The effectiveness of the Total Quality Recovery (TQR) scale for elite badminton players during periods of intense training

Dissertation submitted in accordance with the requirements of University of Chester for the degree of Master of Science

Neil Cottrill

September 2007
Acknowledgements

I would like to thank the badminton players and coaches at the High Performance Centres in Bath and Cardiff for their participation in the study. Thanks are also extended to my dissertation supervisor, Mr David Kellett, for his support and guidance and also Mr Mike Morris for his statistical input.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TQR scale</td>
<td>Total Quality Recovery scale</td>
</tr>
<tr>
<td>TQRact</td>
<td>Actual Total Quality Recovery score</td>
</tr>
<tr>
<td>TQRper</td>
<td>Perceived Total Quality Recovery score</td>
</tr>
<tr>
<td>RPE</td>
<td>Rate of Perceived Exertion</td>
</tr>
<tr>
<td>UPS</td>
<td>Unexplained Underperformance Syndrome</td>
</tr>
<tr>
<td>GI</td>
<td>Glycaemic Index</td>
</tr>
<tr>
<td>BMR</td>
<td>Basal Metabolic Rate</td>
</tr>
<tr>
<td>HPC</td>
<td>High Performance Centre</td>
</tr>
<tr>
<td>URTI</td>
<td>Upper Respiratory Tract Infection</td>
</tr>
<tr>
<td>POMS</td>
<td>Profile of Mood States</td>
</tr>
<tr>
<td>MD</td>
<td>Major Depressive disorder</td>
</tr>
<tr>
<td>WIS</td>
<td>Welsh Institute of Sport</td>
</tr>
</tbody>
</table>
Declaration

The work is original and has not been previously submitted in support of a degree, qualification or other course.

Signed

Date
Dissertation author consent form

Copy No

Location

Author Neil Cottrill

Title The effectiveness of the Total Quality Recovery scale for elite badminton players during intense training.

Author’s Declaration

I agree that this dissertation shall be available for reading in accordance with the regulations governing the use of University of Chester dissertations.

Signature

Date 14/02/08

User’s Declaration

I undertake not to reproduce any portion of, or to use any information derived from this dissertation, without first obtaining written permission from the Head of Department.

<table>
<thead>
<tr>
<th>Date</th>
<th>Signature</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The effectiveness of the Total Quality Recovery (TQR) scale for elite badminton players during periods of intense training.

Contents

Abstract 9
Chapter 1 Introduction 11
Chapter 2 Methodology 43
Chapter 3 Results 48
Chapter 4 Discussion 53
Chapter 5 Conclusion 78
Chapter 6 Bibliography 79

List of Tables

Table 1 Baseline data for the High Performance players involved in the study 43
Table 2 Preferred badminton discipline and employment status at the Bath HPC 44
Table 3 Preferred badminton discipline and employment status at the Cardiff HPC 44
Table 4 Mean RPE, TQRact and TQR per scores for the badminton players at the two High Performance centres 48
Table 5 Individual player differences in RPE, TQRact and TQRper scores 49
Table 6 Percentage of the maximum TQR score for each component 50
Table 7 Mean values for the TQRact category scores 51
Table 8 Mean dietary analysis findings for High Performance badminton players 52
Table 9 TQRact Recovery Points scoring for Nutrition category 58
Table 10 TQRact Recovery Points scoring for Sleep and Rest category 64
Table 11 TQRact Recovery Points scoring for the Relaxation and Emotional Support category 67
Table 12 TQRact Recovery Points scoring for the Stretching and Warm down category 70
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>A model of the components contributing to elite sports performance</td>
<td>11</td>
</tr>
<tr>
<td>Figure 2</td>
<td>The continuum of training states in relation to changes in performance</td>
<td>13</td>
</tr>
<tr>
<td>Figure 3</td>
<td>The ratio of Lactate:RPE for an incremental exercise test</td>
<td>16</td>
</tr>
<tr>
<td>Figure 4</td>
<td>General Adaptation Syndrome</td>
<td>18</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Typical profile of response from the POMS questionnaire</td>
<td>18</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Iceberg profile and global mood state from POMS questionnaire</td>
<td>19</td>
</tr>
<tr>
<td>Figure 7</td>
<td>The cyclical mechanism of increased risk of URTI in athletes</td>
<td>21</td>
</tr>
<tr>
<td>Figure 8</td>
<td>“J” shaped curve to explain the incidence of URTI following different levels of training</td>
<td>21</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Incidences of URTI following increases in training load, monotony and strain</td>
<td>22</td>
</tr>
<tr>
<td>Figure 10</td>
<td>A schematic of the relationship between the Central Nervous System and the cytokine influence</td>
<td>23</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Changes in IL-6 following CHO supplementation</td>
<td>27</td>
</tr>
<tr>
<td>Figure 12</td>
<td>TQR scale to monitor recovery and the Borg scale to monitor exercise intensity</td>
<td>29</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Theoretical model of the expected mechanisms of massage</td>
<td>33</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Differences between the mean RPE, TQRact and TQRper values</td>
<td>49</td>
</tr>
<tr>
<td>Figure 15</td>
<td>The differences between the percentage maximum TQR component scores</td>
<td>50</td>
</tr>
<tr>
<td>Figure 16</td>
<td>The individual player differences between their total RPE and TQRact scores</td>
<td>53</td>
</tr>
<tr>
<td>Figure 17</td>
<td>The individual player differences between their total RPE and TQRper scores</td>
<td>55</td>
</tr>
<tr>
<td>Figure 18</td>
<td>The individual player differences between their total TQRact and TQRper scores</td>
<td>56</td>
</tr>
<tr>
<td>Figure 19</td>
<td>Mean distance to target intakes of CHO and Protein for players involved in study</td>
<td>59</td>
</tr>
<tr>
<td>Figure 20</td>
<td>Percentage Carbohydrate (CHO) Fat and Protein (PRO) values reported by players in comparison to target values</td>
<td>61</td>
</tr>
<tr>
<td>Figure 21</td>
<td>The number of players reporting the use of recovery modalities during the monitoring period.</td>
<td>68</td>
</tr>
<tr>
<td>Figure 22</td>
<td>Mean warm down scores for badminton players involved</td>
<td>71</td>
</tr>
<tr>
<td>Appendices</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>Appendix 1</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>Player handbook</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appendix 2</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>Participant information sheet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appendix 3</td>
<td>117</td>
<td></td>
</tr>
<tr>
<td>Example Dietplan nutritional analysis outputs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appendix 4</td>
<td>121</td>
<td></td>
</tr>
<tr>
<td>Ethics Approval Letter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appendix 5</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>SPSS outputs (CD ROM)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Abstract

This study investigated the efficacy of the Total Quality Recovery (TQR) scale (Kentta & Hassmen, 1998) for elite badminton players at two High Performance Centres (HPC).

Nine male (age 24.4 ± 3.4yrs) and three female badminton players (age 20.0 ± 2.0yrs) were recruited on the basis that they were members of the HPC and were undertaking multiple training sessions on a daily basis. The hypothesis tested was that there would be an imbalance between Rate of Perceived Exertion (RPE) (Borg 1998) and actual (TQRact) scores during recovery.

The study was a repeated measures design involving daily recording of Rate of Perceived Exertion (RPE), perceived recovery (TQRper) and recovery action score (TQRact) during a five day training cycle. Nutritional intake, amount of sleep and rest, relaxation modalities employed and level of warm down completed were recorded in player handbooks.

Agreement between the RPE, TQRper and TQRact was assessed using the Friedman ANOVA and Spearman correlation coefficient. The TQR scale category differences were assessed by the Friedman ANOVA technique with appropriate Mann Whitney U test post-hoc analysis with Bonferroni adjustments applied for the repeated measures.

Results showed a significant imbalance between perceived effort and actual recovery score (p= 0.006) indicating players recovery activities were not sufficient for the level of training undertaken. The results also indicate that key areas for improvement would be to increase carbohydrate intake, to utilise different recovery modalities such as massage and cryotherapy, and to ensure completion of an appropriate warm down.
It is concluded that the TQR scale is a useful tool for coaches and players to monitor training and recovery but that HPC badminton players need to focus more attention on recovery actions to avoid overtraining and optimise their training.
Chapter 1 - Introduction

The requirements of competitive badminton

Badminton is a complex, physically demanding sport, requiring diverse training, practice and recovery strategies to achieve optimum performance (Figure 1).

Figure 1. A model of the components contributing to elite sports performance (Smith, 2003).

The wide range of elements that combine to produce any elite performance requires great diligence and attention to detail to ensure that one area does not under-perform bringing about a decrement in overall performance. With the globalisation of modern day sport, with badminton being no exception, the players are expected to play and train all year round, all around the world. (Reilly et al, 1998).

The pressures of elite sport.

Due to the financial rewards at the elite level in most sports, the pressure on athletes to constantly perform at their optimum level is extreme. This means that the training these performers undertake must be effective to allow them to produce the required level of
performance in competition although the increasing competitive demands and training schedules are not ideal for peak performance (Smith, 2003).

In some instances, the training stress placed on performers can be too great and a subsequent decrement in performance observed, which could also be accompanied by increased incidence of injury. In English football, this has been shown to cost €125 million euros across the whole football league during season 1999/2000 (Hawkins et al, 2001) and levels of performance have been shown to deteriorate due to the number of games, especially towards the end of the competitive season (Ekstrand, Walden & Hagglund, 2004).

This deterioration in performance could be characterised as the Overtraining Syndrome (Budgett, 1994). Overtraining has been investigated by a number of researchers (Mackinnon & Hooper, 1996, Rowbottom et al, 1997, Urhausen et al, 1998, Nieman et al, 1998) in an attempt to fully understand the condition and to try to identify and prevent it before it happens. This has proven to be a difficult process as no one cause has been accepted by the scientific community due to its individual and multi-factorial nature (Petibois et al, 2002, Robson, 2003).

Another significant factor in the lack of cohesive knowledge is the use of different terminology surrounding overtraining (Derman et al, 1997), with terms such as burnout, staleness, overreaching, overtraining, overstressed being seen in the research literature (Kentta & Hassmen, 1998). The most commonly used term is overtraining, but this has been redefined by Budgett et al, (2000) as Unexplained Underperformance Syndrome (UPS). The reason for this redefinition is that the term overtraining suggests that the athlete has simply trained too much, whereas the actual causes behind the symptoms are considerably more complex (Robson, 2003).
Overtraining and Overreaching

Under normal circumstances, when the athlete trains there is a subsequent cellular disturbance, which is the main stimulus for initiating physiological adaptation. The body continues to recover past the homeostatic level and achieves a Super Compensation, which should result in performance enhancement (Kuipers, 1998). If the body does not have sufficient recovery time following a training stimulus then overtraining or overreaching can occur. (Kentta & Hassmen, 1998). The body is thought to be in constant flux along the continuum of adaptation and mal-adaptation dictated by training volume intensity and recovery (Smith & Norris, 2000).

Over reaching is a transient condition that describes a brief period of overload followed by inadequate recovery (Armstrong & VanHeest, 2002) (Figure 2.). It has been seen to elicit a decrement in performance, but only lasts a short period of time and can result in super compensation (Budgett, 1994). The state is often used deliberately by athletes to induce performance enhancement, providing they have sufficient recovery time (Halson & Jeukendrup, 2004).

Figure 2. The continuum of training states, showing the transition from under training through over reaching to overtraining, in relation to changes in performance (Armstrong & VanHeest, 2002).

If overreaching is not recovered from, it can lead to the more long standing condition of overtraining. This would manifest itself in a variety of ways, and symptoms would not
recover in two weeks of rest and could take several months to recover. (Budgett, 1994, Derman et al, 1997).

Often for the athlete, the first sign of overreaching and/or overtraining is a decrement in performance (Petibois et al, 2002). This then triggers off a cycle of more intense training to try to overcome this lack of performance (Halson & Jeukendrup, 2004), which will then perpetuate the overtrained status and performance will continue to be compromised. It is therefore important that over reaching is identified by the athlete before it results in overtraining/UPS.

Signs and symptoms of Overtraining

There are numerous signs and symptoms that the athlete/coach can look for to identify over reaching and overtraining. Fry, Morton and Keast, 1991 (cited IN Smith, 2000), defined four categories of symptoms associated with overtraining/UPS;

1. Physiological performance
2. Psychological or information processing
3. Immunological markers
4. Biochemical markers

These four categories have 93 reported individual symptoms within them (fatigue, insomnia, loss of appetite, increased heart rate etc) that are used to determine whether an athlete is overtrained (Smith, 2000). These categories have also been used as a framework for research to find a reliable marker for diagnosing overtraining/UPS (Gastmann & Lehmann, 1998, Lehmann et al, 1998b, Armstrong & VanHeest, 2002, Halson et al, 2002, Urhausen & Kindermann, 2002). The overtrained athlete would not suffer from all of the symptoms, making the use of a single reliable marker problematic (Smith, 2000). However, different athletes may suffer from different symptoms due to the type of training they undertake.
Two different classifications of overtraining have been identified by Lehmann et al., (1998b). Parasympathetic Type Overtraining Syndrome is reported to be the most common form of overtraining and is characterised by altered mood state and persistent fatigue. It is a negative feedback response to sustained levels of stress, affecting circulating levels of catecholamines such as noradrenaline. Sympathetic Type Overtraining Syndrome which has been likened to thyroidal hyperfunction (Israel, 1976 cited IN Lehmann et al, 1998b) is less common in modern day sport and is characterised by hyper-excitability (Lehmann et al, 1998b).

Endurance athletes often suffer from fatigue and apathy commonly associated with parasympathetic overtraining and explosive type athletes suffering from hyper-excitability associated with sympathetic overtraining (Lehmann et al, 1998b). The research presented by Lehmann et al, (1998b) was focussed on endurance athletes, rather than a range of activities as there may be some examples of elite explosive type sports performers such as badminton players, suffering from parasympathetic overtraining symptoms, especially if they perform both aerobic and anaerobic training due to the varied physiological demands of the sport.

1. Physiological performance markers of overtraining

A number of symptoms reported by Fry, Morton and Keast, 1991 (cited IN Smith, 2000) fall into the physiological performance category, such as loss of appetite, changes in resting heart rate and prolonged recovery time after bouts of exercise. Such examples have been reported by a number of authors (Kentta & Hassmen, 1998, Armstrong & VanHeest, 2002, Halson & Jeukendrup, 2004) and are regarded as an evolved strategy aimed at reducing energy expenditure to promote survival (Smith, 2000).

McKenzie (1999) suggested that overtrained athletes show a decrease in time to exhaustion in a cycle ergometer test at 110% of the individual’s anaerobic threshold.

Work done by Urhausen, Gabriel and Kindermann (1998) found a 27% decrease in time
to exhaustion at 110% of anaerobic threshold in 17 male endurance athletes (\( \dot{V}O_2 \text{max} 
61.2 \pm 1.8 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} \)) tested five times over two days. The subjects were exposed to short term overtraining then their work responses tested. A number of the physiological variables reported by Fry et al (1991) remained unchanged, but the anaerobic performance decreased.

The protocol of the study did not actually use overtrained athletes, just extrapolated from over reached athletes, which may introduce error. It has to be assumed that overtraining is a more severe over reaching response, as ethically it is unacceptable to elicit a truly overtrained status as part of an experimental protocol (Foster, 1998).

Another method of assessing the overtrained status is to compare the lactate production and Rate of Perceived Exertion (RPE) (Borg, Lunggren & Ceci, 1985 cited IN Snyder, 1998). The overtrained athlete will perceive that they are working harder at a given exercise intensity than their physiology would suggest, due to the increased feelings of fatigue due to the lactic acid accumulation.

The ratio of Lactic acid production to RPE shows that overtrained athletes find the given workload at higher intensities more difficult than the non-overtrained athletes (Fig 3. Snyder, 1998).

