Chapter 4 – Discussion

The purpose of this study was to compare the effects of pre-exercise ingestion of foods with high and low glycemic indices on aerobic performance and skill during an experimental protocol that closely simulates the demands of actual badminton.

Much is known about the beneficial role of CHO ingestion together with the glycemic index on endurance exercise, with limited research on intermittent high intensity exercise, but the role of CHO and in particular the role of the glycemic index on cognitive function during exercise requiring a high degree of cognitive and motor skills is much less understood. There is very limited research in the area of badminton, other game sports and nutrition. No known research has been carried out on the effects of pre-exercise LGI and HGI meal on intermittent, multi sprint game sports such a tennis, squash and in particular badminton. This resulted in a lack of literature and lack of comparative data from which to draw comparisons.

The main findings of this study was that pre-exercise ingestion of foods with high and low glycemic indices ingested one hour prior to exercise does not effect aerobic performance or skill in badminton players. No differences were observed in multistage fitness test to exhaustion ($P = 0.404$), simulated badminton performance test ($P = 0.431$) and skills test (long serve, clear and drop) ($P = 0.078$) following ingestion of a LGI or HGI meal.

The sample size in this study was small a larger sample may have resulted in greater statistical power. However the population pool from which to draw subjects from was itself quite small. Badminton is not a particularly big sport. Of the numbers who play badminton nationally there are significantly less players playing at national, provincial or senior 1 level, above the age of 16. The small population pool combined with individual's time constraints and injury status proved difficult when recruiting subjects to participate in this study. Perhaps the time of year also contributed to this difficultly as the study was conducted out of season. Players were likely to be involved in alternative sporting activities during this time and were possibly less likely to participate given that they may have had other sporting commitments and given their dedication during the previous badminton season may merely have wished to take a break from badminton during this time. As the trial was conducted during the summer months many players were also on vacation at various times throughout the summer months. Perhaps if this study was conducted during the badminton season there may have been more willingness to participate. In addition to participation levels the fact that the research was conducted out of season may also negatively impact on the results of both aerobic performance and the skills tests carried out. As players may not have played badminton during the summer months to the extent that they would during the season, which may result in decrements in their aerobic performance but particularly in their skills performance. However, it is unlikely that all subjects played no badminton during the summer months as most players of this standard play some badminton all year round and use the summer months to do additional training for the upcoming season.

Ingestion of foods with high and low glycemic indices prior to exercise does not result in a performance advantage is in support of previous findings (Wee et al., 1999; Fabbraio et al., 2000b; Stannard et al., 2000; Kirwan, et al., 2001b; Erith et al., 2006; Sparks et all., 1998; Febbraio & Stewart, 1996). Of these studies only one known study by Erith et al. (2006) looked at the effects of LGI and HGI pre-exercise meal on subsequent exercise capacity during intermittent high-intensity exercise. In this study no significant differences were found between trials in time to fatigue, sprint performance and distance covered. In a study by Stannard et al. (2000) of ten trained cyclists. Subjects performed an incremental exercise test to exhaustion 65 min after ingesting a LGI and HGI meal. Subjects started cycling at a workload of 50 watts (W) the load was then increased by 50 W every 3 minutes. The exercise intensity required to perform the incremental cycle to exhaustion would be quite similar to the demands of multistage fitness test and simulated badminton performance test carried out in the present study. Similarly Stannard found that exercise time to fatigue did not differ between trials. This is in contrast to other studies where a performance advantage has been found between meal types (DeMarco et al., 1999; Kirwan et al., 1998; Kirwan et al., 2001; Thomas et al., 1991a; Wu and Williams, 2006).

