Temporal analysis of elite level men’s singles in badminton and possible training implications

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1 Introduction

The game of badminton has gone through a number of changes over time. Since it was first introduced in the Olympics in Barcelona in 1992, the Badminton World Federation has experimented with the scoring system (four different systems have been used during this time). There has also been some development in the equipment as well as in the athletes themselves. And there is a big pressure from TV to make the game as spectator (and commercial) friendly as possible – this stands for shorter matches with predictable breaks, rules easier for the audience to understand and many exciting moments. All these factors have had an impact on the game itself.

There are few written sources for physical training in badminton except for “the bible:” Bo Ømosegaard’s book Physical Training for Badminton, which was published in 1996 and relies on studies done in the 1990’s and before. As we were aware of the above mentioned changes in the game, we were intrigued to find out, how does the game exactly look like today regarding the temporal structure and would the possible changes have any effects on the physiological demands on the players.

We decided to focus in the elite level men’s singles, because that was main interest for us and because of lack of sources for women’s singles. The second reason was to keep our work focused. This lead to our formal problem statement:

"The temporal structure of elite level men's singles badminton has changed over time which may have implications for the physiological demands on players."

To find an answer to the problem we needed to find out:

1. How has the temporal structure changed and

2. What might be some implications for the physiological demands on players?

The first question required us to find out what the existing studies have to say about the game and also do our own study on the temporal structure. Our findings in these matters will be presented in chapters 1 and 2.
As we are badminton coaches, probably the most interesting question to answer was the second one – trying to figure out, how the possible changes would affect the physiological demands on players and the training they need to do to meet those demands. This is of course a complex area to analyze and there are no exact answers, however our study points to potential areas for further investigation. Our analysis and suggestions for training applications, based on the knowledge we were able to gather, are presented in chapter 3.

2 Description

In this chapter we will present the theoretical background on the energy systems and the existing knowledge on the temporal structure of the game. In the first part we will go through an overview of the energy systems working in human beings and how they work during the game of badminton. In the second part we present a review on the studies that have been done on the temporal structure in badminton.

2.1 Physiological background: the energy systems

The human being, whether active or at rest, is constantly converting energy from one form to another. During the game of badminton the most obvious use of energy is to maintain the muscle activity. The large muscular activity of running and jumping, lunges and smashes, starts and stops, the muscles involved in the finer movements of coordination and balance, and the muscles of the heart and respiration all require a constant supply of energy. This energy comes mainly from chemical energy stored originally in food, carbohydrates, fats and proteins, or in the atmosphere but which is involved in a complex series of changes which produce the high-energy molecule known as adenosine triphosphate (ATP). The energy stored in the chemical bonds of ATP are released when the bonds are broken and can be used by the cells to perform biological work, including muscular activity. In performing these chemical processes the body can function with a high or low efficiency.

All muscular activity is dependent upon one or more of the three basic energy systems,
each of which make energy available to the muscle cells so that they can contract and cause movement. They are:

1. the ATP-PCr system
2. the lactic acid system
3. the oxygen system

The three energy systems can be divided into those requiring oxygen (aerobic) and those not requiring oxygen (anaerobic). The ATP-PCr and lactic acid systems are anaerobic and do not require oxygen. As the name suggests the one requiring oxygen is called the oxygen system. These three energy systems have different properties when it comes to the speed with which they can supply ATP, and the amount of ATP they can supply. The important point to remember is that all three of these energy systems are working together at different ratios (i.e. overlapping) to maintain the ATP supply [MKK07, pg 470]. During a specific sports activity, the energy requirements of muscle are related to

![Diagram of energy systems](image)

**Picture 1:** The three energy systems work together to meet the energy demands of any level of physical activity. Width of arrows denotes degree of energy contribution. [Hen06]
the intensity and duration (power output) of the activity.

**Picture 2:** ATP contribution of the three energy systems to maximally sustained activities of very short, high intensity exercise (such as shot put) to low-intensity maximally sustained exercise lasting longer than 3 minutes (such as marathon running). [Hen06]

Activities of a long term nature like middle distance running, for example, operate mainly on the oxygen system. The training for middle distance running is therefore aimed at developing a highly efficient oxygen system. Such events are characterised by lengthy periods of exercise with some, but little, variation in intensity. This is called **steady state work** with the oxygen system being used almost exclusively throughout.
<table>
<thead>
<tr>
<th>Energy System</th>
<th>Energy System Complexity</th>
<th>Maximal Rate of ATP Production</th>
<th>Capacity to make ATP</th>
<th>Lag Time to Increased ATP production</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATP-PCr</td>
<td>Low; one-step process</td>
<td>Very fast</td>
<td>Very limited</td>
<td>None</td>
</tr>
<tr>
<td>Anaerobic</td>
<td>Moderate; 12-step process</td>
<td>Fast; runs a close second</td>
<td>Limited</td>
<td>Seconds</td>
</tr>
<tr>
<td>(lactic acid)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerobic</td>
<td>Very high; many processes and steps</td>
<td>Very slow; distant third</td>
<td>Unlimited</td>
<td>Minutes</td>
</tr>
<tr>
<td>(w/oxygen)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Comparison of Characteristics of the Three Energy Systems [Hen06]

2.1.1 The ATP-PCr system

In many activities, however, the form of the activity is incompatible with steady state work. This is typical of badminton where the intensity of play fluctuates. Parts of the game are spent standing still, parts in moving slowly (retrieving the shuttle) and much time in moving quickly. In such a game the oxygen energy system is not sufficient. Shortly after starting to move quickly, the aerobic method of supplying energy to the working muscles becomes totally inadequate. The muscles work so rapidly that the energy they require is simply not met by the transfer of oxygen from the atmosphere. In this situation, alternative, more rapid methods of providing energy have to be found.

