

The Effects of Macronutrients on Performance and Recovery in Intermittent Sports

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Intermittent sports include running at various speeds, along with a few seconds of active rest for the duration of the game. Soccer demands high levels of consistent performances across a large number of matches in a year. Nutrition strategies can prove to be beneficial when implemented and used as ergogenic aids to enhance performance and recovery. Macronutrient intake before, during, and after exercise can affect performance and recovery. Nutrition plays a special role in providing adequate energy requirements to ensure optimal performance and efficient recovery in between matches and training sessions. The physiology of the sport includes walking, jogging, and similar low-intensity motions for the majority of the game, combined with explosive movements such as sprinting, change of direction, tackling, and jumping. The average intensity of the match requires 70-75% of VO<sub>2</sub> max, whilst maximum energy demands arise from actions mentioned above along with performing soccer-specific technical aspects such as shooting, passing, and dribbling (Goedecke et.al., 2013).

The most basic strategy in terms of providing fuel for performance is to focus on high-carbohydrate meals on and before match days, and carbohydrate supplements before kick-off. This review summarizes the strategies and research carried out by Andreson et.al. (2016, 2017) on carbohydrate periodization, which educates about the importance of carbohydrate inclusion days before, and after matches in professional players. Whether these meals should be carbohydrate dense, or an evenly distributed mixed macronutrient meal has also been assessed in research by Wynne et.al. (2021). Ideal recommendations for carbohydrate solutions consumed pre, during, and post-matches include consuming a beverage or gel form of carbohydrate at a 6-8% concentration. However, studies carried out by a few authors have gone beyond such numbers to test how beneficial it would be to increase the percentage of concentration and manage to take performance to the next level. According to Gutierrez et. al.

(2012), players might require different amounts of energy intake based on the position they play. Goalkeepers compared to outfield players do not require much running. Similarly, a midfielder has more ground to cover compared to a wide attacking or defensive player.

Consuming carbohydrates as an ergogenic aid is widely used as a strategy, with the concentration of ingestion varying based on individual strategies. However, studies have shown results where combining carbohydrates with other substances such as caffeine, protein, L glutamine, and L carnitine might or might not be beneficial compared to consuming carbohydrates only.

Amino acids assist with muscle damage regeneration and can prove to be very effective when used as a recovery strategy for soccer players. Research conducted by Abbott et.al. (2019) showed how consuming casein protein 30 minutes before bed can enhance recovery by expediting protein synthesis. Similarly, Poulouis et.al. (2018) demonstrated results where high amounts of protein consumed right after a match might speed up recovery by attenuating neuromuscular fatigue. The effects of whey protein compared to soy protein were also examined in a study by Kritikos et.al. (2021) which found not many differences between the two, however, did manage to prove the positive effects of protein on recovery kinetics. This paper also reviews the effects of combining fish oil with whey protein, leucine, and carbohydrates on recovery from eccentric muscle damage showing promising results on perceived muscle soreness.

The purpose of this literature review is to understand the effects of carbohydrates and protein, on performance enhancement and recovery strategies in soccer players. To gauge an understanding of periodization, what carbohydrate percentages work best, and what nutrient combinations with carbohydrates prove to be most beneficial. The paper will also present research on protein consumption and its effects on recovery. Studies reviewed concentrate

mainly on soccer, however, the findings could be applied to different intermittent sports such as basketball, American football, lacrosse, and rugby.