Prolonged intermittent high intensity exercise is reliant on muscle glycogen as a primary source of fuel (Bean, 2006; Erith et al, 2006). As a consequence, as exercise intensity increases, muscle glycogen stores become depleted at a much greater rate. As muscle glycogen stores become depleted blood glucose is required to maintain the body's energy requirements (Bean, 2006). In a study by Wee et al. (2005) subjects ran at 71% $\dot{V}O_2max$ on a treadmill for 30 minutes following ingestion of a LGI and HGI breakfast. Muscle glycogen utilisation during exercise was greater in the HGI ($P < 0.01$) compared with the LGI trial thus a sparing of muscle glycogen during exercise was observed in the LGI trial. The reason for muscle glycogen utilisation being greater for HGI compared to LGI meal may be that following a HGI meal subjects tend to exercise using more CHO because of its greater availability than fat whereas following a LGI meal there may be a greater tendency to use fat than CHO as an energy source (Erith et al., 2006). The average heart rate in all racket sports played competitively exceeds 150 bpm and involves high intensity activity for very short periods of time. In match play lasting between 30 and 90 min, this places a significant demand on energy supply from muscle glycogen. We can therefore assume that a very significant portion of our limited glycogen stores in the body is used up during match play (MacLaren, 1998). Depletion of muscle glycogen during exercise is directly related to fatigue (MacLaren, 1998). The main aim of the multistage fitness test and the simulated badminton performance tests was to reproduce the physiological demands of badminton play and result in a total duration of time similar to that of a badminton match. However the use of a multistage fitness test to volitional fatigue combined with the simulated badminton performance test may have resulted in the total time falling short of a typical match. Perhaps the use of a maximal test was not best placed and a sub-maximal shuttle run performance test of longer duration would have been more appropriate. In addition this would also more accurately reflect the intensity demand placed on the body for the duration of a badminton match as badminton itself does not involve exercising to levels of exhaustion.

The lack of difference in aerobic performance during the present study may be due to a number of different factors. One explanation might be that the exercise duration may not have been of sufficient length for any significant depletion in muscle glycogen stores to occur. However, in a study by Boobis, Williams and Wootton (1982) a 14% reduction in muscle glycogen was found following a 6 sec sprint alone (as cited by MacLaren, 1998). During exercise as muscle glycogen reserves are depleted there is a shift from muscle glycogen to blood glucose as a source of fuel. Given the short duration of the exercise protocol in the present study perhaps muscle glycogen stores did not become sufficiently depleted for a shift in blood glucose utilisation to occur. Therefore sufficient muscle glycogen may have existed for both meals to carry out the exercise performance tests to the same degree. Another factor that may have contributed to the lack of difference in performance was that blood glucose concentrations did not differ significantly between meals. Perhaps if muscle glycogen concentrations were depleted during the exercise protocol and a concomitant shift from muscle glycogen to blood glucose utilisation did occur, the available circulating blood glucose may have been sufficient in both trials. However the reduced sample size

(n = 4) may have been insufficient to detect any significant differences in blood glucose concentrations between meals if they existed. If however blood glucose concentrations were significantly different between trials and a shift in blood glucose utilisation did occur then it may be reasonable to expect a difference in exercise performance between trials.

Approximately three hours is required for complete digestion and absorption of CHO (Wee et al., 1999). The rates at which CHO leaves the stomach and is absorbed by the small intestine are two potential factors that can limit the availability of CHO during exercise (Leiper et al., 2001). Gastric emptying during intermittent high intensity exercise may be slowed compared to low or moderate intensity exercise (ACSM, 2000; Leiper et al., 2001). During exercise, increased activity of the sympathetic nervous system causes splanchnic vasoconstriction reducing the rate of absorption (Leiper et al., 2001; Wee et al., 1999). In a study by Leiper et al. (2001) exercise at a constant workload at 66% $\dot{V}O_2$max did not affect gastric emptying however cycling at 66% $\dot{V}O_2$max incorporating short high intensity intermittent sprints slowed gastric emptying compared to rest and steady state exercise. During the present study it is possible that both digestion and absorption was still taking place as the subjects began exercising (Sparks et al., 1998). Muscle glycogen re-synthesis may not have been optimised in the 60 minutes between ingesting the meal and performing the exercise tests. In addition, during the present trial, water was not administered in a measured quantity therefore gastric emptying may not have been maximised during the trial as the quantity of water consumed may not have been sufficient. As a result perhaps the gastric emptying rate of ingested CHO was insufficient to give subjects the benefit whilst undertaking the exercise performance tests.

