS) and compared with previous research. In addition, indicators of physical strain were recorded (heart rate, jump heights, sweat loss, tympanic temperature). Nine club cricketers (mean ± s: age 20 ± 3 years; body mass 79.5 ± 7.9 kg) performed the simulated innings outdoors. There was a moderate trend for distance covered in the simulated innings to be less than that during One-Day batting (2171 ± 157 vs. 2476 ± 631 m; effect size = 0.78). This difference was largely explained by a strong trend for less distance covered walking in the simulated innings than in One-Day batting (1359 ± 157 vs. 1604 ± 438 m; effect size = 1.61). However, there was a marked trend for distance covered both striding and sprinting to be greater in the simulated innings than in One-Day batting (effect size > 1.2). Practically, the simulated batting innings may be used for match-realistic physical training and as a research protocol to assess the demands of prolonged, high-intensity cricket batting.

Keywords: Cricket, batting, fatigue, simulation, training

Introduction
In this paper, we describe a novel cricket batting exercise simulation for scientific testing and training, the rationale of its development, and an assessment of its validity. Furthermore, we document a selection of physical strain indicators during the simulation. The simulated batting innings was developed to reflect the typical physical demands of a One-Day International century, since scoring 100 runs when batting is a recognized mark of achievement in cricket. Although simulated batting protocols have previously been used, they have neither been prolonged nor based on comprehensive match analysis (Christie, Todd, & King, 2008; Gore, Bourden, Woolford, & Pederson, 1993; Neave et al., 2004).

It is proposed that the simulated batting innings may be used to progress research on the physical fatigue demands of cricket batting. Compared with other team sports, research into the physiological demands of cricket is sparse (Bartlett, 2003; Nevill, Atkinson, & Hughes, 2008). This may be due to a stereotypical opinion that competitors do not need to be fit to play cricket (Noakes & Durandt, 2000; Petersen, Pyne, Dawson, Portus, & Kellett, 2010). Yet, this perspective has been challenged recently by the advent of Twenty20 international cricket. There have been two recent time–motion analysis studies of cricket batting (Duffield & Drinkwater, 2008; Petersen et al., 2010). Duffield and Drinkwater (2008) reported a work-to-recovery time ratio of high- (running, striding, sprinting) to low-intensity (stationary, walking, jogging) activity as 1:47 and 1:67 for One-Day and Test cricket respectively (e.g. for every 1 s of high-intensity activity there is 47 s of low-intensity activity). Petersen et al. (2010) collected global positioning system (GPS) data from first-class, Twenty20, One-Day, and multi-day cricket games and found similar ratios of high- to low-intensity activity to Duffield and Drinkwater (2008) (1:50 and 1:61 for One-Day International and multi-day games respectively). These data highlight the physical load during matches and will be used to further validate the movement patterns during the simulated batting innings.
Despite these physical demands, it is appreciated that mental fatigue is more likely to contribute to failure in cricket batting than physical fatigue (Noakes & Durandt, 2000). Nevertheless, it has been suggested that traditional physiological fatigue models do not adequately explain physical fatigue when batting (Noakes & Durandt, 2000), because: the reported ratios of high- to low-intensity activity should allow adequate replenishment of phospho-creatine stores on most occasions (Duffield & Drinkwater, 2008; Noakes & Durandt, 2000); accumulation of lactate (only 2–3 mmol·L⁻¹) is limited (C. Petersen, unpublished work); the aerobic energy system is not significantly stressed (mean $V'O_2$ of only 26.7 ml·kg⁻¹·min⁻¹) (Christie et al., 2008); and there are usually ample opportunities to consume food and fluid to prevent depletion of energy and fluid stores (Noakes & Durandt, 2000). Yet, the above data hide the fact that, when batting, intermittent high-intensity activity may continue for up to 3.5 h (covering a total distance of ~9 km at various speeds) without a scheduled rest (Petersen et al., 2010). Therefore, batting for a prolonged period may induce biomechanical and/or neuromuscular fatigue due to the accumulation of intermittent, high-intensity activity with repeated eccentric loading (Nicol, Komi, & Marconnet, 1991; Noakes & Durandt, 2000). Such activity is required during changes of direction when running-between-the-wickets. These repeated, eccentric muscle contractions may lead to impaired elastic energy utilization (biomechanical fatigue) in the locomotive muscle–tendon units (Noakes & Durandt, 2000). Elastic energy is stored in muscle–tendon units during eccentric movement (e.g. when decelerating into a 180° turn) and may subsequently be used to provide positive mechanical power (e.g. when accelerating out of a 180° turn). Standing jump heights can be used to indirectly assess elastic energy and neuromuscular fatigue in athletes. For example, countermovement jumps have been used as an indicator of fatigue following an Australian Rules Football match (Cormack, Newton, & McGuigan, 2008).