Figure 3. The ratio of Lactate:RPE for an incremental exercise test. (Snyder et al 1995, cited IN Snyder, 1998)
This protocol attempted to elicit overtraining over a seven day period in eight competitive male cyclists, so therefore the subjects were overreached rather than overtrained. During the test, maximal workload was decreased by 3% during the overtraining period, but $\dot{V}O_2\text{max}$ and heart rate remained the same as the normal training period and the absolute lactate values were higher than during the normal training period. This suggests a greater contribution from the anaerobic system, possibly due to decreased carbohydrate stores (although this was not measured), which could also explain the decrease in workload.

From a physiological perspective there are a range of symptoms that could suggest an athlete was overtrained, such as increased RPE and decreased performance in time to exhaustion tests. In isolation, the physiological tests are inconclusive in determining whether an athlete is overtrained, due to the conflicting findings in the research.

2. Psychological markers for overtraining.

The symptoms of UPS can initially be triggered by a stressful event either in the personal or sporting life of the athlete (Armstrong & VanHeest, 2002) resulting in the inability of the hypothalamus to deal with the stress being placed upon it (Kuipers, 1998). The stress placed on the body from a sporting context can result in either physiological adaptation or maladaptation. This follows Selye’s General Adaptation Syndrome (GAS), (Selye, 1978).

Figure 4 shows the GAS model. It is split into three stages; Alarm, Resistance and Exhaustion and there are associated hormonal responses driven by the hypothalamus for each stage. During the Alarm stage, the body reacts to the stressors, during the Resistance stage, the body is coping with the stressors and during the Exhaustion stage, the body has been under stress for some time and is not coping, resulting in a loss of performance.
The GAS model follows the aetiology of UPS but does not explain the exact mechanism of what happens to the body in an athlete suffering from UPS.

Figure 4. General Adaptation Syndrome (Selye, 1978). (Graphic taken from http://www.qeliz.ac.uk/psychology/kiecolt+glasier.htm)

The most common psychological symptoms of UPS are emotional instability, lack of confidence and depression (McKenzie, 1999, Smith, 2000, Filaire et al, 2004). The Profile of Mood States (POMS) questionnaire (McNair et al, 1992 cited IN Filaire et al, 2004) has been used successfully in a number of studies to assess mood state in overtrained athletes. The questionnaire assesses tension, depression, anger, vigour, fatigue and confusion, with the overtrained athlete often showing high on the fatigue and depression states compared to the control (Figure 5).

Figure 5. Typical profile of response from the POMS questionnaire. (Budgett, 1994).

The POMS questionnaire was utilised by Achten et al, (2004) in their study into the effects of a high carbohydrate diet during intensified training. They used the POMS as one of their identifying markers for the overtrained state, as they tried to induce it
through intense training. The group found the typical overtrained response during this intense training (Budgett, 1998), with a significant general deterioration in global mood state (p < 0.05), a decrease in vigour, but increase in fatigue and increases in anger and tension at day 11 compared to day 1 (Figure 6).

One of the questions regarding the validity of the POMS questionnaire is the fact that the subjects have to regularly complete 65 questions, which can be time consuming and demotivating (Van Someren, personal communication, 24th May 2006). The subjects in the study by Achten and colleagues (2004) performed the shortened POMS questionnaire to try to combat this, but also had to complete the Daily Analysis of Life Demands of Athletes (DALDA) questionnaire, a training diary and a muscle soreness chart, all of which may have erroneously contributed to the fatigue and lack of vigour findings. However, the DALDA questionnaire may have merit as it is shorter than the POMS questionnaire and easy to complete.

Figure 6. Iceberg profile and global mood state from POMS questionnaire of day 1 and day 11 of high carbohydrate (H) trial and control (C) trial (Achten et al, 2004).
Halson et al, (2002, 2003) also found global increases in POMS scores following bouts of induced overtraining, which was supported by other biochemical indices such as increased creatine kinase. This supports the idea that mood state profiling on a regular basis has been suggested at the most useful indicator of UPS (Budgett, 1998), but even more effective if completed alongside testing for relevant biochemical indices (Halson & Jeukendrup, 2004).

Some of the signs and symptoms mentioned previously (Smith, 2000) to describe UPS, such as fatigue, insomnia, lack of appetite are very similar to the symptoms for major depressive disorder (MD). This suggests that the athletes’ mental well-being may be deteriorating and manifesting itself as altered mood states, insomnia and fatigue (Armstrong & VanHeest, 2002).

"Patients reject the implications of loss on control, diminished vitality and inadequate coping skills... and often vow to work harder so as to overcome their inadequacies, which usually lead to even more severe symptoms and dysfunction" (Schwenk, 2000. p4).

This supports the concept from Halson and Jeukendrup (2004), that the athlete, who is goal driven will work harder to try to overcome the unexplained underperformance and magnify the symptoms up to the point where they are so fatigued, they cannot compete (Noakes, 2000).

From a psychological perspective the mental state of the athlete is of significant concern as excessive stress, such as competitive, social or work stress, can lead to UPS, which has been shown to be akin to mental illness (Armstrong & VanHeest, 2002). The assessment therefore of this parameter via mood state profiling is vital in the overall wellbeing of the athlete.
3. Immunological markers for overtraining.

Another of the commonly reported symptoms of the overtrained athlete is the increased frequency of Upper Respiratory Tract Infections (URTI) (Budgett, 1998, Smith, 2000, Halson & Jeukendrup, 2004). The role of exercise induced immuno-suppression has therefore been explored to find a link with UPS.

Several authors have suggested the existence of an “open window” of suppressed immunity (McKenzie, 1999, Nieman, 2000, Pedersen & Toft, 2000), where the athlete is at greater risk of URTI, in particular during heavy training and after major events (Nieman, 2000).

Figure 7. The cyclical mechanism of increased risk of URTI in athletes (Budgett, 1998)

This is not to say that all athletes will suffer from an increased frequency of URTI, as different people react differently to the same stress. A “J” shaped curve (Figure 8) has been suggested to explain the risks of URTI, with moderate levels of exercise actually reducing the risk (Mackinnon, 1999).

Figure 8. “J” shaped curve to explain the incidence of URTI following different levels of training (Mackinnon, 1999)
Foster (1998) investigated the incidence of URTI in 25 experienced athletes against the athletes training load, monotony and strain. When the URTI were correlated against the training indices, it was found that there were more incidences of URTI following an increase in training (Figure 9).

Figure 9. Incidences of URTI following increases in training load, monotony and strain (Foster, 1998)

It was also shown that the athletes were able to train at high intensity without suffering from URTI, showing that athletes can train hard and with sufficient recovery periods positive adaptation should occur (Foster, 1998). However, nutritional intake was not measured during this study, along with amount of sleep or recovery activities, all of which could have contributed to altered responses to the RPE scores. If the performer had a vitamin deficiency in their diet, this could also have contributed to the risk of URTI. The study did not deal with actual overtrained athletes, just extrapolated from over-reaching athletes, which may affect the incidences of URTI.

Various factors have been investigated to find the reason for this proposed immuno-suppression. The main areas of investigation in this area have included cytokines (Smith, 2000, Robson, 2002) and Glutamine (Rowbottom et al 1997, Bowtell et al 1999).

Cytokines are polypeptide molecules that perform a number of functions within the body including immunity, cell growth and repair and inflammation (Robson, 2003). The
cytokine of most interest within UPS has been Interleukin 6 (IL-6) as it is involved in erythropoeisis, regulation of the immune system and inflammation.

Normal training results in microtrauma to the working muscles which is thought to be the first step on the "injury continuum" (Smith, 2000). This microtrauma is said to be adaptive as it invokes an inflammatory response via the cytokines, which with sufficient recovery promotes healing and adaptation. (Smith, 2000).

If the recovery is insufficient, cytokines are released which in turn will ultimately cause systemic inflammation. IL-6 is a pro-inflammatory cytokine which contributes to this systemic inflammation.

Figure 10 shows the effects of cytokines such as IL-6 on the anterior pituitary gland and the subsequent hormonal changes following their release. Loop A follows the autonomic system resulting in a raised level of catecholamines in the blood preparing the body for exercise. Loop B follows the Hypothalamic – pituitary – adrenal (HPA) axis and the increased release of cortisol, which normally helps to restrain the inflammation, but the release of cortisol is reduced for the athlete suffering from UPS (Lehmann et al, 1998a, Urhausen et al, 1998).

Figure 10. A schematic of the relationship between the Central Nervous System and the cytokine influence (Smith, 2000).
The net results of these effects are the classic symptoms of fatigue, loss of appetite, depression, insomnia, all of which are associated with UPS.

Cytokines such as IL-6 have been shown to have links to a number of areas associated with UPS (Robson, 2003), however they have not been reliable markers for identifying UPS.

Halson et al (2003) found no change in IL-6 and Tumor Necrosis Factor (TNF) following a period of two weeks intensified training, attempting to over-reach eight male subjects, although there was a decrement in cycle ergometer performance. In contrast, Ronsen et al (2002) found elevated levels of IL-6 following a second bout of high intensity exercise (75 minutes at 75% \( \dot{V}O_2\max \)) following three hours recovery. However, Ronsen et al (2002) suggested that this IL-6 response was due to a lack of glycogen repletion but did not measure this by taking biopsy samples. Also, three of the subjects IL-6 data were excluded due to being considered outliers which reduces the sample size for IL-6 responses to six subjects.

Glutamine is a non-essential amino acid synthesised by skeletal muscle and is the main fuel for macrophages and lymphocytes (Bowtell et al, 1999). A number of studies have investigated the effects of excessive training on Glutamine concentrations with a proposed link to the reported immuno-suppression previously mentioned.

Rowbottom et al (1997) found that with balanced training over the course of a season eight male triathletes found an increase in their plasma Glutamine levels, which was correlated to an increase in performance. This lends support for the "J" shaped curve (Mackinnon, 1999) in that the immune function may be strengthened with appropriate training, although incidence of URTI was not measured in this study.
Parry-Billings et al., (1992) (cited IN Halson & Jeukendrup, 2004) reported a decrease in plasma Glutamine in 40 athletes diagnosed to be suffering from UPS, which may suggest a link to immunosuppression.

Mackinnon and Hooper (1996) monitored the plasma Glutamine levels of 24 swimmers (8 male and 16 female) during four weeks of intense training. During this training period, eight swimmers were regarded as showing symptoms of UPS due to deteriorating performance and increased fatigue. They found a 23% lower Glutamine concentration in these overtrained swimmers, but no significant link to changes in URTI rates. The classification of overtraining in these subjects may be open to question due to the relatively short four week training period.

From the research presented there has not been a clearly accepted link between URTI, Glutamine and UPS. However, Smith and Norris, (2000) monitored Glutamine and Glutamate concentrations in 52 national level athletes over the course of a season, with five athletes being diagnosed with UPS during the season. They found that following heavy training Glutamine concentration decreased and Glutamate increased. Therefore the ratio of Glutamine:Glutamate may suggest how well the athlete is responding to training and could be an indicator of UPS.

4. Biochemical markers for UPS

Some of the potential biochemical markers for UPS such as IL-6 and Glutamine have already been discussed. The other major factors that have a bearing on training status are the macro nutrients; carbohydrate (CHO) fat and protein and also the ratio between testosterone and cortisol.

Levels of carbohydrate stores have an effect on some of the mechanisms previously mentioned and links to the central fatigue hypothesis of overtraining (Smith, 2000).
If an athlete trains at high intensity and has insufficient recovery both in terms of muscle regeneration and nutritionally, then he/she will become glycogen depleted. If this state occurs, the body will oxidise protein in the form of branch chain amino acids (BCAA) (Snyder, 1998).

This increased oxidation of BCAA reduces the levels within the blood and therefore increases the ratio of free BCAA : Tryptophan. Tryptophan is an amino acid that enters the brain where it is converted into the neurotransmitter, Serotonin. In certain parts of the brain, Serotonin induces sleep, depresses appetite and alters mood state, autonomic and endocrine function (Kreider, 1998, Smith, 2000) all of which are symptoms of UPS.

Carbohydrate supplementation has been a much utilised method of enhancing performance for the athlete (Christensen & Hansen, 1939 cited IN Astrand & Rodahl, 1986), but it could also be of benefit with regard to the onset of UPS.

Halsen et al, (2004) supplemented six male endurance cyclists (High CHO 20% solution/low CHO 2% solution) during normal, intensified and recovery training. They found a performance decrement following the low CHO supplement, lower muscle glycogen content, increased fat oxidation and also a decreased endocrine response, with regard to cortisol levels following the intensified training regime designed to over-reach the subjects.

Nieman et al, (1998) monitored ten triathletes following CHO (6% solution) and placebo ingestion after 2.5 hours of high intensity exercise. They found a similar attenuation of the endocrine response but also a decreased IL-6 concentration (Figure 11), which may have controlled the cortisol decrease by affecting the HPA axis. This effect on the HPA axis is also thought to have an affect on the URTI incidences (Nieman, 2000).
It is also thought that IL-6 may perform a regulatory role in circulating glucose levels, namely by the liver producing IL-6 to release hepatic glucose if levels fall during exercise (Ronsen et al, 2002, Robson, 2003).

Figure 11. Changes in IL-6 following CHO supplementation (Nieman et al, 1998).

The brain also has an increased demand for CHO during recovery from strenuous exercise (Nybo et al, 2003), which may support the maintenance of mood state found by following a high CHO diet during intensified training (Achten et al, 2004).

On the other side of the Central Fatigue concept, supplementation of BCAA to maintain the BCAA:Tryptophan ratio has been suggested, but there is no consensus as to whether supplementation is beneficial due to the non-standardised methodologies used (Gastmann & Lehmannah, 1998). It has also been reported that supplementing with CHO decreases the levels of Free Fatty Acids (FFA), resulting in lower Tryptophan levels, which ultimately affects the BCAA:Tryptophan ratio delaying the symptoms of fatigue (Gastmann & Lehmannah, 1998).

As well as CHO and protein intake, fat intake may be of consequence to UPS. The traditional low fat high carbohydrate diet (15% fat, 65% CHO, 25%, 20% Protein) of the
athlete may contribute towards some of the symptoms of UPS (Venkatraman et al., 2000). The low fat diet has been shown to increase the action of inflammatory cytokines, so a diet with a moderate fat intake may be of benefit.

The cortisol:testosterone ratio has also been monitored with a view to determine the onset of UPS, but again the results have been equivocal (Halson & Jeukendrup, 2004). The ratio is thought to indicate the balance of the anabolic activity (testosterone) and catabolic activity (cortisol) in the body, showing the positive and negative effects of training, so theoretically could show adaptation to training stress. Studies have shown a decrease in the ratio not affecting performance (Filaire et al., 2004), overtrained athletes having no change in the ratio (Urhausen et al., 1998) and Maso et al (2004) found a correlation between overtraining and testosterone level but not cortisol, therefore making the ratio as a marker alone invalid (McKenzie, 1999).

Recovery following training stress

Taking all the parameters discussed into consideration, the inadequacy of recovery following a training stress seems of paramount importance and monitoring the athletes to deal with this problem before it develops is far more effective. It has been suggested by Kentta and Hassmen (1998) that the recovery process needs to match the stress and these recovery strategies have been identified in four categories:

- Nutrition and hydration – to ensure CHO and fluid replenishment following intense training
- Sleep and rest – no physical activity and sufficient sleep
- Relaxation and emotional support – massage and time away from competitive environment
- Stretching and warm down – low volume and intensity training to promote recovery (Kentta & Hassmen, 1998)
In order to assess the effectiveness of recovery the Total Quality Recovery (TQR) scale (Figure 12) was developed by Kentta and Hassmen (1998).

![Figure 12. TQR scale to monitor recovery and the Borg scale to monitor exercise intensity (Kentta & Hassmen, 1998).](image)

The Total Quality Recovery (TQR) scale was presented by Kentta and Hassmen (1998) not as a tool to detect UPS, but to focus the attention of the athlete and coach towards the importance and relevance of recovery following training bouts. This would go some way to reducing the risks of the athlete suffering from UPS. It is a user-friendly scale that is relatively easily utilised by athletes or coaches and could be a possible alternative to more demanding psychological tools such as DALDA and POMS and the invasive and costly measurement of biochemical markers.