Lactate production and accumulation is accelerated as exercise intensity increases (McArdle et al., 2006). A 4.0 mmol lactate value indicates the onset of blood lactate accumulation (OBLA). OBLA begins to accelerate and rise exponentially at approximately 55% of an individual's $\dot{V}O_2$max. Blood lactate accumulation during maximal exercise is > 8 mmol (McArdle et al., 2006). Mean blood lactate concentrations throughout this study were maintained above 8 mmol following both performance tests indicating that subjects were working at very high levels of intensity. Blood lactate concentrations between trials was not different. These finding are supported in previous studies by Erith et al. (2006), Sparks et al. (1998) and Wu and Williams (2006) where no differences in blood lactate concentrations between LGI and HGI trials were found. However in a study by Stannard et al. (2000), Thomas et al. (1991) and Wee et al. (2005) blood lactate concentrations were found to be significantly higher for HGI trial compared to LGI trial during exercise. Interestingly in the study by Stannard et al. (2000) blood lactate concentrations were higher for HGI meal compared to LGI meal where the workload was sub-maximal, as the exercise intensity increased (>200 W) no differences was observed in blood lactate. This would indicate that elevation in blood lactate concentrations as a result of ingesting a HGI meal becomes insignificant as exercise intensity increases (Stannard et al., 2000). During the present study level of exertion was assessed on the basis of blood lactate concentrations. It would have been desirable to record the subject's heart rate response combined with their blood lactate during this study to more accurately assess intensity and levels of volitional fatigue upon completion of the multistage fitness test and the simulated badminton performance test. This would have lead to greater reliability and perhaps identified whether the subjects perceived level of intensity causing them to withdraw from the multistage fitness test and effort exerted during the simulated badminton performance test was indeed maximal. Subjects were also given verbal encouragement during the performance tests, however during the multistage fitness test the last remaining subject may have been inclined to withdraw from the test due to a lack of desire and competition from their peers. They may therefore have withdrawn because they felt that they had merely done enough but given more encouragement they may have been able to continue for a few seconds longer. The use of heart rate would also have been desirable to accurately assess whether the heart rate response during the performance tests was similar to those experienced during match play therefore more accurately simulating the physiological demands of badminton match play prior to completing the skills test.

The overall mean number of repetitions for LGI and HGI meals for the four simulated badminton performance tests was 18.19 ± 2.67 reps and 17.47 ± 2.24 reps respectively ($P = 0.431$). This would indicate that subjects during the LGI trial tended to perform more repetitions during the simulated badminton performance test than subjects in the HGI trial but these differences were not significant. During this test one repetition represents each subject covering all 6 corners of the court. These results may represent some potential beneficial effect of LGI vs. HGI ingestion prior to playing badminton. The differences observed could be of some consequence during match play. If a player is not capable of covering the court and getting to the shuttle in time performance during a game will invariably decline.

A badminton match consists of three games to 21 points. The scoring system in badminton is a rally system, therefore the side winning a rally shall add a point to its score (Badminton Ireland, n.d.). This rally scoring system means that there is little to no room for error during each game, players need to be able to start well and maintain very high levels of concentration and skill throughout the entire duration of a match. Any lack of concentration or deterioration in skill may lead to loss of valuable points and ultimately loss of a game or match. This is particularly evident in badminton where it is played at a very high level. Coming back in a game where someone is a number of points down can be very difficult.

The results of the present study suggest that the glycemic index of a meal does not influence skill performance in badminton players. This is in line with previous studies where no performance advantage in skill maintenance was reported (Bottoms et al., 2006; Zeederberg et al., 1996) whilst others have shown a favourable performance advantage in skill maintenance following CHO ingestion (Graydon et al., 1998; Ostojic & Mazic, 2002; Welsh et al., 2002; Winnick et al., 2005). However of these studies carried out no known study has looked specifically at the role of the glycemic index on skill maintenance during game sports.