The aims of the present study were to compare the physical demands of the simulated batting innings with data from real matches and to assess selected markers of physical strain during the simulation (e.g. change in jump heights).

**Methods**

**The simulated batting innings**

The simulated batting innings is composed of six 21-min stages that, together with rest intervals, form an innings lasting 2 h 20 min (Figure 1), which is the typical length of a One-Day International hundred (Duffield & Drinkwater, 2008). Each stage of the simulation is based upon theoretical phases of play that may occur during a batting innings. During each stage of the simulated innings, one coach or researcher delivers five overs (30 balls thrown over-arm or with use of a bowling machine) to a batsman in a netted practice area. Data collated from CricInfo (available for public access at: http://static.cricinfo.com/db/ARCHIVE/; accessed 24 April 2009) demonstrated that a ball is delivered every 43–44 s across all formats of the game (One-Day International, n = 48 innings; Twenty20, n = 40, Tests, n = 21). Therefore, during the simulated innings, a ball is delivered every 42 s (35 s between balls, 80 s between overs). An audible track is used to notify when the investigator is required to release the next ball (Audacity, v.1.2.6 and Verbose text to speech, v.1.13). Before the start of each over, this audio track also instructs what shuttle runs (running-between-the-wickets) need to be completed in the coming over; for example, the batsman might be told to run “1, 1, 2, and 4” shuttle runs (of 17.68 m, the length of a cricket pitch). The batsman completes the instructed runs (Table I) in any order within the over but is encouraged to match the runs with the shot played and field setting associated with each stage (e.g. dropping the ball at the feet and running a “1” turn). The running requirements during each stage of the simulated batting innings (see Table I) are based on typical running-between-the-wickets patterns ascertained from analysis of team innings during the 2007 (n = 20) and 2009 (n = 20) Twenty20 World Cups, the 2003 (n = 24) and 2007 (n = 24) One-Day International World Cups, and the home and away Test match series between Australia and South Africa.
Table I. The statistical basis for the workloads during each 21-min stage and the runs completed in each over of the simulated batting innings.

<table>
<thead>
<tr>
<th>BATEX stage and description</th>
<th>Statistical basis of running load</th>
<th>Runs completed in each over of BATEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Building momentum</td>
<td>Establishment of the batsman’s innings and the first partnership (low risk)</td>
<td>Over 1</td>
</tr>
<tr>
<td></td>
<td>ODI WC 2003–2007, mean (× 2) of batsmen 1–4, n = 191</td>
<td>1, 1</td>
</tr>
<tr>
<td>2. Taking initiative</td>
<td>Acceleration (medium risk)</td>
<td>ODI WC 2003–2007, mean (× 2) of batsmen scoring 49 to 100 runs, n = 58</td>
</tr>
<tr>
<td>3. Fighting back</td>
<td>Re-establishment after loss of wicket(s) (low risk)</td>
<td>Test match series 2008–2009, overall innings mean, n = 21</td>
</tr>
<tr>
<td>4. Power play</td>
<td>T20 cricket (high risk)</td>
<td>T20 WC 2007–2009, overall innings mean, n = 20</td>
</tr>
<tr>
<td>5. Maintaining tempo</td>
<td>Conservation (low risk)</td>
<td>ODI WC 2003–2007, overall innings mean, n = 48</td>
</tr>
<tr>
<td>6. Closing out the game/innings</td>
<td>‘Finishing’ (high risk)</td>
<td>ODI WC 2003–2007, overall innings maximum, n = 48</td>
</tr>
</tbody>
</table>

Note: Movement requirements are as if batting in a partnership and therefore incorporate the runs made by both batsmen. See text for running requirements for a “4”. No running is required in BATEX for “6s”. ODI = One-Day international (50 overs); T20 = Twenty20 cricket; WC = World Cup.