Muscle glycogen is a predominant source of energy in soccer. Subsequently, nutritional recommendations for optimizing match performance include high carbohydrate availability before, during, and post-matches. However, the intensity of games varies from that of training sessions. Anderson et.al. (2016) conducted a study to quantify training and match physical loads over three separate game weeks in professional outfield soccer players in the English Premier League. Twelve outfield players were included in the study, which included every position on the field. The data was collected over three different seven-day periods. Each period varied in how many games were played during that week, including one, two, and three-game weeks. Each week included training sessions and recovery sessions based on how many games were played. The results of this study found that there was clear evidence of training periodization that took place in all three trials. In one and two game weeks, periodization of training loads took place where intensity dropped in terms of total distance and average speed in days approaching each game (Anderson et.al. 2016). However, the three-game weeks only included two training sessions since the number of games being played was high and the main priority was recovery. The total weekly load was higher in the two and three-game weeks compared to one-game weeks. Periodization of carbohydrates here becomes essential to quantify carbohydrates being consumed and manipulate it as per energy needs and amount of glycogen replenishment required based on physical loads. With this evidence of training periodization, it gives reason to implement nutritional periodization as well. Periodization for carbohydrates can be administered in a manner wherein high amounts of carbohydrates (6-10g.kg) are available on the day before a game, on the game day, and a few meals following the game to replenish glycogen stores

(Anderson et.al. 2016). However, carbohydrate availability in such bulk might not be necessary on training days (4-5g.kg) since the physical load and demands are much lower compared to game days (Anderson et.al., 2016). Limitations here are the population size, and that it was performed on just a single professional club in the English Premier League.

Based on the results obtained from the aforementioned study, Anderson et.al. conducted another research in 2017, intending to quantify energy intake with regards to energy expenditure in six male professional soccer players from a team in the English Premier League. A seven-day in-season period was studied, which consisted of two match days and five training sessions. Total distance, duration, and average speed were used as variables to analyze training and match data. Energy expenditure was estimated using the Doubly Labeled Water (DLW) method, for which participants orally ingested a solution consisting of isotopes of hydrogen and oxygen in large atomic quantities. To analyze the results of this method, urine was collected daily and vacuum distilled. For energy intake, players recorded a seven-day food diary. Anderson et.al. (2017), showed that energy intake according to body mass was different on game days (3789 kcal) compared to training days (2959 kcal). Carbohydrate consumption on game days was higher (508g, 6.4g.kg) compared to that on training days (330g, 4.2g.kg). The data displayed in the study showed that professional players tend to consume anywhere between 3000-4500 kcal per day. With this quantity of energy intake, carbohydrate periodization was evident where the intake was higher on match days compared to training days. The findings also showed that two of the six participants reported higher carbohydrate intake during match play compared to the rest of the participants. The two who reported such high values happened to be midfielders who tend to endure the maximum amount of physical load in terms of distance covered in matches. In light of this evidence of carbohydrate periodization which was in line with the findings of training load

periodization by Anderson et.al. (2016), carbohydrate intake was still below the recommended value for when players are competing in two games per week (Anderson et.al., 2017). The limitations of this study are similar to the previous one reviewed.

Past studies have shown that in soccer, different positions demand a different level of physicality, athleticism, and agility. Fullbacks, wingers, and midfielders have a higher aerobic demand, whereas the work rate profiles of goalkeepers, center-backs, and forwards include more anaerobic qualities. Iglesias- Gutierrez et.al. (2012) carried out an evaluation study to understand the eating patterns of young high-level soccer players according to the position they play. Eighty-seven male soccer players from the first-division Spanish league were part of this study. Players from all positions were included in the study (goalkeepers 12, midfielders, 24, full-backs 12, center backs 15, forwards 12, and wingers 12). Sprint performance over 10,20, and 30m, countermovement jump height, and the Yo-Yo test for intermittent endurance were used to evaluate overall physical performance. Diet was analyzed over a six-day period where players recorded their daily intake, and were asked to maintain normal eating habits without altering them. Performance-based results as per Iglesias-Gutierrez et.al. (2012) were in agreement with past studies which showed that fullbacks, midfielders, and wingers had the highest intermittent capacity as compared to goalkeepers and center-backs. However, goalkeepers and center-backs had higher results in jumping ability which was also significantly higher than midfielders. As for dietary intake, Iglesias-Gutierrez et.al. (2012) showed that carbohydrate consumption was below recommended levels for most players, and they also reported higher than recommended protein and fat intake. However, as per positional differences, carbohydrate intake in goalkeepers was significantly lower as compared to all outfield players (3.9g.kg), which can be explained by the lower physiological demands of their position. Center backs reported the second lowest