The TQR scale has two sub-dimensions; TQR perceived (TQRper) and TQR action (TQRact).

The TQRper scale is a global measure of perceived recovery, assessing the perception of overall recovery from the previous 24 hours activity. The TQRact scale grades
individual recovery actions from the four main categories of recovery mentioned previously.

The athlete accumulates points over a 24 hour period to measure the quality of recovery which equate to the values on the TQR scale. The process of completing the TQR scale should focus the attention of the athlete on the quality of recovery rather than just training and performance feedback. This may help prevent the onset of UPS, although this subjective measure could be easily influenced by extrinsic factors, such as time, perceived appropriate results or other players’ results and become invalid.

The four categories of the TQRact scale have a different number of points available depending on the importance of that category to the recovery process.

**Nutrition and Hydration**

The Nutrition and Hydration category is vitally important for the athlete (Maughan, 2002). It has been shown to preserve physical and decision making capacity (Graydon et al, 1998, Vergauwen et al, 1998, Welsh et al, 2002, Winnick et al, 2005)

Graydon et al (1998) measured shot accuracy of club level squash players (N=8) when fatigued following ingestion of a carbohydrate solution or placebo. They found that shot accuracy was significantly maintained during the carbohydrate trial (p<0.01).

Vergauwen et al (1998) measured the stroke quality of 13 male tennis players nationally ranked in Belgium (ranked 50-350). They also ingested a carbohydrate solution or placebo and following exercise inducing fatigue the accuracy of the service and groundstrokes were maintained with the carbohydrate solution compared to the placebo (p<0.05).
The players in these two studies were at different levels of performance and significantly lower comparative level than the High Performance Centre (HPC) players involved in this study. This relatively low level of performance could have accounted for the variation in skilled performance, but the strokes measured during the studies by Graydon et al (1998) and Vergauwen et al (1998) were well controlled. Studies have also shown that intermittent exercise performance is also positively affected by increased carbohydrate levels in the body (Welsh et al, 2002, Krstrup et al, 2006).

Welsh and colleagues (2002) found that when ten physically active subjects undertook controlled physical drills designed to simulate the intermittent high intensity activity experienced in basketball, supplementation with carbohydrate increased the time taken to run to exhaustion by 37% (p<0.05) and also a faster 20 metre sprint time in the fourth bout of the testing (p<0.05).

Krusrup et al (2006) looked at the possible causes of fatigue of 31 professional Danish footballers during a simulated football match. They reported a decline in sprint performance later in the competitive game which was linked to a reduction in muscle glycogen levels.

Although these studies are concerned with football and basketball, they both possess a similar intermittent high intensity energy demand to badminton (Shi & Gisolfi, 1998, Welsh et al, 2002). This may have a bearing on the badminton players at the HPC, hence the reason for the maintenance of CHO levels between training sessions being included in the TQRact scale.

Effective rehydration following training or competition has also been shown to delay fatigue and benefit performance (Therminarias et al, 1994, Maughan, 2002, Reilly & Ekblom, 2005, Barnett, 2006). It is for these reasons, the athlete can achieve up to 10 recovery points in the Nutrition and hydration category.

Sleep and Rest

It is important that the athlete has sufficient rest and sleep in between training bouts to allow for adaptation to the training stress. Effective sleep allows the body to produce sufficient Human Growth Hormone (hGH) to repair tissue damaged by intensive training (Van Cauter, 1997, Godfrey et al, 2003). Sleep and exercise are the two most powerful stimuli of Human Growth Hormone (hGH) stimulation, with the largest release of hGH being approximately an hour after the onset of night time sleep (Godfrey et al, 2003). Exercise also stimulates the production of hGH, so the more training the players are doing, the greater the circulating levels of hGH.

The effects of this increased circulation of hGH are an increase in protein synthesis, developing the cross sectional area of the muscle, an increase in lipid metabolism due to the release of free fatty acids and also an increase in mineral metabolism, enhancing bone density (Godfrey et al, 2003). The release of free fatty acids for metabolic purposes spares the carbohydrate stores and promotes nutritional recovery in preparation for the next training bout.

Conversely, a lack of effective sleep for the athlete has been shown to cause mood disturbances which can result in less efficient training (Taylor et al, 1997) and a greater perceived effort during training (Mougin et al, 2000, Scott & McNaughton, 2004). For these reasons the athlete can earn up to 4 recovery points in the Sleep and rest category.
Relaxation and Emotional Support

The relaxation and emotional support category while still important, plays a much less significant role in the recovery process and is only worth 3 recovery points. However it is of importance to the athlete in their psychological wellbeing as this may affect their attitude towards their training (Hemmings et al, 2000, Barnett, 2006). This relaxation could be in the form of massage, which is not universally agreed to have physiological benefits, but athletes often feel more recovered (Hemmings et al, 2000, Weerapong et al, 2005, Barnett, 2006).

Massage is used extensively with elite athletes to promote recovery due to its perceived benefits. These theoretical benefits are shown in Figure 13.

Figure 13. Theoretical model of the expected mechanisms of massage. ↓ indicates decrease; ↑ indicates increase (Weerapong et al 2005)

Weerapong et al (2005) in their review suggest that massage could theoretically help with stiffness and pain after training, increase circulation, decrease anxiety and increase range of motion all of which would be beneficial to the badminton player, however, these assumptions are questioned following some equivocal research (Barnett, 2006).

A group of amateur boxers (N=8) completed two bouts of exercise on a boxing ergometer after which they received a massage or completed a passive rest interval. The boxers perceived recovery was significantly higher following the massage recovery
protocol (p<0.01) but there was no significant physiological difference in relation to lactate removal or blood glucose levels (Hemmings et al, 2002).

The physiological demands of boxing are quite different to badminton, with regular extended periods of work being completed before regular recovery periods. Badminton is much more irregular in terms of work:rest ratios and may well develop higher lactate production. A similar study using badminton players may have generated alternative findings.

Mondero & Dunne (2000) investigated the response to recovery protocols of 18 trained male cyclists on two 5km time trials separated by 20 minutes recovery. During the recovery periods, the cyclists were subjected to passive recovery, active recovery, massage and a combination of active recovery and massage. They found that massage had no significant impact on lactate removal during recovery, but when used with active recovery, the blood lactate removal was enhanced (p<0.05). This study used aerobic athletes as subjects and the demands of the testing are quite different to the short intermittent work performed by badminton players.

These studies add support to the conclusions by Weerapong et al, (2005) and Barnett (2006), that massage may be beneficial to the athlete in a psychological sense, as the athletes may have a perceived increase in relaxed state. More research needs to be done in this area, with larger sample sizes looking at activities that produce higher lactate concentrations.

The same could also be said of the use of cryotherapy, as the research is equivocal, but athletes may psychologically feel more recovered and ready for the next training or competition stress (Howatson & Van Someren, 2003, Howatson et al, 2005, Barnett, 2006, Wilcock et al, 2006).
Cryotherapy is widely used to treat injury due to its analgesic effects, such as ice massage in the treatment of soft tissue injury (Howatson & Van Someren, 2003, Barnett, 2006). This idea has been extended to try to use cold water therapy for the treatment of Delayed Onset Muscle Soreness (DOMS) or muscle damage following intense activity. Badminton players complete a significant number of eccentric muscle contractions during the course of a game, due to the large number of times the player must change direction at speed. These type of movements are linked to muscle damage (Thompson et al, 1999, Byrne et al, 2004, Vikne et al, 2006)

This muscle damage results in oedema in the muscle which causes stiffness and a decrease in power output. Wilcock et al, (2006) suggest that athletes competing in high intensity intermittent activities may benefit from cold water immersion due to a reported increase in stroke and plasma volume, which is thought to shift the metabolites such as lactate through the systems faster, thus promoting recovery (Shiraishi et al, 2002).

Howatson and Van Someren (2003) reported that when 9 resistance trained males were subjected to resistance exercise designed to induce muscle damage, no significant difference in the markers of muscle damage were found. Similar findings were also reported by Howatson et al, (2005). It would appear from the literature that more research needs to be carried out to find a standard protocol for cryo-therapeutic treatment that would achieve the theoretical benefits of the modality.

**Stretching and Warm-down**

The immediate recovery strategy following a training stress can promote recovery and prepare the athlete for the next training bout, especially if the athlete trains more than once a day. The immediate recovery strategy contributes up to 3 recovery points.

Research into this area is also equivocal, with studies showing no significant physiological differences between active and passive recovery for ice hockey players
(Lau et al, 2001) and studies on resistance training (Corder et al 2000) and multiple sprint cycling (Mondero & Donne, 2000) showing greater Lactate recovery following active recovery. Glycogen resynthesis has been shown to be enhanced following passive recovery following maximal cycling (Mondero & Donne, 2000), but Fairchild et al, (2003) reported no difference in Glycogen replenishment with active and passive recovery.

None of these studies were with rackets sports players and the physiological demands on these players are quite different to cycling and strength trained athletes. The ice hockey study (Lau et al, 2001) closely followed the demands of competitive ice hockey, which is an intermittent sport like badminton, but the technique involved in skating can dramatically affect the exercise intensity the players are working at, so comparisons to badminton have to be questioned.

The performer will achieve a recovery score by accumulating recovery points from the four categories. There are set criteria for the awarding of the points so that the performer can compare recovery performance on a daily basis in direct comparison to the Rate of Perceived Exertion (RPE) score (Borg, 1998) for the preceding training period (Kennta & Hassmen, 2002).

RPE is a scale commonly used to estimate perception of effort. It is more often used with testing bouts such as \( \tilde{V}O_2 \) max testing (Herman et al, 2003, Seiler et al, 2003) but the scale has also been used effectively with high intensity training bouts (Foster et al, 2001, Day et al, 2004, Impellizzeri et al, 2004, Green et al, 2006).

High intensity exercise is generally reported to be difficult to quantify in terms of training load due to the variable nature of measures such as heart rate (Foster et al, 2001). In a study investigating perceived responses to steady state and interval cycling and basketball practice, it was found that RPE measures for each session followed a
similar pattern to heart rate responses following a regression analysis. This suggests that session RPE measures may be useful across a variety of exercise sessions (Foster et al, 2001).

Day et al, (2004) and Sweet et al, (2004) reported that RPE values were strongly correlated ($r = 0.88$) in repeated bouts of resistance training, suggesting that the session RPE values are appropriate markers for high intensity training.

The RPE scale is therefore generally accepted as a valid and reliable tool for measuring perceived exertion for both aerobic and anaerobic exercise activities (Hampson et al, 2001), although this validity has been called into question by Lamb et al, (1999). They found that their 16 male subjects varied in up to a 3 point difference during two repeated equal intensity trials when the data was analysed using the Limits of Agreement technique, suggesting some caution when using the RPE scale, although the weight of reported evidence backs the use of RPE if used appropriately.

In order for the performer to train effectively, their TQR score should match as closely as possible their RPE score for the preceding training stress. If there are large discrepancies between the scores, there may be potential problems with regard to performance.

**Elite badminton in the UK**

Since 1992, badminton has been involved within the Olympic movement and with Great Britain having been successful in recent Olympics, there has been substantial financial investment in facilities and players from UK Sport (Guide to World Class Pathway Summer Olympic Investment 2006-2009, UK Sport).

This investment has brought about the formation of a network of regional centres of elite badminton known as High Performance Centres (HPC) run by the governing body,
Badminton England. Similar centres have also been adopted in Wales, with the senior national players training on a daily basis at the Welsh Institute of Sport (WIS) in Cardiff.

Bath University host one of the HPC, where approximately 12 athletes train on a daily basis under the control of the HPC coach, who is a former international player. All the performers in the HPC are funded by Badminton England or UK Sport and are seen as potential international players in the next Olympic cycle. The HPC in Cardiff is smaller in scale with only around 6 players training full time; however, the players are of equivalent standard.

Many of the players at the Bath HPC are currently in the senior top 20 in England in their respective discipline, with the others striving to achieve national recognition and are training daily to try to achieve this. The Welsh players involved have all represented the National team at world level events, with several of the players being ranked in the top 30 in the world.

**Physiological demands of elite badminton**

As the nature of competitive badminton involves multiple variable duration high intensity bursts of effort, followed by short irregular recovery periods, the demands on the anaerobic energy systems are great.

The body has sufficient Adenosine Tri Phosphate (ATP) to produce energy for 1-2 seconds of high intensity work. (Bogdanis *et al.* 1998). In order to continue to exercise, the body must resynthesise ATP to produce sufficient energy to power the muscular contractions.

In the first instance, the ATP-PC system produces the greatest proportion of energy. This system can provide ATP at a fast enough rate to be utilised during the high intensity rally, but is quickly depleted. Bogdanis and colleagues (1998) found that after
two minutes rest following a ten second maximal bike sprint, the subjects were able to
match the peak power output measured previously, thus showing that the body had
resynthesised sufficient Phosphocreatine needed to produce ATP. (Bogdanis et al, 1998).

Within competitive badminton, very rarely will the athlete have two minutes in between
bouts of high intensity exercise. Therefore, the anaerobic glycolysis system must then
contribute significantly towards the ATP production (Lees, 2003).

This system has a more profound consequence on the nutritional status of the athlete, as
the fuel for this system is stored carbohydrate in the form of glycogen. The by-product
of this system contributes towards fatigue, in that the lactic acid generated following the
metabolism of carbohydrate creates an acidic environment that inhibits the optimal
action of the glycolytic enzyme Phosphofructokinase (PFK). This has a resultant effect
of slowing down the rate of glycolysis, thus slowing down the rate of ATP production

In addition to the enzymatic effect, the hydrogen (H+) ions formed by the dissociation of
lactic acid are thought to compete with the calcium (Ca²⁺) ions for the binding site on
the muscle protein, troponin. The result of this is that fewer cross bridges between the
muscle proteins, actin and myosin are formed, producing a less forceful contraction.

Badminton at a competitive level involves numerous high intensity bursts for duration of
approximately thirty minutes (Majumdar et al, 1997, Cabello Manrique & Gonzalez-
Badillo, 2003). To be able to sustain this level of exertion, the aspiring badminton player
has to train often at a high intensity.

Majumdar and colleagues found the average rally length in badminton to be 4-5 seconds
with a recovery time of about 10 seconds. They also found an effective playing time of
35%. (Majumdar et al. 1997). Cabello Manrique and Gonzalez-Badillo, (2003) found similar results with mean rally time of 5-8 seconds and match duration of 30 minutes.

There has also been shown to be a differentiation between singles and doubles players and this is usually reflected in the type and focus of the training undertaken. The mean duration of international men’s singles rallies was found to be 9.15 seconds (SD±0.43) compared to men’s doubles at 6.35 seconds (SD± 1.39) which was found to be significantly longer (p<0.01) (Liddle & O’Donoghue, 1998).

In the ladies game, the doubles rallies were found to be longer than the singles (mean values 6.73 seconds SD±1.25 compared to 7.61 seconds SD±1.81) although this difference was not found to be significant (Liddle & O’Donoghue, 1998).

This information is utilised by the players and coaches and implemented in the selecting appropriate intensity and duration for intermittent training bouts. This study only used players from one particular event on the European tour. A larger sample with more players from Far Eastern countries such as China and Indonesia may produce slightly different mean values.

With regard to levels of activity during the match, studies have been conducted to investigate the average heart rate during competition. Badminton players were shown to reach 80-85% of their predicted maximum heart rate. (Doherty, 1982, cited IN Wonisch et al, 2003). Similar mean heart rate values were also reported by Cabello Manrique and Gonzalez-Badillo, (2003), and Majumdar et al (1997) and expend anywhere between 29-46 kJ min-1 (MacLaren, 1998).