Table II. Example of the first two (of six) batting scenarios during a simulated innings (BATEX).

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1. Building momentum</th>
<th>2. Taking initiative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score: 0–0</td>
<td>Low risk taking</td>
<td>Score: 1–50</td>
</tr>
<tr>
<td>Start of team innings</td>
<td>Establishment of partnership</td>
<td>20 overs bowled</td>
</tr>
<tr>
<td>Opening bowlers, looking to bowl good length outside off stump (10–20 cm), 100–110 km · h⁻¹</td>
<td>Strike rotation/single</td>
<td>First changes of bowlers (i.e. fresh) – medium pace, bowling full length outside off stump (10–20 cm), 100–110 km · h⁻¹</td>
</tr>
<tr>
<td>Both batsmen new at the crease</td>
<td>Defence/leaving</td>
<td>Partnership of 40 runs</td>
</tr>
<tr>
<td>All runs at self-selected pace, “CRUISING”</td>
<td></td>
<td>Both batsmen on 20 runs</td>
</tr>
</tbody>
</table>

Note: Inner circle on fielding diagrams represents the 30-yard (27.4-m) circle (not to scale) used when fielding restrictions are required (e.g. during “powerplays”). Scenarios are based on the batting team setting a total.
Africa (2008–2009, \( n = 21 \)). All statistics were collated from CricInfo (available for public access at: http://static.cricinfo.com/db/ARCHIVE/; accessed 24 April 2009). The inclusion criteria for a One-Day International team innings were that both teams scored >200 runs in the match and were major cricket playing nations. To reflect different stages of a One-Day International innings, data were also collated for the maximum distribution of run frequency, individual innings of batsmen 1 to 4, and when individual 50 to 100 runs were scored. In the latter two situations, the run frequency was doubled to reflect two batsmen batting together. Only major cricket playing nations were included in analysis of the 2007–2009 Twenty20 World Cups. The team innings mean score in the 2007 and 2009 Twenty20 World Cups was 152 and 141, respectively. Therefore, only matches where both teams had scored over 150 and 130 (the latter being <140 to allow adequate sample size) were included in the analysis of the 2007 and 2009 Twenty20 World Cups, respectively. The lower mean innings score in the 2009 Twenty20 can be partly explained by the lower contribution and frequency of 6s scored, rather than different running-between-the-wickets demands (http://www.cricinfo.com/wt202009/content/story/410203.html"http://static.cricinfo.com/db/ARCHIVE/; accessed 24 April 2009).

Test innings from the 2008–2009 home and away Test match series between Australia and South Africa were included if a team scored >200 runs (regardless of the opposition’s score). A summary of the above analysis is presented in Figure 2, with total time and run distribution of team innings collated and presented as frequency per hour. Running 5 or more runs was not included in the analysis, as their occurrence is rare. Also, running-between-the-wickets when extras were scored was excluded since scorecards did not report how (i.e. 1s, 2s or 3s run) these runs were completed. The batting simulation was designed to reflect the fact that batsmen run not only the runs they score but also the runs of those they partner. Although each stage is based on a different format/stage of the game, overall the physical workload is designed to reflect the mean run distribution of a One-Day International (Figure 2). Runs made during stages 2, 4, and 6 are to be completed at maximal speed, whereas runs in stages 1, 3, and 5 are at a “self-selected cruise” pace. Batsmen are encouraged to bat with a mindset appropriate for the match scenario (Table II).

Participants

Nine healthy male, club cricket batsmen were recruited (mean ± s: age 20 ± 3 years; height 1.80 ± 0.06 m; body mass 79.5 ± 7.9 kg; district grade: 1st, \( n = 1 \); 2nd, \( n = 3 \); 3rd, \( n = 3 \); 4th, \( n = 2 \)). All participants batted in the top six of the order. Ethical clearance for this study was granted by the university’s human research ethics committee. All participants were given full details of the demands of the study before providing written informed consent.