Fortunately, there is a limited store of energy available in the working muscles which can be released rapidly to supply this greater demand. As this supply is not dependent upon the availability of oxygen it is called the anaerobic energy system. There are two components of the anaerobic energy system which make the energy available in different ways.

The first one to be activated is the ATP-PCr system (adenosine triphosphate and phosphocreatine). The breakdown of these chemicals makes the energy available very
rapidly. Very short, intense activities which take only a few seconds will get their energy from this system. So, in badminton, an explosive movement such as a jumping lunge to kill a serve, which only takes a second, will be using the ATP-PCr system.

ATP serves as the ideal energy transfer agent. ATP’s phosphate bonds ‘trap’ a large portion of the original food molecule’s potential energy. Hydrolysis of this molecule produces a new compound, adenosine disulphate (ADP), a phosphate ion and approximately 7.3kcal of energy, available for work. [MKK07]

\[
\text{ATP} + \text{H}_2\text{O} \leftrightarrow \text{ADP} + \text{P} + 7.3 \text{kcal/mol of energy}
\]

There is normally enough intramuscular store of ATP to power a few seconds (3-5 seconds) of explosive, all out exercise. ATP re-synthesis proceeds uninterrupted to continuously supply energy for biological work. Despite the fact that ATP is stored in very limited amounts, it is important to note that cells never completely deplete their ATP stores. Picture 3 shows ATP levels during an intense sprint lasting 14 seconds. Note that at the point of exhaustion roughly 30% of the muscle’s ATP still remains. Obviously athletes perform activities that last longer than 3 seconds every day, so the body must have ways of replenishing ATP once it is used. In fact every cell, particularly muscle

![Picture 3: Effect of intense activity on the ATP levels in muscle. Even when an activity results in exhaustion, ATP levels are not totally depleted. [Hen06]](image-url)
cells can replenish any ATP that is used to keep the ATP stores topped up. If the ATP levels fall too low because the activity is so intense that the muscle cell cannot make ATP fast enough, protective mechanisms kick in that in turn cause **fatigue**. Fatigue is a noted decrease in performance level, which slows down or even stops the activity and thus protects the cell’s ATP levels.

Fat and glycogen represent the major energy sources for maintaining ATP re-synthesis. Some energy for ATP re-synthesis also comes from the anaerobic splitting of phosphocreatine (PCr), again providing energy for a few seconds (5-10 seconds) [MKK07, pg 140].

$$\text{PCr} + \text{ADP} + P \leftrightarrow \text{Cr} + \text{ATP}$$

### 2.1.2 Lactic Acid

The second anaerobic energy system activated is the lactic acid. It is called the lactic acid (or glycolytic) system because the chemical fuel, glycogen, stored in the muscle, is converted into energy with lactic acid forming. Lactic acid was once viewed as a waste product, however is now thought to be a contributor to the production of ATP when oxygen supplies become available again. Like the ATP-PCr system, energy can be produced rapidly by this system. However, the muscle cells cannot tolerate a high quantity of this ‘waste’ product, lactic acid, and the muscles cease to function effectively and become extremely painful. If an activity is of such high intensity that the anaerobic system is used exclusively, then the available energy will only last for about 2-3 minutes.

$$\text{C}_6\text{H}_{12}\text{O}_6 + \text{ADP} + P \rightarrow \text{lactic acid} + \text{ATP}$$

### 2.1.3 The Oxygen System

This system, is essential for badminton play, and relies on the transport of adequate supplies of oxygen from the atmosphere to the working muscles. Oxygen is required at the working muscles as part of the reaction to provide energy. The lungs, the bloodstream and the heart are all involved in this transfer and must be highly efficient to ensure that oxygen reaches the muscles with the minimum of delay. As previously stated, when
the intensity of exercise is such that the supply of oxygen from the atmosphere is adequate for the demands of the working muscles, the oxygen system is used. Many activities of a long-term nature (endurance activities) operate predominantly with the oxygen system. This is most clearly seen in activities such as middle and long distance running.

\[ C_6H_{12}O_6 + 6 O_2 + ADP + P \rightarrow 6 CO_2 + 6H_2O + ATP \]

**Oxygen uptake**

The results of a number of tests on the maximum oxygen uptake of elite badminton players were provided in early studies in Denmark between the periods 1977-1995 (see table 2):

<table>
<thead>
<tr>
<th>Study</th>
<th>Number</th>
<th>Weight</th>
<th>VO2 max (ml/min/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danish elite 1977</td>
<td>9</td>
<td>74,1</td>
<td>59</td>
</tr>
<tr>
<td>Danish elite 1985</td>
<td>6</td>
<td>73,3</td>
<td>61</td>
</tr>
<tr>
<td>Danish elite 1988</td>
<td>10</td>
<td>73,7</td>
<td>65</td>
</tr>
<tr>
<td>Danish elite 1992</td>
<td>14</td>
<td>76,9</td>
<td>64</td>
</tr>
<tr>
<td>Danish elite 1995</td>
<td>10</td>
<td>74,5</td>
<td>63</td>
</tr>
<tr>
<td>International 2007</td>
<td>4</td>
<td>70,3</td>
<td>62</td>
</tr>
</tbody>
</table>

*Table 2: The maximal oxygen uptake in numerous studies [Omo96, Fau07]*

The figures show average values. They did however show some individual variation, for example, the men’s maximum oxygen uptake varies in 1988 between 58 and 70 ml oxygen/min/kg. The level for men is 10-20% higher than that for women. **The difference is physiological.** It is due especially to the fact that woman as a rule have more fatty tissue than men, and that women’s blood consists of 13g of haemoglobin per 100ml, 15g per 100ml in men.
The energy sources during a game of badminton

As indicated above the majority of sporting events, badminton included, do not rely exclusively on either the aerobic or anaerobic energy systems, but the requirements of the game demand that each system is used. For this reason any training should be designed to ensure that all systems are developed sufficiently.