This type of data should however be treated with caution, as the physiological demands from one game to the next are extremely variable, and using average values for intensity
activities such as racket sports may not give an accurate enough representation of the complexity of the physiology involved. (Glaister, 2005)

The contributions of the anaerobic systems have a significant impact on the fuel usage and on fatigue during the racket sports. Badminton players have exhibited lactate values during competition of between 3-6 mmol -L\(^{-1}\), which seems low, but training values of 8-10.5 mmol -L\(^{-1}\) have been recorded. (Majumdar et al, 1997). This level of lactate production shows a considerable reliance on anaerobic glycolysis for energy production during badminton (Wonisch et al, 2003). As the sole fuel for anaerobic glycolysis is carbohydrate, the nutritional status of the athlete prior to during and post event or training is of importance if they are to attain optimum performance levels.

**Research Question.**

The TQR scale (Kentta & Hassmen, 1998) may be a useful monitoring tool for players and coaches to use to try to achieve balance between training and recovery. Monitoring training is crucial in an attempt to detect potential UPS before the complex condition negatively affects long term performance (Urhausen & Kindermann, 2002, Smith, 2003).

As the main focus of many an aspiring athlete is the training, it is anticipated that there will be a discrepancy in the RPE values for training and the TQR scores for recovery which may have negative consequences for the athlete. Therefore, the use of the TQR scale may enable the elite badminton players and coaches to monitor their recovery and maximise their training.
Aims of the investigation.

The aims of the investigation are threefold:

- to complete an overall assessment of the quality of recovery in comparison to training stress for high performance badminton players establishing if there is an imbalance between RPE, TQRact and TQRper
- to review the different components of the TQR scale and see if there were any common areas for improvement in recovery. This may lead to strategies being implemented by the HPC coach or individual players
- to evaluate the structure of the TQR scale as a practical measure for players and coaches to use to optimise training gains and try to prevent Unexplained Underperformance Syndrome

Hypotheses

There will be a negative balance between RPE and TQRact for the elite badminton players.

There will be areas of the recovery strategy (nutrition, sleep, relaxation or warm down) for the elite badminton players that require attention and improvement for optimal recovery.

The TQR scale is an appropriate tool to monitor recovery from training stress for elite badminton players.
Chapter 2 - Methodology

Subjects.

Nine male and three female badminton players were monitored with regard to their usual training and recovery procedures during a five day training cycle. Their baseline data are shown in Table 1. Ethical approval for this study was granted by the Ethics Committee of the School of Applied and Health Sciences at the University of Chester (Appendix 4).

Table 1. Baseline data for the High Performance players involved in the study
(Values mean ± SD)

<table>
<thead>
<tr>
<th>Male players (N=9)</th>
<th>Female players (N=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bath HPC</td>
<td>Bath HPC</td>
</tr>
<tr>
<td>4 players</td>
<td>2 players</td>
</tr>
<tr>
<td>Cardiff HPC</td>
<td>Cardiff HPC</td>
</tr>
<tr>
<td>5 players</td>
<td>1 player</td>
</tr>
<tr>
<td>Age (years)</td>
<td>Age (years)</td>
</tr>
<tr>
<td>24.4 ± 3.4</td>
<td>20.0 ± 2.0</td>
</tr>
<tr>
<td>Height (m)</td>
<td>Height (m)</td>
</tr>
<tr>
<td>1.83 ± 0.6</td>
<td>1.61 ± 0.07</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>Weight (kg)</td>
</tr>
<tr>
<td>80.8 ±8.8</td>
<td>59.7 ± 3.2</td>
</tr>
</tbody>
</table>

All the players provided informed consent to participate in the study and were selected on the basis of their inclusion in either the Bath or Cardiff High Performance Centre (HPC) as inclusion in these training centres required intense daily training sessions. The mixture of singles and doubles specialists and the full time and part time players at each centre is shown in Tables 2 and 3.

The players all reported that at the time of the study they were at the end of their year long competitive season, in sufficient physical condition to attend their usual HPC training in preparation for the new season.
Table 2. Preferred badminton discipline and employment status at the Bath HPC
(*Players could select more than one discipline).

<table>
<thead>
<tr>
<th></th>
<th>Bath HPC (N=6)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preferred discipline*</td>
<td>Employment status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Singles</td>
<td>Doubles</td>
<td>Mixed</td>
<td>Badminton</td>
<td>Student</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singles</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 3. Preferred badminton discipline and employment status at the Cardiff HPC. (*Players could select more than one discipline).

<table>
<thead>
<tr>
<th></th>
<th>Cardiff HPC (N=6)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preferred discipline*</td>
<td>Employment status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Singles</td>
<td>Doubles</td>
<td>Mixed</td>
<td>Badminton</td>
<td>Student</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singles</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Design.

The study was a repeated measures design involving the daily recording of Rate of Perceived Exertion (RPE), Perceived recovery (TQRper) and Recovery action score (TQRact) for 12 elite badminton players during a 5 day training cycle. Nutritional intake, amount of sleep and rest, relaxation modalities employed and the level of warm down completed were also recorded. This level of detailed recording allowed the calculation of the TQRact score and also enabled an analysis of recovery practice in each area identified in the TQR scale (Kentta & Hassmen, 1998).

Materials

The players completed their usual training at their respective centre where all facilities and equipment required for the training were provided. Prior to the first training session involved in the study, each player was issued with a handbook containing all the
information (Appendix 1) and questionnaire sheets pertaining to the study, which was explained in detail by the researcher.

The questionnaires were designed specifically for the study following consultation with the authors of the TQR concept, Goran Kentta and Peter Hassmen. The questionnaires were designed to obtain evidence about the individual recovery and training actions that fit the points table as documented by Kentta and Hassmen (2002).

The questionnaires were trialled by national junior badminton players based at the High Performance Centre in North Wales with some questions being amended for clarity following the pilot study. This trial included an online version of the questionnaire, but this format was not used in the actual study due to the lack of access to online facilities prior to the training session.

**Procedures.**

The subjects undertook their normal daily training schedule under the guidance of their respective coaches and were asked to record their training activities and dietary intake for each 24 hour period (Appendix 1).

Prior to training the following day, the players were required to complete a questionnaire asking them to reflect on their perceived effort during the sessions and their perceived state of recovery from the previous day’s training. They were also asked to record the steps they had taken in an attempt to recover effectively. This process was repeated each day of the 5 day training cycle with the final Training and Recovery questionnaires being completed on the morning after the final monitored training session. All the Training and Recovery questionnaires were completed prior to the morning training sessions as advised by Kentta and Hassmen, (2002) in an attempt to standardise the protocol.
Prior to the monitoring period, the subjects were fully briefed on the procedure, including protection of their data and timing of the completion of the different data collection sections (Appendix 2). The researcher was also at hand during the daily group training sessions for the duration of the training cycle to respond to any questions that arose during the monitoring period.

The subjects were all requested to behave exactly as they would during a normal weekly training cycle in terms of their nutrition, hydration, training effort and recovery strategies in order to obtain valid data.

There is some debate about the length of time a dietary analysis should be conducted as different nutrients require different lengths of study to estimate usual intake. It was suggested by Reeves and Collins (2003) that three days is required to effectively estimate energy intake. This study used five consecutive days to estimate usual dietary intake as this would be an average length of time before a rest day would be taken for elite badminton players. Any longer might have resulted in drop out from the study, as the act of accurately recording dietary intake can be time consuming.

Reeves and Collins (2003) reported that subjects not achieving energy intakes above 1.5 times their Basal Metabolic Rate (BMR) should be discounted from any group analysis due to the risk of underreporting in their food diaries. The subjects BMR were estimated using the Harris-Benedict equation (Harris & Benedict, 1919, cited IN Wong et al, 1996.) Underreporting has been reported to be the usual error in self reported dietary analysis (Burke et al, 2006).

The players at the Cardiff training centre were encouraged by the HPC coach to conclude the study after four days due to preparation for the forthcoming World Team championships in Glasgow. This was agreed with the researcher and the players’ data was included for the four days training.
At the Bath HPC, two of the players only completed four days training during the monitoring period due to illness and injury, so their data was included for the four completed days.

**Data Analysis.**

The nutritional intake logs were analysed using the Dietplan6 programme (Forestfield Software, West Sussex, England, 2005) and this information, along with the training and recovery responses were used to calculate the RPE, TQRper and TQRact scores (Appendix 3).

Data analysis comprised descriptive and inferential statistics. Variables were checked for normal distribution by the Shapiro-Wilk statistic and appropriate descriptive statistics generated. The agreement between the RPE, TQRper and TQRact was assessed using the Friedman ANOVA and the Spearman correlation coefficient as the data collected did not meet the assumptions required for the Limits of Agreement (LoA) technique (Bland & Altman, 1986; Lamb, 1998).

The TQR scale category differences were assessed by the Friedman ANOVA technique with appropriate Mann Whitney U test post-hoc analysis due to the fact that the research design was repeated measures and the data did not meet the assumptions required for parametric testing. The nutritional intake data also did not meet the required assumptions so were assessed using the same non-parametric methods. All data analyses were conducted using SPSS for windows (version 14.0) and alpha was set at the 0.05 level.
Chapter 3 - Results

The Rate of Perceived Exertion (RPE), Total Quality Recovery action (TQRact) and Total Quality Recovery perceived (TQRper) results collected from the High Performance badminton player questionnaires are summarised in Tables 4, 5.

Table 4. Mean RPE, TQRact and TQR per scores for the badminton players at the two High Performance centres (All values mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Mean RPE</th>
<th>Mean TQRact</th>
<th>Mean TQRper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bath HPC (n=6)</td>
<td>14.92** ± 2.18</td>
<td>13.08 ± 3.1</td>
<td>13.64 ± 2.1</td>
</tr>
<tr>
<td>Cardiff HPC (n=6)</td>
<td>13.54** ± 1.8</td>
<td>13.08 ± 1.4</td>
<td>13.96 ± 1.9</td>
</tr>
<tr>
<td>Overall (n=12)</td>
<td>14.24* ± 2.1</td>
<td>13.08* ± 2.4</td>
<td>13.8 ± 2.0</td>
</tr>
</tbody>
</table>

(* denotes significant difference p= 0.006 for Mean RPE and Mean TQRact, **denotes significant difference p= 0.016 for Mean RPE between Bath and Cardiff HPC).

The players in this study were asked for session RPE values which informed a global RPE value for all the training that they had completed during the course of each 24 hour period. This global RPE value was used to compare against the global perceived recovery score (TQRper) and the points score awarded for the players individual recovery actions (TQRact).

When analysing the RPE, TQRact and TQRper results it was noted that the data were not all normally distributed and therefore did not meet the assumptions required for parametric statistical analysis (Williams & Wragg, 2004). Therefore the results were analysed using the Friedman ANOVA technique (Williams & Wragg, 2004).

A significant difference (p=0.006) was found between the overall mean RPE and the mean TQRact score, but no significant difference between the RPE and TQRper scores.
and no difference between the TQRact and TQRper scores (Figure 14). This suggests an imbalance between the perceived effort of training and the quality of the actions taken to recover effectively.

![Graph showing differences between mean RPE, TQRact, and TQRper values. (*) denotes significant difference, p=0.006)](Image)

Figure 14. Differences between the mean RPE, TQRact and TQRper values. (* denotes significant difference, p=0.006)

<table>
<thead>
<tr>
<th>RPE/TQRact difference</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75</td>
<td>0.5</td>
<td>0.25</td>
<td>1</td>
<td>5.25</td>
<td>0.2</td>
<td>1.33</td>
<td>2</td>
<td>-2.75</td>
<td>3.2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.5</td>
<td>-2.5</td>
<td>-1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0.2</td>
<td>3.33</td>
<td>-0.25</td>
<td>2.4</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1.25</td>
<td>-2.5</td>
<td>-1.5</td>
<td>0.75</td>
<td>0</td>
<td>-3.25</td>
<td>0</td>
<td>-1</td>
<td>1.33</td>
<td>2.5</td>
<td>-0.8</td>
<td>-2.2</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Individual player differences in RPE, TQRact and TQRper scores

Due to the data failing the assumptions for the Limits of Agreement technique to determine correlation, the Spearman non-parametric analysis was performed. This analysis did not detect a significant correlation between RPE, TQRact or TQRper.

**TQR scale**

Each component of the TQR scale (Nutrition and Hydration, Sleep and Rest, Relaxation and Emotional Support and Stretching and Warm-down) achieved a maximum score depending on the recovery actions taken by each individual.
Table 6. Percentage of the maximum TQR score for each component. (All values mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Mean % max TQR Nutrition score</th>
<th>Mean % max TQR Sleep score</th>
<th>Mean % max TQR Relaxation score</th>
<th>Mean % max TQR Warm down score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bath HPC (n=6)</td>
<td>76% ±18.7</td>
<td>56% ±25.3</td>
<td>44.9% ±18.9</td>
<td>57%*** ± 28.1</td>
</tr>
<tr>
<td>Cardiff HPC (n=6)</td>
<td>83.5% ± 9.3</td>
<td>53.3% ±13.7</td>
<td>43% ±28.1</td>
<td>35.9%*** ± 22.1</td>
</tr>
<tr>
<td>Overall (n=12)</td>
<td>79.6%* ±15.3</td>
<td>54.7%*/** ± 20.4</td>
<td>44%* ±17.2</td>
<td>46.9%*/** ± 27.3</td>
</tr>
</tbody>
</table>

(*/***/*** denotes significant difference p<0.0125)

When the percentages of the maximum scores were analysed for each component, it was noted that there were significant differences between the Nutrition score and Sleep (p=0.005), The Nutrition score and the Relaxation score (p=0.005) and the Nutrition score and the Warm-down score (p=0.005). There was also a difference between Sleep and Warm-down scores (p=0.012) (Table 6, Figure 15).

Figure 15. Differences between the percentage maximum TQR component scores. (*/** denote significant differences, p <0.0125)
The TQR component scores showed correlations with the overall TQR act scores. The Nutrition score had a modest correlation with TQR act \((r=0.676)\) (Cohen & Holliday, 1996). The Sleep and Relaxation scores also had modest correlations \((r=0.529, r=0.6)\), with the Warm down score not being significantly correlated following a Bonferroni adjustment applied in an attempt to avoid a Type 1 error (Franks & Huck, 1986).

Table 7 shows the mean values for the TQR category scores for the badminton players involved in the study, reflecting the good performance in the Nutrition category and more variable performances in the other three categories.

**Table 7. Mean values for the TQRact category scores (All values mean ± SD)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Mean Category score</th>
<th>Maximum category score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrition and Hydration</td>
<td>7.93 ±1.52</td>
<td>10</td>
</tr>
<tr>
<td>Sleep and Rest</td>
<td>2.16 ±0.75</td>
<td>4</td>
</tr>
<tr>
<td>Relaxation and Emotional</td>
<td>1.33 ±0.52</td>
<td>3</td>
</tr>
<tr>
<td>Support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stretching and Warm down</td>
<td>1.43 ± 0.82</td>
<td>3</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>13.08 ±2.4</td>
<td>20</td>
</tr>
</tbody>
</table>

The dietary analysis results that were used to inform the award of TQRact points are shown in Table 8.

The mean values in Table 8 were calculated using seven of the twelve subjects as the other five subjects had recorded energy intakes below the 1.5 times BMR threshold as reported by Reeves and Collins (2003). The dietary analysis data required for the TQR investigation remains valid as the subjects did not need this detailed level of data for the award of TQRact points.
There were no significant links between the carbohydrate and protein intake with perceived effort (RPE) and perceived recovery (TQRper). The mean energy intake for the males (3118.4 kcal SD: 757.6) was significantly higher than the females (2293.6 kcal SD: 687.8) (p=0.005), but there were no significant differences between the carbohydrate and protein intake values or percentage carbohydrate, fat and protein intakes.