Figure 2. Frequency distributions of runs per hour across One-Day Internationals (ODI, World Cups 2003 and 2007), Test matches (Australia vs. South Africa 2008–2009), and Twenty20 matches (T20, World Cups 2007 and 2009). Note the similar distribution of the batting exercise simulation (BATEX) to the ODI innings mean. *Original data multiplied by 2 to represent two batsmen at the crease.
Procedures

All testing was carried out at an outdoor, synthetic net facility at 09.00 h \((n = 7)\) or 16.00 h \((n = 2)\). Participants had been familiarized with the demands and routine of the batting simulation during previous training sessions. On arrival, the requirements of the batting simulation were again explained and the body mass of each participant was measured wearing only shorts \((\pm 0.05 \text{ kg, UC-321 Precision Personal Health Scale, A&D Weighing})\). Participants were then familiarized with the squat jump and countermovement jump techniques. In both the squat and countermovement jump, the participants kept their hands on their hips throughout and performed neither hip nor knee flexion during the flight phase. When performing the squat jump, participants squatted to approximately 90° knee flexion and held this position for 2–3 s before jumping vertically. In contrast, during the countermovement jump, participants squatted to approximately 90° before immediately jumping vertically.

After fitting a 1-Hz GPS unit (SPI 10, GPSports, Australia) and heart rate belt (Polar Team System\textsuperscript{TM}), the player carried out a standardized warm-up (3 min of gentle 20-m shuttle running, 4 min of dynamic stretching, and three practice turns). Next, the height of six maximal-effort jumps were recorded using a contact mat (Innervations, Kinematic Measurement System, v.2009.1.0), allowing 1.5 min standing rest between jumps. These were carried out in one of two orders: squat jump/countermovement jump repeated three times, or countermovement jump/squat jump repeated three times. This order was the same for each participant before and after the batting simulation but was counterbalanced between participants to ensure that jumps were not systematically affected by the previous jump. The highest countermovement and squat jumps were used in later analysis.

Participants wore full protective batting gear (leg pads, helmet, gloves) during the simulated batting innings. Before and after the simulation, environmental conditions were assessed using a weather station (QUESTemp\textsuperscript{TM} 32 Thermal Environment Monitor, Quest Technologies). All deliveries during the batting simulation were thrown by the investigator with quality of bat contact rated as “good”, “bad”, “left” or “no contact” (Müller & Abernethy, 2008). Water was freely available during the trial and participants consumed 300 mL of sports drink (Gatorade\textsuperscript{TM}, 309 kJ) and 25 g of marshmallows (Pascall\textsuperscript{TM}, 351 kJ) at the half-way point. After each stage of the simulated batting innings, tympanic temperature was measured using an infrared device (ThermoScan\textsuperscript{TM}, Braun\textsuperscript{TM}) and rating of perceived exertion recorded using the 15-point Borg scale (Borg, 1998).

On completing the simulated batting innings, participants again completed six maximal test jumps. After drying off excess sweat, participants were weighed wearing only shorts. Change in body mass during the batting innings was adjusted for fluid consumed to provide an estimation of sweat loss.

Data analysis

All data are presented as means ± standard deviations \((s)\). The GPS data are presented in metres per hour to allow comparison with data of Petersen et al. (2010). Effect sizes (ES) were reported as moderate \((0.6–1.2)\), large \((1.2–2.0)\) or very large \((>2.0)\) (Hopkins, 2004). The difference in countermovement jump and squat jump performance, expressed as a percentage of squat jump height, was used as an indicator of elastic energy augmentation (Kubo, Kanchisa, & Fukunaga, 2005). Pre- and post-jump heights (countermovement jump, squat jump, and countermovement jump–squat jump augmentation), environmental conditions, and body mass were compared using paired \(t\)-tests and effect sizes. Other variables were analysed using a one-way analysis of variance (ANOVA). Statistical significance was set at \(P < 0.05\). Pearson’s correlation coefficients \((r)\) were used to assess relationships between variables.

Statistical analysis was carried out using PASW Statistics v.18.0.0 (formally known as SPPS Statistics).

Results

Environmental conditions

Dry bulb temperature was 26.5 ± 4.1°C, typically increasing 3.5 ± 3.4°C \((P = 0.015, ES = 0.74, \text{range } -3.8\ to\ 6.7°C)\) from pre to post the batting simulation \((2.5 \text{ h})\). Wet bulb globe temperature (WBGTV) index was 22.5 ± 2.6°C and increased 3.7 ± 4.1°C from pre to post the innings \((P = 0.026, ES = 0.99, \text{range } -3.7\ to\ 7.5°C)\).