carbohydrate intake (4.3g.kg) compared to midfielders, wingers, and fullbacks. Midfielders, wingers, and fullbacks all had similar carbohydrate intake (4.9g.kg), along with the highest aerobic intermittent capacity hence explaining the correlation between position and consumption. Forwards reported the second highest carbohydrate intake (4.6g.kg). The carbohydrate intake as reported was coordinated with the results in workload as per previous studies and the tests carried out in this study as well. Although carbohydrate intake reported was lower than recommended values, there were no complaints of underperforming players during training or matches by the coaching staff (Iglesias-Gutierrez et.al., 2012). Future research could include implementing a revised diet plan for a few weeks which would include higher amounts of carbohydrate intake to test for any performance improvements. Limitations here could be the fact that the players might have either under-reported or over-reported values being consumed and that the entire study was not purely in the control of the researchers.

Studies have been carried out to test the efficacy of carbohydrates on performance by combining carbohydrates with other nutrients to understand their effects and whether they can be more beneficial than consuming carbohydrates just by itself. Highton et.al (2013) conducted a study to compare the effects of carbohydrate-protein co-ingestion to that of carbohydrates only on the performance of multiple-sprint sports. Nine male college-level athletes were tested, of which seven were soccer players and two were rugby players. The athletes completed two modified Loughborough Intermittent Shuttle Tests (LISTs ) separated by a week, where they consumed either a 6% carbohydrate plus 2% whey protein beverage (P-CHO), or an 8% carbohydrate-only beverage (CHO). The entire test was about ninety minutes. Part A of the test lasted for an hour and was a simulated LIST where participants engaged in intermittent exercise, paced by a beep. Part B lasted thirty minutes where the test was no longer simulated by a beep

and was to be replicated by the athlete itself. Beverages were consumed thirty minutes before the test and at every 15-minute mark of the test. The beverages were altered as per energy needs to remove any possibility where any of the athletes have more or less to drink to avoid depletion or access availability. Highton et.al. (2013) showed that the distance covered in the last fifteen minutes of the test was significantly lower than the first fifteen minutes, in both trials. Maximal speed also reduced after the 45-minute mark but did not change due to beverage consumption. However, the average speed and average distance covered in the last 15 minutes were significantly lower than the first 15 minutes in the CHO group compared to P-CHO. P-CHO consumption showed small benefits in cruising and sprinting speeds. Rates of perceived exertion were reported as similar in both groups, however, the P-CHO group was working at a higher intensity but still reported the same rates of perceived exertion as the CHO group. According to Highton et. al. (2013), a higher plasma urea concentration was found in the P-CHO group at the 60 minute mark which signified the use of amino acids for oxidation and energy increments in the form of increased adenosine triphosphate availability. Once the carbohydrates were used up, extra energy was readily available from the protein source. Limitations pertain to sample size.

Naclerio et.al. (2015) carried out a study including a multi-ingredient beverage (MTN) containing protein (14.5g), carbohydrates (53g), L glutamine (5g), and L carnitine 91.5g). The study aimed to examine the effects of an MTN beverage versus a 69.5g carbohydrate-only (CHO) and placebo beverage on sprint performance, rate of perceived exertion, muscle damage, temporary immune dysfunction, and recovery from intermittent exercise after 24 hours. Sixteen amateur soccer players made up the population for this study. Participants engaged in the intermittent repeated sprint test (IRST) which was a modified version of the Loughborough intermittent shuttle test (LIST), and lasted 90 minutes to simulate the physical load of a soccer

match. The IRST was divided into four blocks, each separated by a three-minute rest period. A 15m sprint test was carried out before the start of the IRST, right after the IRST, an hour, and 24 hours after the IRST. All participants were asked to maintain normal dietary habits, except for the trial day where a standardized meal was provided. The MTN was a 500ml beverage, evenly divided into four parts, consumed before each block of the IRST, and likewise for the CHO and placebo beverage. A second 500ml dose was provided 20 minutes after the IRST. Naclerio et.al. (2015) showed that the supplement had no ergogenic effect on performance. The MTN had no effective attenuation for the reduction of sprint performance. However, it alleviated the perception of fatigue toward the end of the 90-minute IRST. The addition of L glutamine and L carnitine did not seem to have any added effect on IRST performance compared to CHO or placebo. Limitation includes the timing concerning L carnitine consumption. L carnitine tends to show its effects around 3-6 hours post-consumption (Naclerio et.al., 2015), however, in this study, it was consumed right before and during the test which could have played a role in the results obtained.