This study was not designed to determine the underlying mechanisms of potential benefits of LGI and HGI meal on the aerobic performance and skill maintenance. However, the data does lend some support that elevated plasma glucose concentrations observed with LGI trial compared to HGI trial may be beneficial in exercise requiring a high degree of motor and cognitive function. Although not significant the mean total score combining all tests (long serve, clear and drop) was higher for LGI trial (101.67 ± 22.29 pts) than HGI trial (89.17 ± 27.46 pts) ($P = 0.078$). The mean total score combining all tests for points as a result of landing in the small target zone was also higher for LGI trial (56.67 ± 27.33 pts) compared to HGI trial (45 ± 16.43 pts) ($P = 0.246$). Glucose is an essential energy source for the brain, especially in the areas of the brain that are most active during strenuous exercise. Even small changes in glucose within normal ranges can affect cognitive function (Gibson & Green, 2002; Welsh et al., 2002). Low blood glucose can lead to reduced CNS function and may result in feelings of lethargy, increased levels of perceived exertion, negative mood states and decreased arousal whereas maintenance of higher blood glucose concentrations can lead to enhanced CNS functioning during high intensity exercise (Welsh et al., 2002). A number of studies have shown that blood glucose concentrations fall dramatically, rebound hypoglycaemia, at the onset of exercise following a HGI meal particularly where the meal is ingested in the hour prior to exercise (DeMarco et al., 1999; Febbraio et al., 2000b; Sparks et al., 1998; Stannard et al., 2000). It has been recommended that if CHO is ingested prior to exercise in order to prevent this rebound hypoglycaemic response ingesting CHO during exercise as well may be beneficial (MacLaren, 1998). This trend was also observed during the present study where blood glucose concentrations in the LGI trial was maintained throughout the study but in the HGI trial a reduction although not significant between HGI blood glucose sample three and four was observed following the simulated badminton performance test (5.33 ± 0.29 mmol; 3.38 ± 0.38 mmol) ($P = 0.068$) (Table 8). Perhaps during this period where there is a rapid reduction in blood glucose concentrations at the onset of exercise following a HGI meal, cognitive function may be impaired briefly and at a cost during a badminton match, resulting in loss of points in the early stages of a game. During this study subjects did not perform the skills tests in exactly the same sequence during each trial. It would have been useful to have observed any differences between trials in the skills tests performed first. In addition the skills test was performed after the multistage fitness test and simulated badminton performance test, it is possible therefore that blood glucose levels were increasing and beginning to stabilise at the time of the skills test but still remained suppressed for HGI trial compared to LGI trial. Blood glucose concentrations taken following the skills test (Table 8, Glucose sample 5) would suggest that blood glucose concentrations was increasing in the HGI trial from 3.38 ± 0.38 mmol prior to the skills test to 4.18 ± 0.42 mmol following skills test but remained stable during the LGI trial from 5.25 ± 0.83 mmol prior to skills test to 4.95 ± 0.92 mmol following skills test. Perhaps if the skills test was carried out prior to the multistage fitness and simulated badminton performance test and again after, we could have more accurately assessed the impact of any reduction in blood glucose at the onset of exercise on skill maintenance.

Deterioration in skill is also linked to depletion of muscle glycogen stores (Meeusen et al., 2006; Ostojic & Mazic, 2002). In the present study the lack of a significant difference between trials for the skills test may be due to no significant deterioration in muscle glycogen stores occurring as a result of performing the exercise performance tests. Fatigue is associated with a concurrent reduction in exercise performance and skill maintenance (Davey et al., 2002). Fatigue during high intensity intermittent exercise, has been associated with the depletion of muscle glycogen, reductions in circulating blood glucose, hyperthermia and progressive loss of body fluids (Meeusen et al., 2006). Fatigue may be responsible for missed strokes, poor timing and an inability to cover the playing area efficiently and effectively (Davey et al., 2002). During the present study exercise duration coupled with the possibility of maintained concentrations of muscle glycogen and blood glucose may not have been sufficient for subjects to become sufficiently fatigued prior to performing the skills test.