According to Ømosegaard [Omo96], at the highest level both rallies and breaks average 7-12 seconds. Because the work and break times are relatively short, the muscles and circulation react practically as if the work is continuous, with a workload equivalent to the average of works plus breaks. This is due to the substance called myoglobin. Myoglobin is capable of building up an oxygen store of up to 0.5 litres of oxygen in the average person. During breaks the myoglobin stores some of the oxygen which has been taken up. The muscles have both the stored plus the oxygen taken up during the rallies at its disposal.

During an average rally of 10 seconds, the ATP-PCr system runs out of energy after 5-6
seconds. The lactic acid system then takes over. A small amount of lactic acid may be produced but is not significant and is eliminated during breaks.

Rallies played at high speed/intensity will make extra demand on the lactic acid system and will result in the production of more lactic acid. During breaks after such an ‘acid rally’, the muscles immediately start to remove the lactic acid. The lactic acid is transformed into carbohydrate. This requires energy which is supplied via ATP from the oxygen system. If the break is short there is likely to be less oxygen to fill the myoglobin store in time for the next rally. Thus the formation of lactic acid will start earlier during the next rally. For a player to get out of this situation, he has to slow down, play shorter rallies or take longer breaks, until conditions become normal again. [Omo96]

When the energy produced by anaerobic methods is used up it is necessary to reduce the intensity of the activity and to allow the oxygen energy system to operate. This could explain why so many badminton players, after a fast intensive rally, walk around, delay returning the shuttle and take a longer time to prepare for the next rally (see picture 5). They have used up the anaerobic energy supply for the moment and switched to the oxygen system until the anaerobic energy systems are ‘refuelled’.

From the information available on badminton energy demands it is possible to infer which energy systems are required in the game. The game is made up of rallies which involve short bursts of intense activity. These would involve the ATP-PCr system

![An example of rally and rest lengths](image_url)

**Picture 5:** An example of rally and rest lengths. (First game of the Hong Kong Super Series men's singles final 2009, Lee Chong Wei MAS vs Peter Gade DEN)
predominantly. Other rallies which last as long as 20 seconds involve, if played at maximum intensity, about 90 per cent of the anaerobic system, which consists of the ATP-PCr and lactic acid systems.

2.2 Previous studies on badminton

The previous studies on badminton are focused on men’s singles. They are based on measurements of a couple of factors that are important to understand the nature of the game. These factors have an important correlation to the physiological demands of the sport.

During the badminton men’s singles game each of the players has to cover on average between 1.0 km and 1.8 km per game [Omo96]. A singles player takes 593.8 steps per game. That seems to be a short distance for a well trained person such as an elite badminton player. However if we take a look at the court dimensions, then we can see that it is a relatively small area: 5.14 m width and 6.7 m length, so the number of direction changes must be quite high.

The study done by Ømosegaard [Omo96] shows that the average speed of the player measured during the rallies was 6.3 km/h, and that players were faster in moving towards the shuttlecock (average 6.8 km/h) than moving to playing centre (average 5.5 km/h). 14 km/h was the highest speed measured. Based on this data we can say that badminton is a sport where a fairly low tempo alternates with very fast acceleration in movements. Crucial factor found in a Swedish study [Wir83] is the braking time in all four corners.

A badminton match may last between 15 to 90 minutes (old scoring system), depending on breaks between rallies and games and of course on rivals level of equality. When players participate in tournaments it isn’t unusual to play 5-6 matches per day. [Omo96]

Previous studies have found that the rally:break ratio is almost 1:1. Data from Coad [Coa79] and Docherty [Doc82] reported rally lengths of 9.15 +/- 0.43 seconds and break lengths of 13.84 +/- 1.16 seconds. Ømosegaard had similar findings, but rallies and breaks were between 7 and 12 seconds [Omo96]. Ømosegaard also states that the stroke rate is 3.6 strokes per player per rally. An even game of singles consisted of 47 to 70
rallies [Omo96].

The International Badminton Federation tried to make the game of badminton more attractive for spectators, sponsors and television in year 2000, when they introduced an experimental scoring system, which went from previous best of 3 games to 15 points format to best of 5 games to 7 points. The changes were studied during the Welsh Open in 2000 by Pritchard et al. [Pri01]. These are the results they found:

- significant difference between lengths of the games under experimental scoring system: the average dropped from 19:24 under the old system, to 8:53 under new one.
- a tight match in 3 x 15 format may last up to one hour, but in the 5 x 7 points format this decreased to 45 minutes.
- work and rest ratios were seen mostly identical in both systems.
- there were more breaks in play, especially between each game, but on the other hand games were of course shorter than before.
- “critical points”, which are game or match points, occurred 4.05 times per game under the experimental scoring system. This was an increase from 1.76 per game under the traditional scoring system.

On the 1st of January 2006 the International Badminton Federation implemented a new scoring system, which was called the “rally point scoring system”. The game format changed from traditional 3 x 15 points to 3 x 21 points. The major difference between these two systems lies in how the points are count: in the traditional one a player could score a point by only winning a rally after his own service. If he lost the rally his opponent started the next rally with service without getting a point. In rally scoring system every rally counts a point independently from who performed the service.