Table 8. Mean dietary analysis findings for High Performance badminton players

(All values mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Male players</th>
<th>Female players</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n= 5)</td>
<td>(n= 2)</td>
<td></td>
</tr>
<tr>
<td>Daily calorie intake (kcal)</td>
<td>3118.4 ± 757.6</td>
<td>2229.36 ± 687.8</td>
<td>N/A as intakes</td>
</tr>
<tr>
<td>Daily water intake (L/day)</td>
<td>5.54 ± 1.61</td>
<td>3.59 ± 1.87</td>
<td>vary.</td>
</tr>
<tr>
<td>Carbohydrate intake (g/kg)</td>
<td>5.94 ± 1.57</td>
<td>6.39 ± 1.90</td>
<td>6.05 ± 1.64</td>
</tr>
<tr>
<td>Protein intake (g/kg)</td>
<td>1.53 ± 0.62</td>
<td>1.21 ± 0.43</td>
<td>1.45 ± 0.59</td>
</tr>
<tr>
<td>% Carbohydrate intake</td>
<td>58.5 ± 8.8</td>
<td>58.1 ± 11.9</td>
<td>60.4 ± 9.3</td>
</tr>
<tr>
<td>% Protein intake</td>
<td>16.5 ± 4.2</td>
<td>14.3 ± 5.1</td>
<td>15.3 ± 4.8</td>
</tr>
<tr>
<td>% Fat intake</td>
<td>25 ± 7.7</td>
<td>27.6 ± 11.1</td>
<td>23.7 ± 7.9</td>
</tr>
</tbody>
</table>

Training Centres

The data from the two training centres were analysed to see if there were any differences. It was found that there was a significant difference between mean RPE (p=0.016) (Table 4) and also a difference between the percentage of the maximum warm down score (p=0.011) (Table 6).

The mean training time for the Bath players was 205 minutes per day (SD± 56mins) compared to the Cardiff players 185 minutes per day (SD± 58mins), although this difference was not significant.
Chapter 4 – Discussion

The results of this study support the hypothesis that for elite badminton players at the High Performance Centres in Bath and Cardiff, there is a significant difference between their perceived level of exertion of their training stress (RPE mean 14.24 SD± 2.1) and the actions the players performed in order to recover from this training stress (TQRact mean 13.08 SD± 2.4) (p=0.006) (Figure 16). This is in support of the primary hypothesis that there would be a negative balance between RPE and TQRact for the elite badminton players, due to their focus on training rather than recovery.

Figure 16. The individual player differences between their total RPE and TQRact scores during the monitoring period.

As daily session RPE values have been reported to be a valid method of estimating high intensity training stress (Foster et al, 2001, Day et al, 2004, Sweet et al, 2004) this difference suggests that the elite players did not perform sufficient recovery actions during the monitoring period. This discrepancy could be viewed as Overreaching (Armstrong and VanHeest, 2002), but if this insufficient recovery were to continue for a
prolonged period, the players involved may be at risk of suffering from Unexplained Underperformance Syndrome (UPS) (Budgett, 1998, 2000).

Only one player (Player 10) appeared to have recovered in excess of the perceived training demand which would suggest that this individual had an effective recovery strategy. This is one of the highest nationally ranked players involved in the study and also a sports science undergraduate student. The effective recovery strategy may therefore be as a result of an insight into the requirements of training and recovery from her specialist academic knowledge or the influence of top level coaches and other more senior international players beyond the High Performance Centre structure. This supposition was not investigated during the study, but the level of prior knowledge could be questioned in further study in this area.

If the lack of relevant specialist knowledge is the case, then this poses the question as to why the other top level players, competing at an equivalent international level do not apparently possess this vital knowledge or experience.

The players perceived their recovery to be sufficient for their perceived training load as overall there was no significant difference between RPE and TQRper. (Figure 17).

Eight of the players (Players, 4, 5, 6, 7, 8, 9, 11 and 12) reported a positive difference between the two perceived values, indicating they perceived their recovery to be insufficient for their perceived training stress. These results would be in-keeping with the RPE-TQRact findings.

The other four players (Players 1, 2, 3 and 10) reported a negative difference, suggesting that they perceived their recovery to be sufficient. This variance suggests a possible lack of experience in using the RPE and TQRper scales if the players are not used to
monitoring their training and recovery in this detailed manner. Also, the players TQRper scores may be biased towards showing their recovery actions were sufficient, thus demonstrating their supposed good practice in this area.

![Figure 17. Individual player differences between their total RPE and TQRper scores during the monitoring period.](image)

If the TQR scale is to be used with confidence, the TQRact and TQRper scores should ideally be equal. This would suggest that a player can accurately gauge their recovery based on their recovery actions they have taken. Figure 3 shows the differences in TQRact and TQRper scores reported by each player in the study.

There was no significant difference between the mean TQRact and TQRper scores, but Figure 18 clearly shows some discrepancy between the values. Only two players (Players 5 and 7) demonstrated an equal score with seven players (Players 1, 2, 3, 6, 10, 11 and 12) perceiving their recovery to be better than the recovery actions would suggest, with the other three (Players 4, 9 and 10) players performing recovery actions in excess of their perceived level of recovery.
Again, this variance in the scores suggests a possible lack of experience using perceived recovery scores to regularly monitor their training and recovery and the potential bias as previously mentioned.

![Graph showing individual player differences between their total TQRact and TQRper scores during the monitoring period.](image)

**Figure 18. Individual player differences between their total TQRact and TQRper scores during the monitoring period.**

There was no significant correlation between RPE/TQRact, RPE/ TQRper or TQRact/TQRper, as overall effort and recovery are matched. As the individual players were performing their own training away from the group session and the fact that two training centres were used, it was impossible to obtain valid data to assess the repeatability of the scale in following two similar training sessions.

The TQR scale relies on accurate and reliable perception of the training effort and recovery state. In order for the values generated to be reliable, the player needs to have experience of reflecting on how they feel, rather than just continuing with their usual training and recovery regimes. This reflection is alien to some players as the traditional focus is on training intensity and performance (Smith, 2003).
TQR scale categories

When the percentages of the maximum possible scores were analysed, the mean percentage maximum Nutrition and Hydration score was 79.6% (SD±15.3) for the group which was significantly greater than the Sleep and rest score, 54.7% (SD±20.4) (p=0.005), the Relaxation and emotional support score, 44% (SD±17.2) (p=0.005) and the Stretching and warm down score 46.9% (SD± 27.3) (p=0.005) (Table 6, Fig 15). This suggests that the players may have been more aware of nutritional issues related to recovery and performance and less aware of the benefits of the other areas, resulting in better variable performance. A more detailed investigation of each category and a breakdown of how the Recovery Points were scored is included to give a clearer insight into the level of awareness of the players.

TQR Categories – Nutrition and Hydration

Nutrition is of prime importance for the elite badminton player, especially as the majority of players are training more than once a day (Davis et al, 1999, Burke et al 2006) and the TQR scale awards the nutrition related Recovery Points in very specific dietary areas. The points awarded are shown in Table 9 along with a breakdown of the mean Recovery Points scored by the players involved in the study (Kentta and Hassmen, 2002).

The player can achieve five Recovery Points for just having the usual three meals a day, which the majority of the players achieved. Where the more significant points for the player are scored are in the snacking between training sessions to ensure nutrient levels are topped up, carbohydrate reloading and effective hydration during and after training and also throughout the day.
Table 9. TQRact Recovery Points scoring for Nutrition category (Kentta and Hassmen, 2002)

<table>
<thead>
<tr>
<th>Nutritional area</th>
<th>Recovery Points available</th>
<th>Mean Recovery Points scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td>1 point</td>
<td>1</td>
</tr>
<tr>
<td>Lunch</td>
<td>2 points</td>
<td>1.96 (SD ± 0.29)</td>
</tr>
<tr>
<td>Supper</td>
<td>2 points</td>
<td>1.95 (SD ± 0.29)</td>
</tr>
<tr>
<td>Snacks between meals</td>
<td>1 point</td>
<td>0.31 (SD ± 0.47)</td>
</tr>
<tr>
<td>Carbohydrate reloading after practice</td>
<td>2 points</td>
<td>1.27 (SD ± 0.7)</td>
</tr>
<tr>
<td>Adequate hydration during/post workouts</td>
<td>1 point</td>
<td>0.71 (SD ± 0.46)</td>
</tr>
<tr>
<td>Adequate hydration throughout the day</td>
<td>1 point</td>
<td>0.73 (SD ± 0.45)</td>
</tr>
<tr>
<td><strong>Total Nutrition points</strong></td>
<td><strong>10 points</strong></td>
<td><strong>7.93 (SD ± 1.52)</strong></td>
</tr>
</tbody>
</table>

The maintenance of carbohydrate levels is important for the badminton player as this has been shown to maintain decision making and enhance mood state (Winnick et al, 2005) and stroke performance when fatigued (Graydon et al 1998, Vergauwen et al, 1998). This enhanced performance is due to the brain carbohydrate supply being maintained for effective function, resulting in appropriate decision making and feelings of well-being.

Following the dietary analysis there were a number of players whose diet could be enhanced in terms of carbohydrate and protein intake (Figure 19).

Figure 19 confirms that none of the players involved in the analysis achieved a recommended mean CHO intake of 8g/kg body weight. This target value was in the range reported by Kentta and Hassmen, (2002) and Stear (2004) of 8-10 g/kg for an athlete training 2-4 hours a day. Similar target values were also reported in Burke et al (2006), in their review of dietary intakes of male soccer players. The mean CHO intake was 6.05g/kg (SD± 2.68) which according to Stear (2004) would be sufficient for
moderate intensity training of 60-120 minutes per day rather than the mean value of 195 minutes per day (SD ± 57mins) the players reported.

Figure 19. Mean distance to target intakes of CHO and Protein for players involved in study, whose energy intake was 150% BMR (Reeves and Collins, 2003)

If this level of carbohydrate intake is not improved over a prolonged duration and the energy expenditure from training remains high, the players may be at risk of an increased metabolism of Branch Chain Amino Acids (BCAA) at the expense of carbohydrate (Snyder, 1998). This could lead to increased levels of the neurotransmitter Tryptophan entering the brain, ultimately inducing some of the symptoms of UPS, such as an altered mood state and loss of appetite. (Smith, 2000).

This carbohydrate level could be increased in a number of players in the form of snacking in between training session with high Glycaemic Index (GI) food and drink such as sports drinks, bread, sweets, and cereals. The Glycaemic Index is a ranking system for the amount of carbohydrate present in different foods. These examples of high GI foods would provide a fast and readily accessible source of carbohydrate for
glycogen replenishment in preparation for the next training bout (Burke, Collier & Hargreaves, 1998). The points awarded for the intake of snacks was very low (0.31 SD±0.47 Recovery Points) so this should be an area of focus for improvement.

Only five players used sports drinks during and after their training, two players from the Bath HPC and three from the Cardiff HPC. There was a significant increase in carbohydrate intake between the days when a sports drink was used (p=0.017) compared to when plain water was used and also a significant increase in percentage daily carbohydrate intake (p=0.0005). More education could be required for the players to understand the implications of using plain water rather than some form of carbohydrate solution and the possible performance enhancements that may be offered by increasing the use of isotonic sports drinks during training and the possible use of hypertonic drinks supplemented with protein during recovery (Ivy et al, 2002).

The protein intake in the diet is important for growth and repair of damaged tissue, which is especially important for players training more than once a day (Stead, 2004). The players were much closer to the target protein intake of 1.5g/kg (Maclaren, 1998, Stead, 2004, Tipton and Wolfe, 2004) with a mean value of 1.45 (SD ±0.59) g/kg, indicating sufficient protein was being consumed in the usual diet to support the level of training undertaken.

The overall percentage intake of carbohydrate, fat, and protein reported by the players are shown in Figure 20. These show similar values to those reported by Reeves and Collins, (2003), Stear (2004) and those found by Burke et al, (2006). The percentage fat intake is within the normal range for an athlete, considerably above the low fat intake (15%) that has been associated with an increase in the inflammatory cytokines (Venkatraman, 2000).
Figure 20. Percentage Carbohydrate (CHO) Fat and Protein (PRO) values reported by players in comparison to target values (Reeves and Collins, 2003).

These findings would suggest that the macronutrient percentage make up of the players diets is appropriate for the level of work that they are undertaking, but the intake of carbohydrates and protein relative to their body weight is insufficient and should be improved to support the training stress. For most of the players involved in the study, this alteration to their nutritional programmes should be facilitated by a sports nutrition specialist to ensure that the players are fully aware of their current individual situation and the potential impact changes to their nutritional strategy could have on their performance.

Carbohydrate reloading after training is also a very significant area in terms of replenishing nutrient stores but also the timing of this replenishment is critical to ensure maximum storage of carbohydrate (Barnett, 2006). This was reasonably well attempted by the players, reporting a mean score of 1.27 (SD ± 0.7) from a possible two Recovery Points.

The highest rate of carbohydrate storage occurs within the first hour after exercise due to the activation of glycogen synthase, brought about by glycogen depletion following training (Burke et al, 2004). From the nutritional logs, it became apparent that the
players would generally have a high carbohydrate evening meal following the training day, usually within the first 2 hours after training, but their reloading in between training sessions was inadequate. Improvement in this area is vital if the maximum training gains are to be taken for the forthcoming sessions (Barnett, 2006, Burke et al, 2006). Further education and guidance from a sports nutrition professional may also be required in this area, to ensure awareness of the importance of reloading with carbohydrate for optimum performance.

Alongside the replenishment of macronutrients, the maintenance of hydration levels has also been reported to delay fatigue and benefit performance (Therinarios et al, 1994, Maughan, 2002, Reilly & Ekblom, 2005, Barnett, 2006). The mean score for hydration during and post workout was 0.71 (SD ± 0.46) from a possible one Recovery Point. With the weight of reported evidence supporting the performance benefits of maintaining a hydrated state, the award of only 1 Recovery Point for this area seems a little unrepresentative of the importance of hydration during and after training.

As changes in body weight pre and post training were not recorded it cannot be suggested how much fluid each individual player would need to take (Armstrong et al, 1998). In general terms, the individual requires 2-3 litres of fluid a day to maintain hydration from both liquid and food sources (Stead, 2004).

The mean water intake from the dietary analysis for the male players was 5.54 litres per day (SD ± 1.9) and for the females 3.59 litres per day (SD ± 1.9). These levels suggest adequate overall hydration, but it is impossible to know by how much the fluid demand was increased on the players due to their training activities, however, it is suggested that the players should aim to recover 150% of their weight loss through drinking fluid (Davis et al, 1999, Stead, 2004). Kentta and Hassmen (2002) advocated the use of the urine test for the individual players to monitor their hydration levels. This could be

The player's hydration performance in terms of volume was acceptable with regard to the TQR criteria, but some of the players may benefit from the use of sports drinks as the electrolytes contained would help to maintain plasma osmolarity and delay dehydration by facilitating the absorption of water through the intestinal wall. The consumption of plain water has been suggested to reduce plasma osmolarity, reducing thirst and increasing urine output (Reilly & Ekblom, 2005) thus delaying rehydration.

It is vital that the badminton players develop an effective hydration strategy during their training, especially in the UK as a large proportion of the major competitions in badminton are held in the Far East, in places such as China, Malaysia and Indonesia. Adaptation to significant thermal stress in part via effective hydration is crucial for resistance to fatigue, maintenance of technique, recovery and ultimately performance (Smith, 2003).

The overall mean score of 7.93 (SD ± 1.52) from a possible 10 Recovery Points suggests that the players performed well with regard to their nutritional status. However, the TQRact score for Nutrition is a little misleading as there were some significant areas that could be improved to optimise performance such as the use of sports drinks, reloading of carbohydrate stores in between training sessions and also the need to increase the amount of carbohydrate intake per kg of body weight.

As the Nutrition category is deemed the most important by the fact that it carries half of the possible TQR Recovery Points (Ivy et al, 2002, Maughan, 2002, Welsh et al, 2002) it is vital that the players understand how best to use their nutritional strategy to benefit performance. The overall mean scores would suggest some application of specific nutritional knowledge, but this has not been seen to be the case with all individuals. It is
therefore essential that badminton governing bodies and high performance coaches educate players in the use of carbohydrates, protein and sports drinks to support their training and competitive performance.