Hypoglycaemia has been associated with reductions in cognitive function (Gibson & Green, 2002). During the present study subjects were not hypoglycaemic but a reduction in blood glucose was observed in the HGI trial compared to LGI trial. If subjects were hypoglycaemic then a significant reduction in skill performance might have been reported during this present study. Dehydration has also been shown to negatively influence cognitive function. Deterioration in mental performance has been associated with a loss of hydration of just 2% (Bottoms et al., 2006). During the present study subjects were encouraged to drink water throughout each trial however the amount of water was not accurately measured during the trial. It is possible that the hydration status of individuals may have differed between trials.

During a crossover design study it is difficult to control motivational factors associated with the skills task (Zeederburg et al., 1996). During trials requiring high levels of attention and concentration like those required in the skills test in the present study it is difficult to measure the levels of attention each task received from subjects. From the subjects' standpoint there may have been limited motivational factors (i.e. what is in it for them?) associated with carrying out each task to the best of their ability. In other studies of cognitive function it has been observed that the more attractive the task is perceived as being the more attention that task receives (Collardeau et al., 2001). It is possible therefore that subjects may under a more controlled environment divert more attention to the skills task required. Perhaps the skills task could be made more attractive by having some form of reward for the individual who scored the most points during the skills test performed.

4.1 Limitations of the study

A limitation of this study is the lack of a fasting control condition. However, the benefits of CHO ingestion on exercise performance (DeMarco et al., 1999; Febbraio et al., 2000a; Guerra et al., 2004; Kirwan et al., 2001a; Kirwan et al., 1998; Thomas et al., 1991) and cognitive function are well documented (Benton & Parker, 1998; Bottoms et al., 2006; Collardeau et al., 2001; Gibson & Green, 2002; Winnick et al., 2005).

Subjects did not perform a familiarisation session prior to commencing the first experimental trial. Therefore it is impossible to rule out a potential learning effect between trials one and two. However, subjects on the present study would be used to performing similar tests as part of their own training regime as those performed in this study.

Difficulties in blood analysis were experienced throughout the present study perhaps this could have been overcome if blood analysis was carried out in a more controlled environment.

4.2 Conclusion

The nutritional and training status on an individual forms two vital components in sports performance. Nutrition is a fundamental component of success in sport. How an individual performs on the day of a competition itself can be determined by the nutritional strategy on the day (MacLaren, 1998). Badminton matches involve periods of high intensity activity, and successful performance during a game is dependent on a number of very significant factors, including technical, tactical, physical, physiological and mental skill (Meeusen et al., 2006). In sports such as badminton and other game sports requiring high levels of cognitive function combined with high intensity activity even small declines in mental performance can significantly influence the outcome of a game (Meeusen et al., 2006).

Current pre-exercise CHO recommendations in order to maximise muscle and liver glycogen storage is 3 to 5 g/kg of body mass where sufficient time, 3 to 4 hours, exists prior to exercise bout (McArdle, et al. 2006) or 1 g/kg of body mass for pre-exercise meal 1 hour prior to exercise (Bean, 2003). Ingestion of CHO in the hour prior to exercise may not represent the optimal nutritional strategy and preparation prior to exercise. It is however, not unusual for individuals to have their pre-exercise meal in the hour prior to exercise. Particularly during competition and tournament play it is also quite common for players to have an hour break in which time to take a meal on board.

The outcome of this present study suggests that the glycemic index of a meal ingested 60 minutes prior to exercise does not provide any performance advantage in aerobic performance and skill in badminton players. However the results during the skills test does lend some support to the potential beneficial effect of LGI meal ingested 60 minutes prior to exercise.

Additional work needs to be done to more fully understand the effects of a pre-exercise meal of differing glycemic indices on aerobic performance and skill maintenance in games requiring high degrees of cognitive and motor skills. Further research needs to be carried out in a controlled laboratory environment where the research is designed to more accurately reflect the actual physical and mental requirements of the sport.