After the new rally scoring system was implemented, studies considered the impact of the new system. Faude et al found in 2007 that rallies last between 4 to 5 seconds with
breaks of 6 to 11 seconds [Fau07]. This indicates a 1:2 ratio between rallies and breaks. 3 to 5 strokes were played per rally on average indicating a stroke rate of 1 stroke per second.

Studies by Tu in 2007 [TuK07] and Cabello Manrique and Gonzallez-Badillo [CoG03] reported rally to break ratios of 1:2. When compared to the older studies most factors are the same except two: number of strokes per rally and total match duration. In traditional system the stroke time was 0.98 +/- 0.26 seconds; and in the new 0.92 +/- 0.20 seconds. The total match time shows a decreasing overall time from 45.9 +/- 3.0 minutes to 32.5 +/- 2.5 minutes.

3 Analysis

Existing studies on badminton show significant variation in findings. Players of different abilities under very different conditions have been used to measure the temporal structure of the game. With this in mind we set out to get an accurate representation of current top level singles play.

3.1 The selection criteria

The first point of reference was the Badminton World Federation (BWF) ranking levels. There are four tournament levels in the current BWF structure.

We chose to analyse the men’s finals of tournaments from level 1 and level 2 in 2009 for our main study, of which there were 17 matches. We included additional men’s and women’s singles matches for reference.

Twelve additional men’s singles and six women’s singles matches were included in the study. The Olympics is not part of the BWF tournament ranking system, although some matches from the Olympics are included, as were a couple of matches from BWF level 3.
### Mens singles finals from 2009

<table>
<thead>
<tr>
<th>BWF Level</th>
<th>Name</th>
<th>Description</th>
<th>Event Type</th>
<th>Frequency</th>
<th>2009</th>
<th>Players</th>
<th>Scoreline</th>
<th>Match Length</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BWF World Championships</td>
<td>World Championships</td>
<td>Individual</td>
<td>Annual (except for Olympic years)</td>
<td>2009</td>
<td>Lin Dan v Lee Chong Wei</td>
<td>21-14 21-18</td>
<td>51</td>
<td>not held in 2009</td>
</tr>
</tbody>
</table>

**Table 3: The matches analyzed.**

### Other mens' singles matches

<table>
<thead>
<tr>
<th>BWF Level</th>
<th>Name</th>
<th>Description</th>
<th>Event Type</th>
<th>Frequency</th>
<th>Year</th>
<th>Players</th>
<th>Scoreline</th>
<th>Match Length</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BWF World Championships</td>
<td>World Championships</td>
<td>Individual</td>
<td>Annual (except for Olympic years)</td>
<td>2009</td>
<td>Kenichi Tago v Marc Zwiebler</td>
<td>21-15 21-10</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Hong Kong</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2009</td>
<td>Peter Gade v Kenichi Tago</td>
<td>21-12 21-13</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Denmark Open</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2009</td>
<td>Long Chen v Kenichi Tago</td>
<td>15-21 18-21 17-17</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Denmark Open</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2009</td>
<td>Sune Gavnholt v Ville Lang</td>
<td>21-12 21-17 21-17</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>All England</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2009</td>
<td>Chong Wei v Lee Chong Wei</td>
<td>21-8 21-13</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>All England</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2009</td>
<td>Taufik Hidayat v Peter Gade</td>
<td>21-17 16-21 21-18</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Dutch Open</td>
<td>International</td>
<td>Individual</td>
<td>Annual</td>
<td>2007</td>
<td>Przemyslaw Wacha v Kendrick</td>
<td>17-21 21-13 12-21</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Japan Open</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2008</td>
<td>Sony Dwi Kuncoro v Lee Chong Wei</td>
<td>21-17 21-11</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Olympics Beijing</td>
<td>International</td>
<td>Individual</td>
<td>Annual</td>
<td>2008</td>
<td>Ville Lang v Vladimir Druzhenko</td>
<td>21-12 21-19</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

**Total:** 12

### Ladies' singles matches

<table>
<thead>
<tr>
<th>BWF Level</th>
<th>Name</th>
<th>Description</th>
<th>Event Type</th>
<th>Frequency</th>
<th>Year</th>
<th>Players</th>
<th>Scoreline</th>
<th>Match Length</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BWF World Championships</td>
<td>World Championships</td>
<td>Individual</td>
<td>Annual (except for Olympic years)</td>
<td>2009</td>
<td>Lin Li v Yingfang Xie</td>
<td>23-21 21-12</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Malaysia Open</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2009</td>
<td>Tine Rasmussen v Zhou Mi</td>
<td>21-17 15-21 21-16</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Denmark Open</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2009</td>
<td>Saina Nehwal v Camilla Sorensen</td>
<td>21-15 21-14</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Denmark Open</td>
<td>Super Series Event</td>
<td>Individual</td>
<td>Annual</td>
<td>2009</td>
<td>Saina Nehwal v Ella Diehl</td>
<td>19-21 21-15 21-16</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

**Total:** 6

---

**Note:** The scores are given in the order of the first player's win, second player's win, and third player's win for matches with three sets. The match length is calculated based on the given scores.
Our main study included rally lengths, break lengths and strokes made in the matches listed in table 3. In the extended study the strokes made were not analyzed. The entire analysis consisted of 35 matches.

3.2 How the study was carried out

The analysis consisted of recording observations of videos from various sources. The videos used were, variously: on www.badmintonfreak.com, first-hand video recordings, on www.youtube.com, or had been downloaded from online file servers. It involved the use of a small program, developed by Antti, called BadTime. It was capable of registering rally time, break time and registering strokes made during play. Some match length data was gathered from www.tournamentsoftware.com. The data was analysed using Numbers ‘08 software 1.0.3.