The better related performance in the Nutrition and Hydration category may mask potential recovery issues in other areas when the combined TQR scores are calculated. Kentta and Hassmen (2002) highlighted the need for consistent performance in all categories as impaired performance in one or more can still lead to under-recovery, even if the global TQRact score is high.

TQR Categories – Sleep and Rest

The Recovery Points awarded for the Sleep category are shown in Table 10 with the breakdown of points scored by the players involved in the study.

Table 10. TQRact Recovery Points scoring for Sleep and Rest category (Kentta and Hassmen, 2002)

<table>
<thead>
<tr>
<th>Sleep duration</th>
<th>Recovery Points available</th>
<th>Mean Recovery Points scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 8 hours</td>
<td>3 points</td>
<td>1.95 (SD ± 0.58)</td>
</tr>
<tr>
<td>Daily nap (20 - 60min)</td>
<td>1 point</td>
<td>0.20 (SD ± 0.41)</td>
</tr>
<tr>
<td>Rest day (Bonus)</td>
<td>2 points per half day</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Sleep points</strong></td>
<td><strong>4 points</strong></td>
<td><strong>2.16 (SD ± 0.75)</strong></td>
</tr>
</tbody>
</table>

The group results suggest the average sleep time is between 6-7 hours per night, which is in part within the accepted usual period of between 7-9 hours (Van Cauter et al, 1997, Mougin et al, 2001). During periods of heavy training, it has been suggested that the athlete would benefit from a “micro-rest” or a nap during the day (Kentta and Hassmen, 2002, Taylor, et al, 1997). This need for a “micro-rest” was not evident in the study, possibly due to the timing of the study, with the players being on the cusp of their new
season. However, the mean sleep scores were quite low (1.95 SD ± 0.58), suggesting that the players may not be fully recovered and might benefit from some extra rest.

High intensity training has been shown to cause sleep disturbances (Taylor et al, 1997) and if this is the case a “micro-rest” during the day would enable to athlete to take complete rest to prepare for the forthcoming training sessions. As the global RPE for the players was 14.24 (SD ±2.1), the players may not have felt the need for a micro-rest during the day, even if they had interrupted sleep the preceding night. The training and social circumstances such as meeting friends and attending lectures also may not have enabled the player to take this micro-rest even if required.

None of the players were awarded any bonus Recovery Points for the inclusion of a rest day, as all players reported that they were to have a rest day on completion of the monitoring period, in line with their own training schedules. This inclusion of a programmed rest day does suggest that the players are aware of the benefits of rest for performance and health. This was taken into consideration when planning the monitoring period by liaison with the HPC coaches.

The training protocols the players were following during the monitoring period had not had a significant affect on their sleep and anxiety levels. There was no significant difference between the amount of sleep during the monitoring period and their reported usual amount of sleep and also no significant difference between their usual perceived level of anxiety and the levels reported during the monitoring period.

The overall mean sleep score of 2.16 (SD ± 0.75) from a possible 4 Recovery Points indicates a reasonable amount of sleep. The behavioural aspects surrounding sleep make it difficult to ensure players get sufficient sleep optimise their training, but players need to be aware of the physiological impact of the amount of sleep and rest that they are able
to get in enhancing their performance, so that they can modify their behaviour with regard to sleep and rest, if required.

The players also need to be aware of the role of sleep and rest within their performance enhancement as the competitive badminton player spends the majority of the competitive season travelling round the world, competing mainly in Europe and the Far East.

When crossing time-zones, the problems of jet-lag become apparent, due to shifts in the body’s circadian rhythms (Reilly et al, 1998). This rhythm disruption has been reported to affect sleep patterns, mental and physical performance, appetite (Reilly et al, 1998) and also glucose regulation (Van Cauter et al, 1997). All of these disruptions may negatively affect performance, so the elite badminton player must be aware of them and create a strategy to minimise their impact. This could involve manipulating their travel arrangements and sleep and rest patterns to adjust to the change in time zone as quickly as possible.

TQR categories – Relaxation and Emotional support

The TQR scale awards a maximum of three Recovery Points, with 2 Recovery Points being awarded for the application of appropriate recovery modalities and 1 Recovery Point being awarded for the level of anxiety being controlled throughout the day. Table 11 shows the Recovery Points available for Relaxation and Emotional Support category and the mean score for the players involved in the study.

Although the physiological benefits of the use of massage and cryotherapy are not universally agreed the psychological benefits such as perceived feelings of recovery and relaxation, have been suggested (Howatson et al, 2005, Reilly & Ekblom, 2005, Weerapong et al, 2005, Barnett 2006). Only two players received massage and three players used cryotherapy during the monitoring period. The players all had access to all
the recovery modalities possible within the Sports Medicine provision at the English Institute of Sport, Bath and the Welsh Institute of Sport, Cardiff, so the lack of uptake suggests a lack of knowledge or desire to utilise every method possible to enhance performance.

Table 11. TQRact Recovery Points scoring for the Relaxation and Emotional Support category (Kentta and Hassmen, 2002)

<table>
<thead>
<tr>
<th>Recovery modality</th>
<th>Recovery Points available</th>
<th>Mean Recovery Points scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massage or ice bath</td>
<td>1 point</td>
<td></td>
</tr>
<tr>
<td>Quiet time/socializing/shower/Jacuzzi (2 required)</td>
<td>1 point</td>
<td></td>
</tr>
<tr>
<td>Perceived anxiety score</td>
<td>1 point</td>
<td></td>
</tr>
<tr>
<td><strong>Total Relaxation score</strong></td>
<td><strong>3 points</strong></td>
<td><strong>1.33 (SD±0.52)</strong></td>
</tr>
</tbody>
</table>

If the players had chosen not to use massage or cryotherapy due to the equivocal research, they were not replacing this with any other modality. The most popular methods of spending recovery time were a hot shower and some planned quiet time away from other people, which would be insufficient to gain maximum Recovery Points in this area. The situation may be different at more stressful times of the season such as during the competitive phase, so further monitoring would be required to establish if this area is also affected by tournament and selection stress.

The fact that the body of research evidence is equivocal regarding the physiology behind different recovery modalities provides justification for the award of only three Recovery Points for the Relaxation and Emotional Support category. However, the category needs to be considered by elite athletes, as benefits have been shown for recovery and performance (Weerapong *et al* 2005, Barnett *et al* 2006). It is an important area that the high performance badminton players involved in the study need to consider and plan into their overall recovery strategy (Smith, 2003).
If this anxiety score was low due to the timing of the study, the mean overall TQRact score for this section was 1.33 (SD±0.52), suggesting a lack of structured recovery practice. Figure 21 shows a breakdown of the numbers of players reporting the different recovery modalities either between sessions or after the daily training during the recovery period.

![Figure 21. The number of players reporting the use of recovery modalities during the monitoring period.](chart)

As well as the players suffering from physiological stress in response to their intense training regimes, they also experience psycho-social stress. Kentta and Hassmen (2002) highlighted the importance of the athletes recovering mentally as well as physically both in between multiple training sessions during the day and also after the training has finished for the day.

Aspiring high level athletes such as the players involved in this study encountered anxiety pertaining to issues such as money (with regard to their funding), training, selection and performance, as well as the usual anxieties faced by people of a comparable age, such as relationships and financial problems. These issues were
observed in the baseline data collected from the players in the study, but were not
monitored specifically during the research period.

Kentta and Hassmen (2002) advocated a combination of mental and physical relaxation
techniques to recover following training and suggest that this relaxed state throughout
the day can promote recovery and restoration. The players involved in this study did not
maximise this avenue of recovery scoring less than half of the Recovery Points
available. This is another area which players and coaches could exploit to further
maximise recovery

The group mean anxiety score was 2.1 (SD±0.96) which would place the group between
very relaxed and moderately anxious on the questionnaire scale.

This relatively low group anxiety score may be influenced by the time of the season
rather than the players adequately dealing with the stress of training. The players at the
Bath HPC were just starting training ready for the new competitive season, with some
players just having had some time away from badminton. The players at the Cardiff
HPC were preparing for the World Team championships prior to their short summer
break from the sport.

The mean anxiety score for the Bath players was 1.9 (SD± 0.67) and the Cardiff players
2.42 (SD± 1.13), which would possibly reflect the different objectives for the training of
singles and doubles players, although this difference was not significant. This anxiety
score may therefore be different during the season, reflecting the different levels of
stress during the competitive phase of the season.
**TQR Category – Stretching and warm down.**

Warming up is an accepted pre-requisite to any training session. Kentta and Hassmen (2002) recognised that an appropriate, active recovery from the training session is equally as important. The classification of the Stretching and Warm down points is shown in Table 12, along with the mean warm down score for the players involved in the study.

**Table 12. TQRact Recovery Points scoring for the Stretching and Warm down category (Kentta and Hassmen, 2002)**

<table>
<thead>
<tr>
<th>Warm down classification</th>
<th>Recovery Points available</th>
<th>Mean Recovery Points scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full warm down and thorough stretching</td>
<td>3 points</td>
<td></td>
</tr>
<tr>
<td>Normal warm down with some stretching</td>
<td>2 points</td>
<td></td>
</tr>
<tr>
<td>Brief warm down</td>
<td>1 point</td>
<td></td>
</tr>
<tr>
<td>No warm down</td>
<td>0 points</td>
<td></td>
</tr>
<tr>
<td><strong>Maximum warm down points</strong></td>
<td><strong>3 points</strong></td>
<td><strong>1.43 (SD ± 0.82)</strong></td>
</tr>
</tbody>
</table>

The use of active recovery is vital, especially when the players are training more than once a day as it has been shown to promote physiological and psychological recovery (Davis *et al.*, 1999, Mondero and Dunne, 2000, Kentta and Hassmen, 2002). However, some studies have shown no significant differences in the removal of lactate or glycogen resynthesis following different recovery protocols, manipulating active and passive recovery and massage (Corder *et al.*, 2000, Lau *et al.*, 2001, Fairchild *et al.*, 2003, Spencer *et al.*, 2006)

The mean score of 1.43 (SD ± 0.82) rates the players warm down as being “brief with some stretching”, indicating that the players do not hold too much regard for the prospective benefits of a thorough warm down. The players’ mean individual warm down scores are shown in Figure 22.
Figure 22. Mean warm down scores for badminton players involved in the monitoring period.

Only one player (Player 10) reported a full thorough recovery each day of their training during the monitoring period, with one player (Player 5) consistently undertaking their normal warm down comprising of some activity with stretching exercises and one player undertaking no warm down at all (Player 2).

For players at this level of performance, this lack of attention to their warm down was surprising, given the intensity that the players were training at. All the players reported that they would usually complete some light aerobic activity followed by stretching the major muscle groups, but did not report following this protocol during the monitoring period.

The possible reasons for this lack of attention to the warm down could be the lack of knowledge regarding the potential benefits, a perceived lack of relevance of warm down within training or possibly time constraints placed on the individual players. Without further questioning the players on their attitudes to warm down in training and
competition it is impossible to explain this lack of effective active recovery during the monitoring period.

The active recovery may be more effective during the competitive situation when future performances will rely on their capacity to recover from the game the previous day. The players may view this need for effective warm down as more significant, although effective warm down during training may allow them to make more gains from the training period, thus enhancing competitive performance.

Without measuring lactate removal or glycogen resynthesis following the warm down, one cannot speculate as to how effective each individual’s warm down protocol was. With the equivocal research evidence regarding active and passive recovery and their effects on blood lactate and muscle glycogen, the award of three Recovery Points seems justified.

The potential merits of warm up and warm down are well publicised for competition and training (Smith, 2003, Barnett, 2006), so the elite badminton players involved in the study might improve their warm down strategy to ensure a full count of Recovery Points to maximise any possible gains. This may involve more guidance regarding the potential benefits of a consistent active recovery, or simply more time being set aside during the training period to ensure effective warm down before the next session or the next training day.
Summary of findings

The primary and secondary hypotheses investigated were accepted by the research findings. There was found to be an imbalance in perceived effort and actual recovery, with the elite badminton players placing more emphasis on their training rather than their recovery actions. This would be of concern to players and coaches with regard to the risks of unexplained decrements in performance (UPS).

When the TQR categories were investigated, it is apparent that there are areas for improvement for the players in terms of their nutritional intake. In particular, the dietary analysis showed an insufficient overall carbohydrate intake and a lack of carbohydrate reloading in between training sessions. The level of hydration, especially with regard to the intake of sports drinks was also inadequate.

The amount of sleep the players are getting is acceptable, but only two players take a nap or “micro rest” during the day, which might be of benefit during periods of heavy training.

The players in the study did not appear to have a specific recovery strategy as in the main; they did not perform much recovery activity. Only three players use massage and cryotherapy in an attempt to recover optimally. The use of different recovery modalities may enable the badminton players to recover more effectively.

The warm down activities following training was also an area that was not highly regarded by the badminton players as the warm down performance was inadequate. Overall, the group would complete a brief warm down, which may not be sufficient to promote recovery for the next training session.
Limitations of the study.

The high performance players that took part in the study all did so in order for them to have a “snap-shot” of their current recovery performance. This led to highly motivated subjects, taking a full part in the study, providing useful valid realistic data. Due to the restricted numbers of players training at the centres due to injuries, illness and vacation, the numbers of players taking part in the study was subsequently limited, which may have had a bearing on the results in terms of statistical significance.

The players fully engaged with the questionnaire format and completed the sheets as accurately as possible, but the previous exposure to the RPE scale was varied amongst the group. Some players had no prior knowledge of the scale which may cast doubt over the validity of their RPE responses. The RPE statements were anchored by clear written statements, in an attempt to clarify the quantified scale (Foster et al, 2001), but it may have been of benefit to run more familiarisation sessions, possibly using some physiological measures, such as heart rate to ensure confidence in the scale and full understanding.

The whole concept of the TQR scale relies on perception of effort and recovery. To effectively and accurately quantify this takes some degree of skill, as each individual was required to reflect on feelings of effort and fatigue. The individual could develop confidence in their reflections with regular exposure and practice and this confidence may be enhanced further by links to quantitative physiological measurements, such as heart rate during training, blood lactate concentrations and plasma glucose levels. This quantitative data, alongside the reflective data would build an individual profile for each player so that after practice, the player might rely on their reflections to effectively appraise their state of recovery.

With the majority of the players starting their training in preparation for the forthcoming competitive season, it would be interesting to repeat the study at different times of the
season. The monitoring period in the study was at the least stressful time for the players and although the training was intensive, the psychological stress often associated with UPS may not have been evident. Studying the same parameters during different phases of the season may provide different results or further reinforce the current findings that overall, the recovery actions were inadequate for the training stress.

**Suggestions for future research**

Kentta and Hassmen (2002) were clear on the fact that the athletes using the scale should base their scoring on their perception of their training effort and recovery state. For an athlete experienced in using the scale and making reliable perceived assessments of their training effort and recovery state, this may be the case. However, for athletes who are new to the scale they will require a calibration phase (Seiler & Sjursen, 2004) where they familiarise themselves with the scale and also for some individuals the act of self reflection on their training effort and recovery state.

This familiarisation process may be enhanced by the use of physiological measures such as heart rate or blood lactate concentration which the athlete can match to the RPE or TQR scale, thus allowing the athlete to provide a quantifiable score reinforced by physiological measures. This type of measurement was not included in the present study, so as the athletes involved had limited prior experience of the TQR scale, the perceived results (TQRper) should be viewed with caution.