Kingsley et.al. conducted research in 2014 which tested the efficacy of combining caffeine with a higher percentage concentration of carbohydrates in a gel form. This study aimed to determine whether a 9.6% carbohydrate-caffeine-electrolyte solution would elevate blood glucose levels throughout the soccer-specific exercise and enhance performance. Fourteen recreational soccer players made up the population for this study, where they took part in three trials in the form of a simulated soccer match which tested each treatment drink separated by seven days each. The simulated match consisted of intermittent free running activity combined with ball skills such as dribbling, passing, and shooting. The total work time was 90 minutes, split into two 45-minute halves separated by a 15-minute rest period. Throughout the trial,

participants either received a 9.6% carbohydrate-caffeine-electrolyte beverage (H-CHO), a 5.6% carbohydrate-electrolyte beverage (CHO), or a placebo plain electrolyte beverage (PL). Kingsley et.al. (2014) showed that both H-CHO and CHO increased blood glucose, heart rate, and sprint performance toward the end of the session. However, the H-CHO had higher numbers in all these realms compared to CHO, which showed that the caffeine intake had assisted to enhance the already evident effects seen in the CHO group. H-CHO improved sprint performance by 3% compared to PL. Absorption of carbohydrates in the intestinal lumen is seen as the main rate-limiting factor for the oxidation of carbohydrates during exercise (Kingsley et.al., 2014). The carbohydrate gels contain a higher amount of carbohydrates which consequently allows for more digestion of carbohydrates. Adding caffeine to the formula enhances the rate of carbohydrate oxidation hence showing better results. Blood glucose levels dropped in all groups at the 60-minute mark and 57% of participants showed hypoglycemic values. Limitations could be the population size, and quality of players since they were recreational and not professional.

The glycemic index refers to the rate at which carbohydrates break down in the bloodstream to be readily available as glucose for absorption and usage. The common notion for pre-game and mid-game “energy” boosting snacks usually are nutrition bars that tend to have a high glycemic index (GI), which means they release glucose in the bloodstream much quicker as compared to a lentil-based nutrition bar which has a relatively lower glycemic index. A study carried out by Kaviani et.al. in 2020 tested this very concept of the significance of GI in nutrition bars consumed before and mid-game. This study aimed to gauge the effects of low and high GI nutrition bars on metabolism and performance during soccer-specific tests when consumed before and halfway through the test. Low GI has a lower insulinemic response. Insulin inhibits fat oxidation and promotes muscles to use up glucose from the bloodstream. A lower

insulinemic response would urge fat oxidation for energy provision and allow for potential glycogen sparing. Eight recreational male soccer players participated in this study. Plasma glucose and insulin, and carbohydrate and fat oxidation were assessed before and during the test. The trial was a combination of running at varying paces alternating with soccer-specific skills assessed such as shooting, dribbling, and heading. The total test time was 90 minutes simulating a soccer match. Two hours before the trial participants were given a Cliff Bar (GI was 101) for one trial, and a low GI lentil-based bar by Genki Foods (GI was 45) for the other trial. Bars were consumed at a quantity where each participant was consuming 1.5g.kg of carbohydrates. At half time they consumed bars at a quantity of 0.38g/kg of carbohydrates. Kaviani et.al. (2020) found that there was a significant difference in jump height for heading and agility seen after the 70th minute after consuming the low GI bars compared to the high GI bars. There was no significant difference between the two conditions in terms of dribbling and shooting performance. However, even though the positive result was seen around the 70-minute mark, it did not last until the 90-minute mark and glycogen depletion was equal enough at the end to affect performance in both conditions. Glucose concentration was higher in the high GI bars in the first 60 minutes but also had a higher insulin response compared to the low GI. The higher insulin response inhibits fat usage for energy and promotes more carbohydrate usage which leads to more glycogen uptake. On the other hand, a slower rate of carbohydrate oxidation as seen in the low GI bars assisted in more glycogen sparing instead of rapidly using up all glycogen stores because of the lower insulinemic response and more promotion of fat oxidation. This might have caused the performance increments later in the game as mentioned above (Kaviani et.al., 2020). A limitation of this study pertained to its sample size and that the game was simulated and not played out.