Movement patterns

There was a moderate trend for greater distance covered per hour in One-Day \((ES = 0.78)\) and Twenty20 \((ES = 0.68)\) batting than in the simulated batting innings, likely explained by the moderate to large trends \((ES = 1.61\ and\ 1.10,\ respectively)\) for greater distance completed at a walking pace (Table III). There were moderate \((ES = 0.60\ and\ 1.12)\), large \((ES = 1.25\ and\ 1.48)\) and very large trends \((ES = 3.44\ and\ 4.09)\) for the simulated batting innings to demand more striding and sprinting than Twenty20, One-Day, and multi-day batting, respectively (Table III). The overall recovery ratio demonstrated that for every 1 s of high-intensity activity,
there was 31 ± 3 s of low-intensity activity (Figure 3). There was moderate variation in the distance covered, distance covered sprinting, and recovery ratio (e.g. stage 1 vs. stage 6: 1:86 ± 73 vs. 1:16 ± 2; ES = 1.13) between the six stages (Table IV and Figure 3).

**Physical strain**

Throughout the batting simulation, mean heart rate was 130 ± 16 beats · min⁻¹ and increased during the simulation (e.g. stage 1: 114 ± 8 beats · min⁻¹; stage 6: 147 ± 15 beats · min⁻¹; P < 0.001) (Figure 3). There was a large trend (ES = 1.13) for higher heart rate in the full-speed stages 2, 4, and 6 (121 ± 13 beats · min⁻¹) than the self-selected pace stages 1, 3, and 5 (139 ± 14 beats · min⁻¹). Tympanic temperature remained stable throughout the simulated batting innings but rating of perceived exertion increased from stage 1 (10 ± 2) to stage 6 (16 ± 1; ES = 1.73) (Table IV). Body mass decreased from pre to post batting simulation (n = 8, 79.5 ± 8.4 to 78.7 ± 8.0 kg; P = 0.004, ES = 0.74), which equated to a loss of 1.0 ± 0.5%. Estimated sweat rate was 0.9 ± 0.2 L · h⁻¹ (range 0.5–1.1 L · h⁻¹). Finally, percentage good bat contacts remained stable across the batting simulation (Table IV).

Eight of nine participants decreased maximal squat jump height from pre to post the batting simulation (36.9 ± 4.1 cm vs. 35.0 ± 5.0 cm; P = 0.014). In contrast, the maximal countermovement jump showed no pre to post change (36.9 ± 3.7 cm vs. 37.3 ± 4.2 cm; P = 0.636). As a result of the decrease in squat jump height, there was a moderate trend for countermovement jump–squat jump augmentation to increase on completion of the batting simulation (0.2 ± 4.7% vs. 6.6 ± 5.3%; P = 0.051, ES = 1.09). At baseline there was no difference between countermovement and squat jump heights (P = 0.985) but following the simulated batting, countermovement jump was significantly higher than squat jump (P = 0.008, ES = 0.62).

**Discussion**

Findings demonstrated that the simulated batting innings requires batsmen to cover less distance (per hour) but a higher amount of striding and sprinting compared with One-Day International batting. In addition, the selected markers of fatigue imply that moderate physical strain was induced.

**Match data comparison**

There was a similar percentage of time spent walking and standing in the simulated batting compared with One-Day International hundreds (Duffield & Drinkwater, 2008). However, despite the simulated batting innings being designed to reflect the running demands of a One-Day innings, there was a moderate trend (ES = 0.78) for less distance to be covered per hour in the simulation than during One-Day batting (Petersen et al., 2010). This difference was likely due to the large trend (ES = 1.61) for less distance to be covered walking in the simulated batting versus One-Day batting. Although there was a large trend for higher striding and sprinting (ES = 1.25 and 1.48, respectively) demands in the

![Figure 3. Mean heart rate (HR), maximal heart rate, and time ratio of low-intensity (standing, walking, jogging) to high-intensity (running, striding, sprinting) activity (i.e. recovery ratio) during the batting exercise (BATEX) simulation. *Main effect of time, P < 0.05.](image-url)

### Table III. Comparison of movement patterns of the batting simulation (BATEX) with different formats of the game as reported by Petersen et al. (2010) (mean ± s).