Future studies might provide a more rigorous familiarisation period, with the possible links to physiological measurements and once established the logistics of future studies may be enhanced by the completion of online TQR and RPE reporting. It would also be interesting to investigate the TQR responses at different phases of the competitive season, to see if the different levels of stress affect the recovery scores.
Mougin et al (2001) found that blood lactate values were higher (p<0.05) during submaximal exercise following a reduced amount of sleep. Blood lactate values were not monitored as part of the study, but this may be of benefit for future studies as it has been shown to be a variable affected by both nutrition and sleep. Also, urine and weight monitoring may be useful in future studies along with heart rate and lactate values to establish a more quantitative recovery score for comparison against the qualitative scores used in the current study.

**Recommendations**

The players involved in the study should review their nutritional strategy as the Nutrition and Hydration elements of the TQR scale, indicate poor hydration and carbohydrate intakes which was more evident in between training sessions.

It is important however that the players involved in the study are provided guidance as to how they can manipulate their nutritional intake further to maximise performance (Clark, 1998).

The sleep category showed a reasonable level of rest, but the players when involved in more intense training could benefit from more rest during the day as it can help both the physiological and psychological recovery. Monitoring the sleep patterns could also be suggested to the players as UPS has also been closely linked to disturbed sleep patterns (Taylor et al, 1997).

The recovery modalities utilised by the players involved in the study could also be considered as not many of the players appeared to have a recovery strategy. To allow the body to recover effectively, the players and possibly coaches need to be educated in the potential physiological and psychological benefits of modalities such as massage and cryotherapy and these services and facilities made available to the players.
The warm down strategies of the players also appeared inadequate, with the players not consistently completing warm down sessions effectively in preparation for forthcoming training sessions either later the same day or the next day.

Overall, the study uncovered less than adequate recovery practice employed by the badminton players at the HPC in Bath and Cardiff, which could be as a result of a lack of awareness or knowledge. This discrepancy in applied knowledge would need to be rectified in order for the players to optimise their training effort. This rectification would need to include some support from a sports nutritionist, some input regarding the relevance of sleep and rest, recovery modalities and warm down for badminton players during intense training and competition.
Conclusions

The primary hypothesis was accepted in that there was found to be a significant discrepancy in the players' recovery strategies in comparison to their training stress, although, the players perceived their recovery to be adequate. The implications of this imbalanced situation for a prolonged period of time would be that players may begin to suffer from unexplained decrements in performance due to UPS.

Analysing the breakdown of the TQR scale categories it is clear to see the reasons why the TQRact score was significantly less than the RPE score as all categories could be improved upon. This imbalance highlights the need to constantly monitor elite athletes, with regard to their training as is convention, but also with an equal emphasis on the nature of the players’ recovery (Smith, 2003).

The secondary hypothesis was also accepted, that there would be areas of the players’ recovery strategies that would require attention and improvement for optimal recovery. The recommendations detailed previously were derived from the findings of the TQRact values.

The final question surrounding these reported findings is the validity of the TQR instrument. The construction of the scale appears sound with regard to the body of research, with the weighting of points in favour of Nutrition and Hydration. The Sleep category is slightly more weighted than the Relaxation and Warm down categories, due to their equivocal research findings, would also appear appropriate.

The focus of elite players is always going to be strongly on their training and competition. The process of using the TQR scale has the potential to create awareness in the benefits of recovery and produce an effective recovery strategy encompassing all the TQR categories. This will enhance the recovery of the player relative to the training stress and enable the player to achieve their optimal potential.
Bibliography

(2004) Higher dietary carbohydrate content during intensified running training 
results in better maintenance of performance and mood state. *Journal of 
Applied Physiology*. 96. 1331-1340.

Maresh, C.M. (1998) Urinary indices during dehydration, exercise and 
rehydration. *International Journal of Sport Nutrition and Exercise Metabolism*. 
8. (4) 345-355.

syndrome, Clues from depression and psychoneuroimmunology. *Sports 
Medicine*. 32. (3), 185-209.

Astrand, P-O., & Rodahl, K. (1986) *Textbook of work physiology*- Physiological bases of 

Barnett, A. (2006) Using recovery modalities between training sessions in elite athletes: 


Champaign, Illinois

79


Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S.,

Franks B.D. & Huck, S.W. (1986.) Why does everyone use the .05 significance level?
*Research Quarterly for Exercise and Sport.* 57, 3. 245-249.


shot accuracy during a conditioned squash match. ). In *Science and Racket
London. E and FN Spon.

Sciences.* 15. 247-256.

(2006) RPE association with lactate and heart rate during high intensity interval


treatment of exercise-induced muscle damage. Scandinavian Journal of
Medicine and Science in Sports. 15, 416-422.

Hughes. M. (1994) Demands of training in elite badminton players. In Science and
and FN Spon.

Ivy, J.L., Goforth Jnr, H.W., Damon, B.M., McCauley, T.R., Parsons, E.C., & Price,
T.B. (2002) Early post-exercise muscle glycogen recovery is enhanced with a
carbohydrate–protein supplement. Journal of Applied Physiology. 93. 1337-
1344.

RPE-based training load in soccer. Medicine and Science in Sports and
Exercise.36. (6) 1042-1047.

synthesis during short term recovery. Sports Medicine. 33. (2) 117-144.


In Enhancing Recovery: Preventing Underperformance in Athletes. (edited by


http://www.qeliz.ac.uk/psychology/kiecol+glaser.htm


**Secondary References.**


The effectiveness of the Total Quality Recovery (TQR) scale for elite badminton players during periods of intense training

Appendices

Neil Cottrill

September 2007
Appendix 1

Player Handbook
The use of the Total Quality Recovery (TQR) scale in assessing recovery status

Player Information Pack

High Performance Centre

Summer 2007.

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Preferred discipline(s):</th>
<th>Employment status (Please tick):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singles</td>
<td>Doubles</td>
</tr>
</tbody>
</table>


MSc Exercise & Nutrition Science
Dissertation

The use of the Total Quality
Recovery (TQR) scale in assessing
recovery status

Player handbook contents:
- Participant information sheet
- Flow chart of study activities
- Participant consent form
- Baseline questionnaire
- RPE scale instruction sheet
- TQR scale instruction sheet
- Training & recovery questionnaire (5 days)
- Nutrition log (5 days)
- Training log (5 days)

High Performance Centre

Summer 2007.
Participant information sheet

The use of the Total Quality Recovery (TQR) scale in assessing recovery status

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?
In order to reach World and European level in badminton, players have to practice and train exceptionally hard. The recovery from training is an essential factor in enhancing performance and is often overlooked. This study proposes to monitor training of High Performance players and investigate and evaluate current recovery practices.

Why have I been chosen?
You have been chosen because you are a member of the High Performance Centre at Bath University and involved in periods of intense training.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect the standard of care you receive in any way.

What will happen to me if I take part?
If you decide to take part, you will be given this information sheet to keep and asked to sign the consent form. This will give your consent for a researcher from the Centre for Exercise and Nutrition Science at the University of Chester to monitor your training and recovery by asking you to complete a daily questionnaire before training relating to your training and recovery for the previous 24 hours.

You will also be asked to provide a daily nutrition log, recording all food and drink consumed for each 24 hour period. The study will last for 5 consecutive training days.

What are the possible disadvantages and risks of taking part?
There are no disadvantages or risks foreseen in taking part in the study.

What are the possible benefits of taking part?
As an elite badminton player looking to improve their performance level, detailed information regarding your responses to training and the effectiveness
of your recovery would be useful. Depending on the results, you may look to implement changes in your recovery strategies to maximise gains from your training.

**What if something goes wrong?**
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the School of Applied and Health Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence (but not otherwise), then you may have grounds for legal action but you may have to pay for this.

**Will my taking part in the study be kept confidential?**
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information. The High Performance Coaching staff will not have access to individual participant data, just the overall group results.

**What will happen to the results of the research study?**
The results will be written up into a report to gain the Master of Science qualification from the University of Chester. All identifying variables pertaining to your data will be removed, thus guaranteeing anonymity for all participants. Upon request, you can be provided with a copy of your own results for your own interest and/or development.

It is hoped that the findings may be used to improve the recovery from periods of intense training, ultimately to enhance performance. Individuals who participate will not be identified in any subsequent report or publication.

**Who is organising and funding the research?**
The Centre for Exercise & Nutrition Science at the University of Chester will be involved in organising and carrying out the study.

**Who may I contact for further information?**
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

*Neil Cottrill*
*University of Chester*
*Parkgate Road*
*Chester*
*CH1 4BJ.*

0516233@chester.ac.uk

Thank you for your interest in this research.
Participant consent form

Title of Project:

The use of the Total Quality Recovery (TQR) scale in assessing recovery status

Name of Researcher:

Neil Cottrill

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Initial box</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my care or legal rights being affected.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I understand that sections of any of my medical notes may be looked at by responsible individuals from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to my records.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I agree to take part in the above study.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Name of participant  Date:  Signature:

Researcher:  Date:  Signature:

Neil Cottrill
Briefing prior to Training Day 1
Issue of player handbooks and answer any questions regarding the study

On court training Day 1
On court training Day 2
   TQR questionnaire 1
   Diet/training log 1 submission
On court training Day 3
   TQR questionnaire 2
   Diet/training log 2 submission
On court training Day 4
   TQR questionnaire 3
   Diet/training log 3 submission
On court training Day 5
   TQR questionnaire 4
   Diet/nutrition log 4 submission
On court training Day 6
   TQR questionnaire 5
   Diet/training log 5 submission

Collation of data
- Dietary analysis
- TQR score calculation
- Statistical analysis RPE vs TQR act vs TQR per
- Report completion
- Feedback to players
Baseline information questionnaire

Name: ___________________________ Date: ___________________________

Preferred discipline: Singles Doubles Mixed Employment status: Badminton Student Work

1. What part of the competitive season are you in at the moment?

________________________________________________________________________

2. What is your current tournament schedule?

________________________________________________________________________

3. What are your short and long term objectives within badminton?

<table>
<thead>
<tr>
<th>Short term:</th>
<th>Long term:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. When did you last have time off from training due to injury? How long were you unable to train and give brief details of the injury?

<table>
<thead>
<tr>
<th>Date:</th>
<th>Length of lay off:</th>
<th>Injury details:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Describe your normal training week. Give details of time, duration & type of activity

<table>
<thead>
<tr>
<th>Mon</th>
<th>Tues</th>
<th>Weds</th>
<th>Thur</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
</table>

6. How many hours sleep would you get on a normal night?


7. Would you normally sleep during the day? If so, for how long

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>How long:</th>
</tr>
</thead>
</table>

8. Describe a typical warm down after a training session. Give details of duration, activities, muscle groups etc.

<table>
<thead>
<tr>
<th>Duration</th>
<th>Activities</th>
<th>Muscle groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9. Circle the score that represents how relaxed have you generally feel.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very relaxed</td>
<td>Moderately anxious</td>
<td>Very anxious</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. Mark all the factors that you generally worry about.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family</td>
<td>Partner</td>
<td>Money</td>
<td>Work or education</td>
<td>Training</td>
<td>Tournaments</td>
<td>Other</td>
</tr>
</tbody>
</table>

11. What do you normally do to relax?

<table>
<thead>
<tr>
<th>Massage</th>
<th>Sleep</th>
<th>Socialise</th>
<th>Other sports</th>
<th>Other:</th>
</tr>
</thead>
</table>

12. What steps do you take to maximise or enhance your performance?

<table>
<thead>
<tr>
<th>Supplements</th>
<th>Diet</th>
<th>Massage</th>
<th>Psychology</th>
<th>Other: Please provide details</th>
</tr>
</thead>
</table>

13. Do you feel you are mentally and physically able to undertake the normal daily High Performance Centre training?

| Yes | No |
Rating of Perceived Exertion Information Sheet (Borg, 1998)

Following your training session, I would like you to rate how strenuous you feel the session was. The perception of exertion depends mainly on the strain and fatigue felt in your muscles and also the feeling of breathlessness and aches in the chest.

Try to be as honest as possible – don’t overestimate or underestimate. It is your own feeling of exertion that is important, so do not be influenced by anybody else.

Rate your training day/session based on the following scale from 6-20, with 6 being no exertion at all and 20 being maximal exertion.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>No exertion at all</td>
</tr>
<tr>
<td>7</td>
<td>Extremely light</td>
</tr>
<tr>
<td>8</td>
<td>Very light</td>
</tr>
<tr>
<td>9</td>
<td>Walking slowly at own pace for a few minutes</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Light</td>
</tr>
<tr>
<td>12</td>
<td>Somewhat hard</td>
</tr>
<tr>
<td>13</td>
<td>Quite hard but feels ok to continue</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Hard (heavy)</td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Very hard</td>
</tr>
<tr>
<td>18</td>
<td>You’ve really got to push yourself to carry on</td>
</tr>
<tr>
<td>19</td>
<td>Extremely hard</td>
</tr>
<tr>
<td>20</td>
<td>Almost as hard as you can work</td>
</tr>
<tr>
<td></td>
<td>Maximal exertion</td>
</tr>
</tbody>
</table>
I would like you to rate how recovered you feel following the training you completed yesterday. The perception of recovery depends mainly on how good your muscles feel, how well you slept last night and how relaxed you feel.

Try to be as honest as possible – don’t overestimate or underestimate. It is your own feeling of recovery that is important, so do not be influenced by anybody else.

Rate your recovery from the training you undertook in the last 24 hours based on the following scale from 6-20, with 6 being no recovery at all and 20 being maximal recovery.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>No recovery at all</td>
</tr>
<tr>
<td>7</td>
<td>Extremely poor recovery</td>
</tr>
<tr>
<td>8</td>
<td>Very poor recovery</td>
</tr>
<tr>
<td>9</td>
<td>Still feel quite stiff with muscle fatigue. Poor sleep quality</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Poor recovery</td>
</tr>
<tr>
<td>12</td>
<td>Reasonable recovery</td>
</tr>
<tr>
<td>13</td>
<td>Quite tired but able to train ok</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Good recovery</td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Very good recovery</td>
</tr>
<tr>
<td>18</td>
<td>Refreshed from sleep and muscles feeling good</td>
</tr>
<tr>
<td>19</td>
<td>Extremely good recovery</td>
</tr>
<tr>
<td>20</td>
<td>Totally refreshed and prepared to get most out of training</td>
</tr>
<tr>
<td>20</td>
<td>Maximal recovery</td>
</tr>
</tbody>
</table>
Data Collection

Monday

Training Day 1
Training & Recovery Questionnaire – Training Day 1 (Monday)

Name:  
Date:  
Time completed:

1. Circle the score that rates how hard do you think the overall training was yesterday.

<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No exertion at all</td>
<td>Extremely light</td>
<td>Very light</td>
<td>Light</td>
<td>Somewhat hard</td>
<td>Hard (heavy)</td>
<td>Very hard</td>
<td>Extremely hard</td>
<td>Maximal exertion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. For each session completed yesterday, give brief details of the type of session (e.g. court session, running, weights etc) and circle the score that represents how hard the individual session was.

Session details:

<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No exertion at all</td>
<td>Extremely light</td>
<td>Very light</td>
<td>Light</td>
<td>Somewhat hard</td>
<td>Hard (heavy)</td>
<td>Very hard</td>
<td>Extremely hard</td>
<td>Maximal exertion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Circle the score that rates how recovered you feel following yesterday's training.