Also, the fact that participants showed up on a 12-hour fast does not simulate optimum conditions for a soccer game.

The recommended percentage for concentration of carbohydrates in a beverage form before, and during exercise is between 6-8%. Moving forward with this concept, the following studies have been conducted to test similar concentrations, as well as higher ones. In 2017, Harper et.al. carried out research where a 12% carbohydrate-electrolyte solution delivering 60g of carbohydrates consumed before and halfway through a simulated soccer match was tested. Fifteen male university-level soccer players were the samples of this study who underwent three trials, of a 12% sucrose-based carbohydrate beverage (CHO), placebo (PL) which was an electrolyte beverage, and water (WAT). The night before each trial all participants consumed the same meal which was carbohydrate dominant, and consumed a standardized breakfast upon arrival for testing. The players took part in a 90-minute simulated soccer match. Of the 90 minutes, 40 minutes were to be carried out at a self-pace, where players had to try and replicate the pace without a beep. Countermovement jump height was also assessed before and after the test. The CHO beverage was a 12% carbohydrate-electrolyte solution and was a 500ml drink, half of which was consumed 15 minutes before the test and the other half during the 15-minute rest period in between. Harper et.al. (2017) showed that compared to PL, CHO showed higher blood glucose values just before the start of exercise, at half-time, and at the 75-minute mark. CHO showed a 27% drop in blood glucose values at the 60-minute mark but was still higher than the PL values. There were no significant differences seen between PL and WAT. Sprint speed dropped as the trial went on, however, the 15m sprints had the highest values in CHO. PL showed better results for sprints across 15m compared to WAT. Countermovement jump height was unaffected across all trials. Carbohydrate ingestion positively affected dribbling precision

and speed and also enhanced the self-paced performance of the trial comparatively. However, the drop in blood glucose at the 60-minute mark still exists as seen in other studies as well, and could not be tackled despite increasing the concentration of carbohydrates. Limitations include a small sample size and the fact that the game was simulated. It could also be more beneficial if instead of having a placebo and water trial, one of those could be a lesser percentage of carbohydrates to understand the effects of a higher versus lower concentration of carbohydrates in the same study.

Staying within the recommended values, Goedecke et.al. carried out a study in 2013 to evaluate whether consuming a 700ml carbohydrate solution (CHO) with a concentration of 7% before and during the Loughborough Intermittent Shuttle Test (LIST) would improve agility and time to fatigue in soccer players who had normal pre-match meals. Twenty- two male soccer players made up the sample size. They underwent two trials, that of CHO and a 0% placebo (PL). Each participant consumed 700ml of a sucrose-based commercially available drink. A bulk of it was consumed before the test (250ml), and the rest every 15 minutes into the test. The solution delivered 49g of carbohydrates. Goedecke et.al. (2013) showed that rate of perceived exertion (RPE) increased with every 15-minute bout of the test, and there was no significant difference between the CHO and PL trials in regards to RPE. Agility was tested before and after the LIST using the Illinois agility test, and there were no significant differences between agility and time to fatigue between the CHO and PL trials. However, the authors discovered that players with a lighter body weight tended to benefit more from CHO consumption compared to heavier ones. Limitations here regard to the fact that the match was simulated and not played out. Pre-match meals were also different for the players and were not administered which could have influenced performance. Players varied in fitness and body mass which increased variability in

results but even after adjusting the results for individual body mass and size, there were not many differences between the two trials.