Since the study was carried out manually, there is a chance for errors in the data. Clear errors by mistyping etc. were taken out of the data where they were identified. Errors typically less than half a second may be present due to reaction times of the operator. Due to the total number of rallies analyzed, we would expect that errors due to reaction times would be minimized. Other errors may be introduced due to the nature of the videos used such as gaps in match coverage.

3.3 Results

The main data set consisted of 1,032 rallies, 1,015 breaks and 9,807 strokes. The extended analysis consisted of 2,655 rallies and corresponding breaks. Strokes were not monitored in the extended survey. Breaks were divided into two types: Match breaks and inter-rally breaks. Match breaks included all breaks in matches, whereas inter-rally breaks were limited to 54 seconds to exclude the match intervals, mid-game intervals and other lengthy breaks.
The main findings of our survey were:

- The average match length was 44 minutes, standard deviation (SD) = 10.2 minutes. This indicated a 99.7% confidence interval that any match would be between 13 and 74 minutes in duration.

- The average rally was 10.3s long, SD=8.4s. The median rally was 7.8s long.

- The average match break was 25s long, SD=17s, and the median break was 21s. The average rally:match break ratio was 0.45 or 1:2.2. This means that the shuttle was in play for 31% of the match, on average.

- The average inter-rally break was 21s, SD=9s, with a correlation of 0.50 between rallies and inter-rally breaks. This is a weak to moderate correlation, which indicates that break lengths are not well predicted by preceding rallies.

- The average stroke rate was 1 per second. This meant that each player typically struck a shuttle once every two seconds, SD=0.22 seconds.

Additional findings were:

- Average match length for the entire survey was 42 minutes, SD=11 minutes. Again indicating a 99.7% confidence interval that all matches would be below 76 minutes.

- The average rally:break ratio was similar in each of the three match categories.

- The ladies’ matches consisted of marginally shorter average rallies (8.3 seconds) and breaks (20.3 seconds), with an average match length of 43 minutes.

More detailed, and additional information about the study can be found in Appendix 1.
The temporal data of extant studies are varied. The studies were conducted using differing scoring systems, player abilities and test conditions.

Ømosegaard [Omo96] noted that a match could last up to 90 minutes. The longest observed match in our study was 70 minutes long, and a confidence interval of 99.7% that matches would last less than 74 minutes. In [Omo96], it was also noted that average rally and breaks were 7-12 seconds, or a play to break ratio of roughly 1:1. Our study has found that the play:break ratio was approximately 1:2.5, including inter- and intra-game breaks. The rally length and stroke rate we found were generally consistent with the previous studies (table 4).

We have seen that the average rally (10.3s, SD 8.4s) for the finals is 12% longer than it is for the lower level men’s matches. The corresponding average inter-rally break is 21s (SD 9s) and the match break is 25s (SD 17s).

Given the sample size of 1,032, we could assume this ratio of 1:2 to 1:2.5 describes the
interval nature of the sport. Even though the observed rally and break lengths were shorter in lower level men’s singles and ladies’ singles the ratio was the same. It might be useful to build training around intervals with these characteristics. This is further discussed in section Error! Reference source not found..

4.1 Possible reasons for differences found

Listed below are some possible reasons for changes in the temporal structure of the game:

- Reduction in match length may be due to rally-scoring system. Particularly when it comes to match lengths. If an average rally and break length are used to calculate an average (n=50) two game match, the length is estimated at 40 minutes, which closely agrees with our observations. In the old scoring system there could be many changes of serve without the accumulation of points. This means that even though the overall score line could be lower, the rally count could be higher.

- Each point is more valuable to each player in the new scoring system, and this could lead to increased competition for each rally. In the old scoring system, it was possible for a player to compete at a lower intensity when they had the advantage of serving.

- Advances in equipment technology and fitness of players could account for tactical changes. The group have no data on smash speeds with older rackets, although recent observations indicate that increased string tension and racket technology could account for increased smash speed. This may have tactical implications for play during rallies, whereby the overall rally is an initiative fight with increased intensity as opponents try to gain initiative.

- Abilities and styles of players - players now have much more all-round ability. Good in defence, fitness, and offense. This may mean that players are working harder to create initiative, particularly in singles.

- Increased intensity could require longer intervals between rallies.
• It might be argued that match officials allow players longer breaks between rallies, as it could allow greater intensity in the rallies.

• An increased amount of jump smashes and diving defence could be indicators that intensity is increasing.

• If players have increased amounts of deception it could be argued that they are forced to spend more time waiting with respect to the amount of time they spend moving, which would increase the power requirements of players.

4.2 Practical applications

It was stated in the first chapter that in the use of the three chemical processes the body can function with a high or low efficiency. How then can we influence/train and improve these energy systems? A training programme for badminton players has to develop these energy systems, each of which operates for a specific period of time and at a certain intensity.

4.2.1 Training principles

Physical conditioning based on sound principles optimises improvements. Two primary training principles are overload and specificity.

Stimulating structural and functional adaptations to improve performance in specific physical tasks remains the major objective of exercise training. Regular application of a specific exercise overload enhances physiological function to induce a training response. Exercising at intensities greater than normal stimulates highly specific adaptations so the body functions more efficiently. Achieving the appropriate overload requires manipulating training frequency, intensity, and duration, with focus on exercise mode (i.e. cycling, running swimming etc). Of these, exercise intensity is the most important. [MKK07 pg 470, 507]

Simply stated specific exercises elicit specific adaptations to create specific training effects. [MKK07, pg 471]
Early studies [MiR77] suggest that the ATP-PC system is best developed by working at the appropriate maximum effort for periods of 5-10 seconds and allowing three times that period to recover. The work rest ratio is 1:3. The lactic acid system is best developed by working at the appropriate maximum effort for periods of 40-60 seconds with a rest period twice the length of the work period. The oxygen system is best developed by working at the appropriate maximum effort for periods in excess of 3 minutes with a rest period the same length as the work period, a ratio of 1/1.