<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No recovery at all</td>
<td>Extremely poor recovery</td>
<td>Very poor recovery</td>
<td>Poor recovery</td>
<td>Reasonable recovery</td>
<td>Good recovery</td>
<td>Very good recovery</td>
<td>Extremely good recovery</td>
<td>Maximal recovery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

110
4. Mark all the meals have you taken in the last 24 hours?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td>Lunch</td>
<td>Dinner</td>
</tr>
</tbody>
</table>

5. How much unbroken sleep did you have last night?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 6 hours</td>
<td>6-8 hours</td>
<td>More than 8 hours</td>
</tr>
</tbody>
</table>

6. Did you sleep at all during the day in the last 24 hours?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

7. What activities did you perform following yesterday’s training? Mark all that apply.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm down</td>
<td>Massage</td>
<td>Shower</td>
<td>Ice bath</td>
<td>Sleep</td>
<td>Quiet time</td>
<td>Meditation</td>
<td>Jacuzzi</td>
<td>Steam bath</td>
<td>Other</td>
</tr>
</tbody>
</table>

8. Circle the score that represents how relaxed have you felt in the last 24 hours.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very relaxed</td>
<td>Moderately anxious</td>
<td>Very anxious</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Mark all the factors that you may have worried about in the last 24 hours.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family</td>
<td>Partner</td>
<td>Money</td>
<td>Work or education</td>
<td>Training</td>
<td>Tournaments</td>
<td>Other</td>
</tr>
</tbody>
</table>

10. Circle the score that represents your immediate post training recovery for the last 24 hours.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not train</td>
<td>Did not cool down</td>
<td>Brief cool down with some stretching</td>
<td>Normal cool down with some stretching</td>
<td>Full cool down stretching all muscle groups</td>
</tr>
<tr>
<td>Time</td>
<td>Food/drink details</td>
<td>Amounts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------------</td>
<td>------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eg 08.30</td>
<td>Weetabix</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sugar</td>
<td>2 teaspoons</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Milk – semi skimmed</td>
<td>Approx 100ml</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toast (brown)</td>
<td>2 pieces</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Margarine – low fat</td>
<td>Approx 5g</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jam – strawberry</td>
<td>2 teaspoons</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fresh orange juice</td>
<td>150ml</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Food/drink details</th>
<th>Amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Training details</td>
<td>Duration (RPE)</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>10.00</td>
<td>Squad court session</td>
<td>2 hours (16)</td>
</tr>
<tr>
<td>13.00</td>
<td>Run – low intensity, continuous</td>
<td>45 mins (13)</td>
</tr>
<tr>
<td>16.00</td>
<td>Weight session – lower body, power</td>
<td>1 hour 30 (17)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Training details</th>
<th>Duration</th>
</tr>
</thead>
</table>
Appendix 2

Participant Information Sheet
The use of the Total Quality Recovery (TQR) scale in assessing recovery status

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?
In order to reach World and European level in badminton, players have to practice and train exceptionally hard. The recovery from training is an essential factor in enhancing performance and is often overlooked. This study proposes to monitor training of High Performance players and investigate and evaluate current recovery practices.

Why have I been chosen?
You have been chosen because you are a member of the High Performance Centre at Bath University and involved in periods of intense training.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect the standard of care you receive in any way.

What will happen to me if I take part?
If you decide to take part, you will be given this information sheet to keep and asked to sign the consent form. This will give your consent for a researcher from the Centre for Exercise and Nutrition Science at the University of Chester to monitor your training and recovery by asking you to complete a daily questionnaire before training relating to your training and recovery for the previous 24 hours.

You will also be asked to provide a daily nutrition log, recording all food and drink consumed for each 24 hour period. The study will last for 5 consecutive training days.

What are the possible disadvantages and risks of taking part?
There are no disadvantages or risks foreseen in taking part in the study.

What are the possible benefits of taking part?
As an elite badminton player looking to improve their performance level, detailed information regarding your responses to training and the effectiveness of your recovery would be useful. Depending on the results, you may look to implement changes in your recovery strategies to maximise gains from your training.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew,
Dean of the School of Applied and Health Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence (but not otherwise), then you may have grounds for legal action but you may have to pay for this.

Will my taking part in the study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information. The High Performance Coaching staff will not have access to individual participant data, just the overall group results.

What will happen to the results of the research study?
The results will be written up into a report to gain the Master of Science qualification from the University of Chester. All identifying variables pertaining to your data will be removed, thus guaranteeing anonymity for all participants. Upon request, you can be provided with a copy of your own results for your own interest and/or development.

It is hoped that the findings may be used to improve the recovery from periods of intense training, ultimately to enhance performance. Individuals who participate will not be identified in any subsequent report or publication.

Who is organising and funding the research?
The Centre for Exercise & Nutrition Science at the University of Chester will be involved in organising and carrying out the study.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Neil Cottrill
University of Chester
Parkgate Road
Chester
CH1 4BJ.

0516233@chester.ac.uk

Thank you for your interest in this research.
Appendix 3

Example Nutrition Analysis output
Llandrillo College
Sports & Recreation Department
Averaged Assessment

Reg.No : MSC5
Sex : Male
Age : 24
Weight : 83.00 kg.
Dietary reference values using :
Occupational activity : Heavy
Personal activity : Very active
Total number of foods : 13

Assessment Date : 04 June 2007
Date of birth : 27 July 1982
Height : 1.83 m.
Body Mass Index : 24.8

Total food intake : 4.20 kg.
per day : 4.20 kg.

Analysis of selected nutrients :

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Unit</th>
<th>Intake</th>
<th>per day</th>
<th>E.A.R.</th>
<th>per 100gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edible proportion</td>
<td></td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Water</td>
<td>gm</td>
<td>3738.3</td>
<td>3738.3</td>
<td></td>
<td>89.1</td>
</tr>
<tr>
<td>Protein</td>
<td>gm</td>
<td>37.1</td>
<td>37.1</td>
<td>44.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Fat</td>
<td>gm</td>
<td>54.8</td>
<td>54.8</td>
<td>131.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Carbohydrate (monosaccharide)</td>
<td>gm</td>
<td>321.8</td>
<td>321.8</td>
<td>545.6</td>
<td>7.7</td>
</tr>
<tr>
<td>Energy (kcal)</td>
<td>Cal</td>
<td>1805</td>
<td>1805</td>
<td>3586</td>
<td>43</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>kJ</td>
<td>7622</td>
<td>7622</td>
<td>15010</td>
<td>182</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>gm</td>
<td>6.11</td>
<td>6.11</td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>Saturated fatty acids</td>
<td>gm</td>
<td>16.6</td>
<td>16.6</td>
<td>39.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Mono-unsaturated fatty acids</td>
<td>gm</td>
<td>16.9</td>
<td>16.9</td>
<td>47.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Poly-unsaturated fatty acids</td>
<td>gm</td>
<td>12.2</td>
<td>12.2</td>
<td>23.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>mgm</td>
<td>41.0</td>
<td>41.0</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Starch - monosaccharide equiv.</td>
<td>gm</td>
<td>149.2</td>
<td>149.2</td>
<td></td>
<td>3.6</td>
</tr>
<tr>
<td>Total Sugars - monosaccharide</td>
<td>gm</td>
<td>170.7</td>
<td>170.7</td>
<td></td>
<td>4.1</td>
</tr>
<tr>
<td>Dietary fibre, Southgate method</td>
<td>gm</td>
<td>15.6</td>
<td>15.6</td>
<td>18.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Dietary fibre, Englisty method</td>
<td>gm</td>
<td>26.0</td>
<td>26.0</td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>mgm</td>
<td>1293</td>
<td>1293</td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>mgm</td>
<td>3728</td>
<td>3728</td>
<td></td>
<td>89</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>mgm</td>
<td>525</td>
<td>525</td>
<td>525</td>
<td>13</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>mgm</td>
<td>271</td>
<td>271</td>
<td>250</td>
<td>6</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>mgm</td>
<td>758</td>
<td>758</td>
<td>525</td>
<td>18</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>mgm</td>
<td>10.73</td>
<td>10.73</td>
<td>6.70</td>
<td>0.26</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>mgm</td>
<td>1.05</td>
<td>1.05</td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>mgm</td>
<td>4.17</td>
<td>4.17</td>
<td>7.30</td>
<td>0.10</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>mgm</td>
<td>2300</td>
<td>2300</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>mgm</td>
<td>2.85</td>
<td>2.85</td>
<td></td>
<td>0.07</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>ugm</td>
<td>14</td>
<td>14</td>
<td></td>
<td>0+</td>
</tr>
<tr>
<td>Iodine (I)</td>
<td>ugm</td>
<td>85</td>
<td>85</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Retinol</td>
<td>ugm</td>
<td>175</td>
<td>175</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Carotene</td>
<td>ugm</td>
<td>4794</td>
<td>4794</td>
<td></td>
<td>114</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>ugm</td>
<td>1.75</td>
<td>1.75</td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>Nutrient</td>
<td>Unit</td>
<td>Intake</td>
<td>per day</td>
<td>E.A.R.</td>
<td>per 100gm</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------</td>
<td>--------</td>
<td>---------</td>
<td>--------</td>
<td>-----------</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>mgm</td>
<td>13.54</td>
<td>13.54</td>
<td>---</td>
<td>0.32</td>
</tr>
<tr>
<td>Thiamin</td>
<td>mgm</td>
<td>1.97</td>
<td>1.97</td>
<td>1.08</td>
<td>0.05</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>mgm</td>
<td>1.35</td>
<td>1.35</td>
<td>1.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Nicin</td>
<td>mgm</td>
<td>15.54</td>
<td>15.54</td>
<td>19.72</td>
<td>0.37</td>
</tr>
<tr>
<td>Tryptophan divided by 60</td>
<td>mgm</td>
<td>8.00</td>
<td>8.00</td>
<td>---</td>
<td>0.19</td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>mgm</td>
<td>3.42e</td>
<td>3.42</td>
<td>0.58</td>
<td>0.08</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>ugm</td>
<td>1.1</td>
<td>1.1</td>
<td>1.3</td>
<td>0+</td>
</tr>
<tr>
<td>Folate</td>
<td>ugm</td>
<td>305+</td>
<td>305</td>
<td>150</td>
<td>7</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>mgm</td>
<td>6.31e</td>
<td>6.31</td>
<td>---</td>
<td>0.15</td>
</tr>
<tr>
<td>Biotin</td>
<td>ugm</td>
<td>19.9+</td>
<td>19.9</td>
<td>---</td>
<td>0.5</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>mgm</td>
<td>269</td>
<td>269</td>
<td>25</td>
<td>6</td>
</tr>
</tbody>
</table>

Key: For one or more contributory foods:
- d: nutrient value derived or deduced
- e: value estimated
- +: present in significant, unknown amounts
- m: missing value

---

**Nutrient contribution by weight**

![Nutrient contribution by weight](image)

- Reg No MSCS Caldwell, Ben.
- Nutrient content of 4195 gm of food

---

**Sources of energy**

<table>
<thead>
<tr>
<th>Calories of energy</th>
<th>Total</th>
<th>per 100g</th>
<th>Percent</th>
<th>Tot(1)</th>
<th>Food(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>148</td>
<td>4</td>
<td>8.0</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>1207</td>
<td>29</td>
<td>65.3</td>
<td>47%</td>
<td>50%</td>
</tr>
<tr>
<td>Fat</td>
<td>494</td>
<td>12</td>
<td>26.7</td>
<td>33%</td>
<td>35%</td>
</tr>
<tr>
<td>Alcohol</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1849</td>
<td>44</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTES 1 & 2. Columns show the percentage energy profile for the UK population as a whole. Tot (1) includes all sources of energy while Food (2) is for food only, excluding alcohol.
### Nutrient contribution to energy

![Nutrient contribution to energy chart](chart.png)

**RegNo MUC5 Caldwell, Eec**

Source of 444 kcal energy from 4195 gm of food

54.6% of 3558 kcal E.A.R. (M.K.W.)

### Food quantities:

<table>
<thead>
<tr>
<th>Src</th>
<th>Ref</th>
<th>Weight</th>
<th>Percent</th>
<th>Food or Recipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKN</td>
<td>19-308</td>
<td>20.0</td>
<td>0.5</td>
<td>Ham</td>
</tr>
<tr>
<td>UKN</td>
<td>13-440</td>
<td>40.0</td>
<td>1.0</td>
<td>Peas, frozen, boiled in unsalted water</td>
</tr>
<tr>
<td>UKN</td>
<td>11-493</td>
<td>50.0</td>
<td>1.2</td>
<td>Fruit 'n Fibre</td>
</tr>
<tr>
<td>UKN</td>
<td>14-294</td>
<td>75.0</td>
<td>1.8</td>
<td>Mangoes, ripe, raw</td>
</tr>
<tr>
<td>UKN</td>
<td>13-460</td>
<td>130.0</td>
<td>3.1</td>
<td>Tomatoes, raw</td>
</tr>
<tr>
<td>UKN</td>
<td>12-312</td>
<td>146.0</td>
<td>3.5</td>
<td>Semi-skimmed milk, average</td>
</tr>
<tr>
<td>UKN</td>
<td>14-013</td>
<td>170.0</td>
<td>4.1</td>
<td>Apples, eating, average, raw, weighed with core</td>
</tr>
<tr>
<td>UKN</td>
<td>14-298</td>
<td>210.0</td>
<td>5.0</td>
<td>Oranges</td>
</tr>
<tr>
<td>UKN</td>
<td>50-661</td>
<td>220.0</td>
<td>5.2</td>
<td>New potatoes, boiled in unsalted water</td>
</tr>
<tr>
<td>UKN</td>
<td>15-377</td>
<td>250.0</td>
<td>6.0</td>
<td>Pasty, vegetable</td>
</tr>
<tr>
<td>UKN</td>
<td>50-867</td>
<td>320.0</td>
<td>7.6</td>
<td>Bananas</td>
</tr>
<tr>
<td>UKN</td>
<td>17-190</td>
<td>564.0</td>
<td>13.4</td>
<td>Fruit drink/squash, concentrated, made up</td>
</tr>
<tr>
<td>MW5</td>
<td>1186</td>
<td>2000.0</td>
<td>47.7</td>
<td>Water</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4195.0</strong></td>
<td><strong>100.0</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The UK Nutrient Databank is Crown copyright and has been reproduced under licence from the Controller of Her Majesty's Stationery Office.

(c) Dietplan6 (c) Forestfield Software Ltd 1991-2007
Appendix 4

Ethics Approval Letter
08 May 2007

Dear Neil

Study title: The use of the Total Quality Recovery (TQR) scale in assessing recovery status
SREC reference: 125/07/NC/CENS
Version number: 2

Thank you for sending the above-named application to the School of Applied and Health Sciences Research Ethics Committee for review.

The application has been considered on behalf of the Committee by Dave Smith as Lead Reviewer and reported to the School Research Ethics Committee.

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form and supporting documentation.

The favourable opinion is given provided that you comply with the conditions set out in the attached document. You are advised to study the conditions carefully.

The final list of documents reviewed and approved by the Committee is as follows:

<table>
<thead>
<tr>
<th>Document</th>
<th>Version</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Form</td>
<td>2</td>
<td>March 2007</td>
</tr>
<tr>
<td>Participant Information Sheet</td>
<td>3</td>
<td>April 2007</td>
</tr>
<tr>
<td>Participant Consent Form</td>
<td>3</td>
<td>April 2007</td>
</tr>
<tr>
<td>Baseline information questionnaire</td>
<td>3</td>
<td>April 2007</td>
</tr>
<tr>
<td>Training and Recovery questionnaire</td>
<td>2</td>
<td>March 2007</td>
</tr>
<tr>
<td>RPE scale</td>
<td>2</td>
<td>March 2007</td>
</tr>
<tr>
<td>TQR scale</td>
<td>1</td>
<td>January 2007</td>
</tr>
<tr>
<td>Nutrition log</td>
<td>2</td>
<td>March 2007</td>
</tr>
<tr>
<td>Training log</td>
<td>2</td>
<td>March 2007</td>
</tr>
<tr>
<td>Data gathering flow chart</td>
<td>2</td>
<td>March 2007</td>
</tr>
<tr>
<td>Powerpoint presentation</td>
<td>1 (5)</td>
<td>January 2007</td>
</tr>
<tr>
<td>Letters/emails providing consent to the research study</td>
<td>n/a</td>
<td>2007</td>
</tr>
</tbody>
</table>
With the Committee's best wishes for the success of this project.

Yours sincerely,

____________________
Stephen Fallows
Chair, School Research Ethics Committee

Enclosures Standard conditions of approval.

cc. Supervisor
    SREC Representative
Appendix 5

SPSS outputs (CD ROM)