In a study conducted by Russell et.al. (2011), results reported that blood glucose concentrations dropped during soccer-specific activity right after the halftime break following the first 45 minutes of exercise while players ingested a CHO solution during the test. Diminishing levels of glucose can adversely affect motor skills and cognitive ability which are essential for peak performance. Thereafter, Russell et.al. carried out a study in 2014 study intending to understand the metabolic responses of carbohydrate ingestion before and during a game of soccer. Ten male players made up the population for this study. Participants were put through two separate trials, that of a 6% sucrose-based carbohydrate solution (CHO), and a placebo (PL). The participants played two matches against another team that was not part of the test. The matches were 90 minutes long with a 15-minute half-time period in between. Two hours before the games the participants received a standardized meal which was carbohydrate dominant, along with 500ml of the treatment beverage. Thereafter they consumed the respective beverage 10 minutes before the start of each half and at every 15-minute mark during the game at a rate of 14 ml. kg. Results of this study showed that CHO had a 30% higher concentration of blood glucose in the first half. However, reductions in glucose levels were observed in both trials after the halftime break. The passive halftime rest period caused a 30% reduction in blood glucose right after play resumed in both trials and thereafter showed no difference in trials. Russell et.al. (2014) explains the physiology that in non-exercising conditions, the body responds to ingesting carbohydrates by increasing the synthesis and secretion of insulin. Insulin as a result inhibits lipolysis and increases glucose uptake in the liver, and muscles. On the other hand hormones such as cortisol and growth hormone, and catecholamines including epinephrine and

norepinephrine are secreted during high-intensity exercises which induce hyperglycemic responses. The effects of epinephrine were seen in the first half as it stimulated glycogenolysis (breakdown of glycogen to glucose for energy usage), increased liver glucose secretion, and decreased insulin production which explains the higher glucose concentrations in CHO until the 30-45 minute mark. Now, since the body was in a non-exercising state after the first 45 minutes, carbohydrate consumption induced insulin secretion as explained above. This increased glucose uptake by the muscles and liver and lowered catecholamine concentrations which reduced liver glycogenolysis causing a reduction in blood glucose concentrations after the start of the second half. The study, therefore, concluded that even though carbohydrate consumption has a positive effect on blood glucose in the first period of soccer match play, a steep drop is seen at the start of the second half and no significant increase develops in blood glucose thereafter. Blood glucose levels being immensely important for peak performance, it was suggested that more effective strategies should be implemented to curb this drop in blood glucose once play is resumed.

Russell et.al. conducted another similar study in 2012 using the same 6% sucrose-based carbohydrate solution on 15 male academy players who this time took part in a simulated soccer match for 90 minutes. The aim was to evaluate the effect of this solution on the soccer-specific skills of the players with the ball (shooting, passing, dribbling), assessed before and after the test. Consumption of the treatment drinks for both trials was in a similar fashion to the aforementioned study. The results showed that shooting precision and the success rate was unaffected by supplementation, however, shot power impairment as exercise progressed was attenuated in CHO, and was higher than PL by 9.7%. Passing precision and success rate remained unaffected in both trials. Dribbling precision and success rate also were unaffected by supplementation. Blood glucose levels were elevated until the first 45 minutes, and similar to the

findings from the aforementioned Russell et.al. (2014), glucose levels plummeted after the onset of the second half, around the 60th minute. Overall, only shooting power and performance was affected positively. The limitations of both studies were the sample sizes.