Intermittent (interval) exercise – manipulating the duration of exercise and rest intervals can effectively overload a specific energy-transfer system [MKK pg 498]

### 4.2.2 Training for badminton

Fitness can be roughly divided into aerobic fitness and anaerobic fitness. The aerobic system is crucial as it supports the anaerobic systems, which are employed during rallies. Given the nature of badminton, and with the principle of individualisation in mind, is it possible to make some general recommendations for the ratio of training in each of the three systems. A study [BCA96] says it is possible to train the aerobic system as a consequence of anaerobic training. Ømosegaard [Omo96] states that aerobic training should be in the form of intervals. This is consistent with McArdle, Katch and Katch [MKK07].

A study [Car07] indicates that aerobic capacity is unrelated or only moderately related to fatigue in high intensity intermittent exercise. And a number of other studies [Fau07, ChC08] point to the need of a high aerobic capacity in competitive badminton players and that badminton training regimes should be designed to induce the development of a sufficient endurance capacity. These additionally suggest that it might be advisable to reproduce the intermittent nature of the sport, particularly with regard to alactacid energy production to improve badminton specific metabolic pathways.

The relationship between aerobic capacity and exercise recovery appears to have certain limitations. Hoffman [Hof97] suggested that there is an important relationship between aerobic fitness and exercise recovery, but this relationship may be limited.
Koziris et al. [Koz96] state:

“...unless the sport involves an event lasting 15 seconds or more or involves repeated efforts of shorter duration without adequate recovery (e.g. football, hockey, wrestling), improving aerobic power would not be a highly effective way to improve performance. Also, such findings, and subsequent training advice, may vary depending on the calibre of the athlete.

Even when the relationship with aerobic power in sprint performance justifies aerobic power as a training goal, the low correlations would lead us to hypothesize that this goal can contribute only marginally to performance. Interval training may be a better way to accomplish this goal...”

“...based on metabolic characterization studies and in the absence of training studies, the shorter the target maximal effort performance is, from 30 seconds to 10 or 15 seconds, the more distance training can be de-emphasized.”

Carey et al. [Car07] state: “the results of this study indicate that aerobic capacity is unrelated or only moderately related to fatigue in high intensity intermittent exercise, with VO2max, accounting for only 17.8% of the variance in fatigue.”

5 Conclusion

As an answer to our problem statement, "The temporal structure of elite level men's singles badminton has changed over time which may have implications for the physiological demands on players", we can now say, that the observed temporal structure of the game definitely has changed compared to earlier observations. The observed rally:inter-rally break ratio is now 1:2.1 with the overall rally:match break ratio of 1:2.5. Effectively this means that the breaks are now longer.

This signifies a potential change in the demand on the energy systems utilized in the game, specifically in the ratio between aerobic and anaerobic work. If this is correct, there are potential implications for training methods used:
- Players may need to develop both aerobic and anaerobic capacity further to stay competitive; however the causal link between the aerobic training and anaerobic improvement is in the studies considered weak.
- It is suggested that interval training at the correct intensities may be sufficient to elicit both the energy systems requirements for the game of badminton as it currently stands.
Glossary

Break
The time between rallies and games, when the shuttle is not in play.

BWF
Badminton World Federation, the current name of the central organization for badminton. Headquarters in Kuala Lumpur, Malaysia.

Conventional scoring system
The winner of a rally gets a point, only if he himself was the server. Best of three games to 15 points for all events, except women’s singles, which was best of three games to 11 points.

Game
also known as a set. A match consists of two or three games.

IBF
International Badminton Federation, the old name for BWF. See BWF.

Inter-rally breaks
Breaks that were limited to 54 seconds to exclude the match intervals, mid-game intervals and other lengthy breaks.

Match breaks
All breaks in a match, including the intervals during and between games.

Notational analysis
Method of recording aspects of competition. In this study, rally length, break and stroke rate were included.

Rally
A rally start with a service and ends when the shuttle hits the ground or a fault is committed.

Rally point scoring system
New scoring format introduces in 2006. The winner of a rally gets a point regardless of who served. Best of three games to 21 points.

Normal Distribution

Distribution of a series of numbers characterised by a high frequency of numbers at the average and tapering off to a low frequency relatively distant to the average.

Confidence Interval

Describes the probability that a value falls within a certain range of the average of all the values. This may be used when a series of values follows a normal distribution.

Standard deviation, SD

Number calculated from a series of values that indicates the spread of the values. The values must follow a normal distribution. Standard deviation can be used to predict confidence intervals.

Stroke rate

The average number of strokes played per second during the rallies.

Temporal

Time

Traditional scoring system

See conventional scoring system.
References


Hen06    Hendrick, H. et al, Practical Applications in Sports Nutrition, Jones and Bartlett Publishers Inc., USA 2006

Hof97    Hoffman, JR, The relationship between aerobic fitness and recovery from high-intensity exercise in infantry soldiers, Military Medicine, vol. 164:


Appendix I: Additional statistics

Notes on Summary Statistics:

- **Match Breaks.** Match Breaks include all breaks and intervals during the matches considered. The reason for including them is that they form an integral part of the game.