<table>
<thead>
<tr>
<th></th>
<th>Walking (m · s⁻¹):</th>
<th>Jogging (m · s⁻¹):</th>
<th>Running (m · s⁻¹):</th>
<th>Striding (m · s⁻¹):</th>
<th>Sprinting (m · s⁻¹):</th>
<th>Overall (m · s⁻¹):</th>
</tr>
</thead>
<tbody>
<tr>
<td>BATEX (m · h⁻¹)</td>
<td>1359 ± 157</td>
<td>233 ± 33</td>
<td>99 ± 10</td>
<td>217 ± 31</td>
<td>261 ± 58</td>
<td>2171 ± 157</td>
</tr>
<tr>
<td>One-Day batting (m · h⁻¹)</td>
<td>1808 ± 400⁺</td>
<td>279 ± 119⁺</td>
<td>86 ± 37</td>
<td>154 ± 70⁺</td>
<td>149 ± 94⁺</td>
<td>2476 ± 631⁺</td>
</tr>
<tr>
<td>Twenty-20 batting (m · h⁻¹)</td>
<td>1638 ± 352⁺⁺</td>
<td>332 ± 103⁺⁺</td>
<td>97 ± 35</td>
<td>187 ± 70⁺⁺</td>
<td>175 ± 97⁺⁺</td>
<td>2429 ± 606⁺⁺</td>
</tr>
<tr>
<td>Multi-day batting (m · h⁻¹)</td>
<td>1604 ± 438⁺⁺</td>
<td>200 ± 90</td>
<td>67 ± 18⁺⁺</td>
<td>107 ± 33⁺⁺</td>
<td>86 ± 28⁺⁺</td>
<td>2064 ± 630⁺⁺</td>
</tr>
</tbody>
</table>

* Moderate effect size (0.6–1.2). ⁺ Large effect size (1.2–2.0). ⁺⁺ Very large effect size (>2.0). All effect sizes are in comparison with the movement demands in the BATEX simulation.
Development and implementation of a simulated batting innings

Table IV. Movement demands, physiological measures, and batting performance during each stage of the batting simulation (BATEX) (mean ± s).

<table>
<thead>
<tr>
<th>Movement demands</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
<th>Stage 6</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance covered (m)*</td>
<td>562 ± 125</td>
<td>900 ± 60</td>
<td>578 ± 89</td>
<td>1047 ± 70</td>
<td>802 ± 75</td>
<td>1161 ± 122</td>
<td>5084 ± 370</td>
</tr>
<tr>
<td>Distance covered (m·h⁻¹)*</td>
<td>1514 ± 148</td>
<td>2307 ± 153</td>
<td>1392 ± 216</td>
<td>2697 ± 189</td>
<td>2055 ± 193</td>
<td>3163 ± 336</td>
<td>2171 ± 157</td>
</tr>
<tr>
<td>Distance covered sprinting (m·h⁻¹)*</td>
<td>27 ± 38ᵇ</td>
<td>445 ± 111ᶜ</td>
<td>30 ± 37ᵇ</td>
<td>503 ± 87ᶜ</td>
<td>26 ± 33ᵇ</td>
<td>572 ± 177ᶜ</td>
<td>261 ± 58ᵇ</td>
</tr>
</tbody>
</table>

| Physiological measures                        |         |         |         |         |         |         |         |
| Rating of perceived exertion*                 | 10 ± 2  | 13 ± 1ᵇ | 11 ± 2  | 15 ± 2ᵇ | 11 ± 2ᵃ | 16 ± 1ᵇ | 13 ± 3  |
| Tympanic temperature (°C)                     | 35.8 ± 0.5 | 35.9 ± 0.8 | 35.8 ± 0.9 | 36.0 ± 1.0 | 35.7 ± 1.0 | 36.1 ± 1.4 | 35.9 ± 0.9 |

| Batting performance                           |         |         |         |         |         |         |         |
| % Good contacts*                               | 83 ± 4  | 85 ± 8  | 85 ± 8  | 82 ± 11 | 83 ± 10 | 84 ± 9  | 84 ± 5  |

* Moderate effect size (0.6–1.2). ᵇ Large effect size (1.2–2.0). ᶜ Very large effect size (> 2.0), when compared with stage 1 with the exception of. ᵃ Compared with distance covered sprinting in a typical One-Day match: 149 ± 94 m·h⁻¹ (Petersen et al., 2010). ᵇ As a percentage of total number of attempted bat contacts. ᵃMain effect of time, P < 0.01.