- **Inter-rally Breaks.** An upper limit was set in order to eliminate breaks and intervals over a minute in the Rally Break section. This limit was set at 54 seconds. It would have been more accurate to identify and remove the inter-game and mid-game intervals only.

General notes on the empirical research:

- **Match lengths** were mostly recorded from the tournament software website. Where this was not possible, match length was calculated from the match data recorded using BadTime.

- The **Korean Open** Super Series Mens’ Singles Final video was not available at the time of writing, so only the match length data for this match was used for the study.

- Matches from the **Beijing Olympics** were included, as the Olympics was considered a top level event.

- Match lengths, stroke rate, rally length and rally:break ratio were considered to follow a **normal distribution** for purposes of representing standard deviation.

- Stroke rate, rally lengths and rally:break ratio were considered to follow a **normal distribution**.

- There are approximately 47 BWF **level 3** events annually, for reference.

- The World Junior and World Senior Championships were not considered in our study.
Brief notes on statistics:

- **Average** is the sum of the values divided by the number of values.

- **Median** can roughly be described as the middle value in a series of numbers.

- **Normal distribution** is observable when a series of numbers is populated around a central, average value. It may also be referred to as a bell curve.

- **Standard Deviation** is a number that is used to give an indication of the spread of a list of numbers. It has particular relevance if a series displays a normal distribution.

- **Ratio** is simply one number divided by another number.

- **Correlation** is a measure of the degree to which one series of numbers predict the value in another series of numbers. In our case, the length of a rally with respect to the length of the following break. Correlation is in the range -1 to +1.

- **Count** refers to the number of a quantity.
## Top Level Finals

<table>
<thead>
<tr>
<th>Matches</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave match length</td>
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<td>m</td>
</tr>
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<td>SD</td>
<td>10.2</td>
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<td>Match Count</td>
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## Other Mens Singles

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</tr>
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</tr>
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## All Singles Matches

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</tr>
</thead>
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<td>m</td>
</tr>
<tr>
<td>SD</td>
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<td>m</td>
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<tr>
<td>Match Count</td>
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## Confidence Intervals

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<th>Confidence Intervals</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
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<td>68%</td>
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<td>54</td>
</tr>
<tr>
<td>95%</td>
<td>23</td>
<td>64</td>
</tr>
<tr>
<td>99,7%</td>
<td>13</td>
<td>74</td>
</tr>
</tbody>
</table>

## Rallies

<table>
<thead>
<tr>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Rally</td>
<td>9 s</td>
</tr>
<tr>
<td>Rally SD</td>
<td>7 s</td>
</tr>
<tr>
<td>Rally Count</td>
<td>887</td>
</tr>
<tr>
<td>Median Rally</td>
<td>7 s</td>
</tr>
</tbody>
</table>

## Match Breaks

- Average Break: 25 s
- Break SD: 17 s
- Break Count: 1015
- Median Break: 21 s

## Inter-Rally Breaks

- Average Break: 21 s
- Break SD: 9 s
- Break Count: 952
- Min Break: 3 s
- Max Break: 54 s
- Median Break: 21 s
- Ave Rally:Break: 0.48 s
- Rally:Break SD: 0.44 s

## Stroke Rate

- Average Break: 20.3 s
- Break SD: 14.4 s
- Break Count: 537
- Median Break: 8 s
Appendix II: The timing software

To conveniently analyze the rally and rest times during match play, a small computer program was developed. The original goal of the program was to be a “dual stop watch” and notepad, so that it would be easy to export the data collected into Excel or any other similar program for analysis. About half way through the data collection an option to record the number of strokes during rallies was added.

Java was chosen to be the programming environment for the program for two reasons: 1) the nature of Java applications to be easily used on various operating systems [Sun09] (Windows XP, Windows Vista and Mac OS were used) and 2) one of the group members had extensive experience working with Java. The latest version (1.6) of Java could not be used, because at this time it was not released for Macs [App09]. Instead version 1.5 was used.

The coding and preliminary testing took about ten work hours. Few additional errors had to be corrected and the stroke calculations were added, but these required only 1-2 hours. The final size of the program is 774 lines of code (including comments). The BadTime badminton match timer is now available as a free software released under the GNU General Public Licence [Raj09, GNU09]

In practise the user would have a match video is running in the background and the timing software is running on top (see picture 6). User registers events by pressing corresponding keys in the keyboard (space to start or end a rally, enter to register a stroke) or by clicking the buttons in the window. If the user makes an error, he can mark the spot with a star (*) by pressing backspace. After the match is finished, the user saves the result into a standard text file and can then correct the errors he made by editing the text file.

The error correction proved to be a difficult task in practise. If the user had started or stopped the rally at a wrong time, it was impossible to deduct the correct times, and thus the entire rally or rallies that were influenced by the error had to be excluded. Another common error, registering an extra stroke at the end of rally, was easy to correct afterwards: just mark the spot with a star and eventually subtract one stroke from all rallies marked with a star.
Picture 6: Timing in practice.
Appendix III: Korean study on the effect of rally point scoring

Some explanation..

In Table 5 the analysis of the game structure can be seen. The data was collected and reported by Chen and Chen while observing Korean top-15 players during two national tournaments in 2005 and 2006 [ChC08].

<table>
<thead>
<tr>
<th>Match duration</th>
<th>Old system</th>
<th>New system</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>1184.7 ± 47.6</td>
<td>1184.7 ± 47.6</td>
<td>0.01</td>
</tr>
<tr>
<td>1st inning</td>
<td>1133.7 ± 68.5</td>
<td>644.3 ± 21.0</td>
<td>0.002</td>
</tr>
<tr>
<td>2nd inning</td>
<td>1273.7 ± 69.2</td>
<td>952.8 ± 55.5*</td>
<td>0.04</td>
</tr>
<tr>
<td>3rd inning</td>
<td>1174.0 ± 32.8</td>
<td>940.3 ± 16.6*</td>
<td>0.02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exercise duration</th>
<th>Old system</th>
<th>New system</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>2754.6 ± 178.9</td>
<td>1949.7 ± 147.6</td>
<td>0.01</td>
</tr>
<tr>
<td>1st inning</td>
<td>239.7 ± 8.7</td>
<td>310.5 ± 16.2*</td>
<td>0.04</td>
</tr>
<tr>
<td>2nd inning</td>
<td>344.4 ± 3.7†</td>
<td>311.7 ± 6.9*</td>
<td>0.04</td>
</tr>
<tr>
<td>3rd inning</td>
<td>368.0 ± 12.6</td>
<td>275.6 ± 11.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Overall</td>
<td>860.7 ± 60.0</td>
<td>667.0 ± 50.0</td>
<td>0.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rest interval</th>
<th>Old system</th>
<th>New system</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>1897.5 ± 123.2</td>
<td>1282.1 ± 106.7</td>
<td>0.04</td>
</tr>
<tr>
<td>1st inning</td>
<td>784.7 ± 50.0</td>
<td>404.0 ± 15.3</td>
<td>0.001</td>
</tr>
<tr>
<td>2nd inning</td>
<td>864.0 ± 54.0</td>
<td>642.3 ± 55.9*</td>
<td>0.03</td>
</tr>
<tr>
<td>3rd inning</td>
<td>844.4 ± 18.9</td>
<td>628.7 ± 8.9*†</td>
<td>0.02</td>
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</table>

<table>
<thead>
<tr>
<th>Exercise duration: Rest time</th>
<th>Old system</th>
<th>New system</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>1 to 2.30</td>
<td>1 to 2.01</td>
<td>0.18</td>
</tr>
<tr>
<td>1st inning</td>
<td>1 to 2.44</td>
<td>1 to 1.75</td>
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<td>2nd inning</td>
<td>1 to 2.06</td>
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<td>0.37</td>
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<tr>
<td>3rd inning</td>
<td>1 to 2.46</td>
<td>1 to 2.10</td>
<td>0.13</td>
</tr>
<tr>
<td>Overall</td>
<td>1 to 5.12</td>
<td>1 to 4.76</td>
<td>0.31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of shots per rally</th>
<th>Old system</th>
<th>New system</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>17.0 ± 0.7</td>
<td>20.1 ± 1.2</td>
<td>0.07</td>
</tr>
<tr>
<td>1st inning</td>
<td>7.4 ± 0.2</td>
<td>7.7 ± 0.2</td>
<td>0.26</td>
</tr>
<tr>
<td>2nd inning</td>
<td>7.6 ± 0.1</td>
<td>8.8 ± 0.3*</td>
<td>0.03</td>
</tr>
<tr>
<td>3rd inning</td>
<td>7.8 ± 0.1</td>
<td>9.6 ± 0.2*†</td>
<td>0.02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rally time</th>
<th>Old system</th>
<th>New system</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>17.9 ± 1.1</td>
<td>19.9 ± 1.3</td>
<td>0.19</td>
</tr>
<tr>
<td>1st inning</td>
<td>8.0 ± 0.3</td>
<td>7.5 ± 0.2</td>
<td>0.24</td>
</tr>
<tr>
<td>2nd inning</td>
<td>7.9 ± 0.1</td>
<td>8.7 ± 0.3*</td>
<td>0.05</td>
</tr>
<tr>
<td>3rd inning</td>
<td>8.4 ± 0.4†</td>
<td>9.7 ± 0.3*†</td>
<td>0.04</td>
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</table>

<table>
<thead>
<tr>
<th>Stroke time</th>
<th>Old system</th>
<th>New system</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
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<td>1.01 ± 0.01</td>
<td>0.17</td>
</tr>
<tr>
<td>1st inning</td>
<td>1.08 ± 0.03</td>
<td>0.97 ± 0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>2nd inning</td>
<td>1.04 ± 0.01</td>
<td>0.99 ± 0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>3rd inning</td>
<td>1.08 ± 0.02</td>
<td>1.01 ± 0.01</td>
<td>0.17</td>
</tr>
<tr>
<td>No. of serves</td>
<td>Old system</td>
<td>New system</td>
<td>( P )</td>
</tr>
<tr>
<td>---------------</td>
<td>------------</td>
<td>------------</td>
<td>--------</td>
</tr>
<tr>
<td>1st inning</td>
<td>43.0 ± 2.4</td>
<td>31.3 ± 0.7</td>
<td>0.01</td>
</tr>
<tr>
<td>2nd inning</td>
<td>52.2 ± 1.9*</td>
<td>35.2 ± 0.9*</td>
<td>0.002</td>
</tr>
<tr>
<td>3rd inning</td>
<td>53.0 ± 4.0*</td>
<td>32.0 ± 0.3†</td>
<td>0.02</td>
</tr>
<tr>
<td>Overall average</td>
<td>47.3 ± 1.5</td>
<td>32.9 ± 0.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Overall</td>
<td>108.4 ± 7.6</td>
<td>78.4 ± 3.9</td>
<td>0.002</td>
</tr>
</tbody>
</table>

**Table 5:** Changes in temporal structure of badminton singles matches (N=15) played under the old and new systems. [ChC08]

\*\( p < 0.05 \) compared to data from 1st inning; †\( p < 0.05 \) compared to data from 2nd inning.