Simulated batting innings, the difference was not great enough to offset the trend for lower walking distance and total distance covered in the simulated innings versus One-day innings. The higher sprinting demands of the simulated versus One-day batting were a result of the maximal effort running required in stages 2, 4, and 6. The full pace running demands of the simulated batting innings resulted in 25 ± 3 sprints (> 1 s) per hour, which is moderately higher than the 13 ± 9 sprints per hour in One-Day batting (ES = 1.00; Petersen et al., 2010). This difference was also reflected in the proportion of time spent sprinting in the simulated innings (1.3%), which was twice that reported in One-Day International hundreds (0.6%; Duffield & Drinkwater, 2008). Although unplanned, in practical terms the differences in high- and low-intensity activity of the simulated and One-day innings are not of undue concern, since they demonstrate the potential for the simulation to be used in training and research to simulate a “worst case” scenario of physical loading.

Compared with One-Day match data collected by Duffield and Drinkwater (2008) and Petersen et al. (2010), the higher physical demands of the simulated batting innings are further highlighted by the moderate trend (ES = 0.80 and 0.94 respectively) for rest-to-recovery ratio to be lower (1:31 vs. 1:47 vs. 1:50 for the simulated batting innings vs. Duffield and Drinkwater vs. Petersen et al.). Indeed, the overall rest-to-recovery ratio in the simulated innings is more reflective of that found for Twenty20 batting (1:38; Petersen et al., 2010). However, the variation in recovery ratio between individual stages of the simulated batting demonstrates that, as intended, each stage may be used to simulate different training loads (e.g. the recovery ratio of stage 1 was 1:86 vs. 1:16 for stage 6).

For the simulated batting innings to be used in scientific research, the distances and exercise intensities need to be similar between participants. However, there was apparent between-participant variation in the total distance covered during the simulated batting innings (5084 ± 370 m). This between-participant variation in the distance covered during the simulated batting may be explained by the faster runners requiring longer stopping distances after running-between-the-wickets. For example, during stage 6 there was a strong correlation between distance covered sprinting (m·h⁻¹) and total distance covered (m) despite the required number of runs being identical between participants (r = 0.803, P = 0.009). In addition, measurement error of the GPS unit may have contributed to the between-participant variation in total distance covered.

Due to ease of access, 1-Hz SPI-10 GPS (GPSports, Australia) units were used to monitor movement patterns during the simulated batting innings. In contrast, Petersen et al. (2010) used 5-Hz MinimaxX (Catapult Innovations, Australia) GPS units when analysing match demands. First, we acknowledge that the reliability of 1-Hz GPS units may not be acceptable for high-intensity activity (Coutts & Duffield, 2010; Petersen, Pyne, Portus, & Dawson, 2009). However, the possible inaccuracy of using a 1-Hz unit in this study is likely minimized by the absence of non-linear movement during the batting simulation (Coutts & Duffield, 2010). Second, it is appreciated that comparison between
data sets collected with different models of GPS units is not ideal (Cousts & Duffield, 2010; Petersen et al., 2009; Randers et al., 2010). When comparing 1-Hz (SP1-10) with 5-Hz (MinimaxX) GPS units, walking to striding activity is potentially underestimated (3%) and overestimated (3%), respectively (Petersen et al., 2009). Therefore, assuming the worst case scenario in the error due to comparing 1-Hz and 5-Hz GPS units, differences in the simulated batting innings and the data of Petersen et al. (2010) for walking to striding intensities may be less than the data suggests. Nevertheless, it is likely that the sprinting demands of the simulated batting innings are genuinely higher than commonly recorded during One-Day batting, since, to standardize effort, full-pace running was required during stages 2, 4, and 6.

Physical strain

Mean heart rate during the simulated batting innings (130 ± 16 beats · min⁻¹) was moderately lower than previously observed in One-Day batting (139–154 beats · min⁻¹), likely due to the absence of match-day pressure during the simulation (Nicholson, Cooke, O’Hara, & Schonfeld, 2009; Petersen et al., 2010). Rating of perceived exertion during either match or simulated batting is not apparent in the literature. Tympanic temperature increased 0.3°C across the 30 overs of the simulation; although tympanic temperature has not been reported, a 1.3°C increase in core temperature was observed during 10 overs of batting in a match (Brearly & Montgomery, 2002). Sweat rate during the batting simulation (0.9 ± 0.2 L · h⁻¹) was in the range of that observed in One-Day matches (0.30 ± 0.31 to 1.44 ± 1.25 L · h⁻¹) in similar environmental conditions (21.9–30.3°C) in males and females (Brearly & Montgomery, 2002; Soo & Naughton, 2007). However, sweat rate during the simulation was higher than that recorded during simulated multi-day batting (~0.5–0.6 L · h⁻¹) in similar environmental conditions (WBGT index 22.1 ± 0.6°C), most likely due to the higher workload in the current batting protocol compared with this previous simulation (Gore et al., 1993). The above findings suggest that physiological strain during the simulated batting innings was moderate.

The ability to store and use elastic energy during movement may be indirectly demonstrated when comparing a squat jump height with countermovement jump height (Kubo et al., 2007). Typically, countermovement jump performance has been demonstrated to be 5–14% higher than squat jump performance, which may be partly explained by the augmented use of elastic energy stored during the eccentric countermovement action (Kubo, Kawakami, & Fukunaga, 1999; Paasuke, Ereline, & Gapeyeva, 2001). However, in this study, baseline countermovement jump and squat jump performances were not different.

Following the simulated batting innings, the decrease in squat jump height was likely due to muscular fatigue. Squat jump height has previously been shown to decrease following the intermittent change of direction exercise required in a soccer match (Thorlund, Aagaard, & Madsen, 2009). Similarly, countermovement jump has been found to decrease following simulated and real-life soccer matches (Magalhães, Rebello, Oliveira, Silva, & Marques, 2010). However, countermovement jump remained unchanged following the simulated batting. The lack of change in countermovement jump (despite decreased squat jump) might be explained by the attenuation of muscular fatigue due to the use of elastic energy stored in the tendon during countermovement, and/or augmentation of muscle force as a result of the countermovement (Bobbert, Gerritsen, Litjens, & Van Soest, 1996; Kubo et al., 2007).

Noakes and Durandt (2000) hypothesized that physical fatigue during batting may be due to a reduced potential to store and use elastic energy as a result of repeated eccentric contractions. It is stressed that countermovement jump–squat jump augmentation is only an indirect indicator of muscle–tendon elastic energy (Kubo et al., 2005). Indeed, the use of countermovement jump–squat jump height as an indirect measure of elastic energy storage may be questioned, since, in this study, the increased augmentation was an artefact of unchanged countermovement jump height accompanied by decreased squat jump height. Therefore, future research should directly observe muscle–tendon mechanical properties before and after the simulated batting innings (Kawakami & Fukunaga, 2006).

Conclusion and practical applications

Batting simulations have previously been used to investigate the demands of batting (Christie et al., 2008; Gore et al., 1993; Neave et al., 2004). Often such simulations have been short (20–30 min) and required all runs to be made at full speed (Christie et al., 2008; Neave et al., 2004). With the current batting simulation, we have attempted to overcome these limitations. When compared with match data, increased high-intensity running demands were found in the simulated batting innings versus One-Day match batting. Therefore, the current simulated innings may be used as a research protocol to investigate the demands of prolonged, high-intensity cricket batting. Future research will evaluate the
reliability of performance measures during this batting simulation.

Training, even for top-level club cricketers, still largely revolves around batting for <20 min, without running-between-the-wickets, which is hardly specific to the demands of batting in a match (Woolmer, Noakes, & Moffett, 2008). The batting simulation developed here (particularly stages 2, 4, and 6) can also be used to increase the specificity of net training while providing a time-efficient physical overload. Specifically, the current batting simulation may aid developing players who do not have the experience of combining the skill, concentration, and fitness demands required for a prolonged batting innings. For training purposes, the stages of the batting simulation may be used independently or in any desired combination to appropriately simulate match-day demands.

References