Foskett et.al. (2008) conducted a study testing the efficacy of a carbohydrate solution on performance and muscle glycogen during intermittent high-intensity exercise, in men who were already carbohydrate-loading in the 48 hours preceding the test. Two trials were carried out, one was a placebo (PL), and the other was a 6.4% maltodextrin carbohydrate solution (CHO). Six recreationally active young men were used as sample subjects. Forty- eight hours before the test they underwent a 90-minute intermittent shuttle run exercise with the purpose of glycogen depletion. Following that they were put on a high carbohydrate diet, including 10g.kg of carbohydrate which accounted for 70% of their diet. Protein made up 15% (2g.kg), and the rest was fat. Participants consumed the prescribed solution 10 minutes before the trials. The subjects then ran through the LIST test for 90 minutes, with a 3-minute rest every 15 minutes. After the 90 minutes, there was a 3-minute rest and they were to continue running the LIST, this time until fatigue with no breaks in between. Results of this study showed that all participants managed to run for longer in the CHO trial compared to the PL. Duration until fatigue was on average 158 minutes for CHO and 131 minutes for PL, representing a 21% increase in intermittent endurance (Foskett et.al., 2008). There were no significant differences in muscle glycogen concentration levels between both trials. Plasma glucose levels were within the normal range throughout the entire test, however, the levels were higher in CHO after the completion of the trial compared to PL. Insulin levels were significantly higher in CHO at all times. There were no differences between rates of perceived exertion between trials. It was concluded that after following a carbohydrate-rich diet, a 6.4% CHO solution has a greater effect on intermittent endurance

capacity (approximately 21%), but does not affect muscle glycogen use. Limitations here are the participant sample size. Participants were also asked to arrive for trials on a 12-hour fast which could have affected results.

Recently, Wynne et. al. conducted research in 2021 comparing high carbohydrate meals to mixed macronutrient meals. This study aimed to compare the effects of pre-exercise meals with different macronutrient contents on performance and physiological responses in female soccer players. Two trials were carried out using 21 female college athletes who were part of the same collegiate team. The two trials were that of a high carbohydrate meal (HCHO) and a mixed macronutrient meal (MM), consumed 4 hours before a scrimmage. The HCHO meal consisted of 203g carbohydrates, 21g protein, and 12g fat. The MM meal consisted of 103g CHO, 52g protein, and 48.5g fat. Two 35-minute halves were played amongst this team and no energy drinks were permitted before and during the trial. Wynne et.al. (2021) showed no significant differences in terms of RPE between the two trials. The results overall showed no significant difference in terms of fatigue, and in both trials, the distance traveled and performance did not differ significantly. It was concluded that a MM meal elicits the same benefits as an HCHO meal, with the only difference being that the MM meal provided a higher feeling of satiety as compared to the HCHO meal. The limitations were the sample size. Participants were also not observed in the time leading up to the scrimmage. There could have been players who did not finish the entire meal provided and might have eaten something after the meals and before the game as well. The games were also 70 minutes long which does not replicate a soccer game. On the other hand, Souglis et.al. (2013) conducted a study where 22 male professional players played two games (90 mins) on separate occasions, which found opposing results to Wynne et.al. (2021). They were split up into teams A and B. Three days

before the first game, team A consumed 8g.kg worth of carbohydrates whereas team B consumed 3g.kg of carbohydrates for those three days. For the second game, team B received the high carbohydrate diet, and team A was on the lower end. It was a short-term diet followed three days before game day. Souglis et.al. (2013) showed that whichever team consumed the high carbohydrate meal won when the match was played. Subjects that consumed the high carbohydrate meals also ended up covering a much higher distance of 1.3km on average, which showed a 17% difference both times. The limitation here could be the sample size.

Intense performance demands of a 90-minute soccer match can cause a lot of muscular fiber damage leading to soreness and inflammatory responses in the hours following a game. Professional athletes have to play in 1-2 matches per week along with training sessions, and for them to be healthy for peak performance, recovery is very essential. Consuming the right amount of protein can be implemented as a strategy to potentially attenuate soreness, and expedite the recovery process of muscles before the next game, especially when hours between two games are limited. Poulios et.al. carried out a study in 2018 to investigate the effects of increased protein intake on inflammatory and performance recovery mechanisms in response to games played 3 days apart. Over two trials, 20 players took part in the study, each trial lasting one week long. The trial included 2 game days separated by 3 days and 4 training days. Testing for performance measurements (10,20,30m sprint, countermovement jump height, concentric and eccentric peak torque of knee extensors and flexors, and delayed onset of muscle soreness (DOMS) took place on all days of the week except for game days. Throughout both trials, participants followed a protein intake of 1g/kg/day through daily dietary foods. In the first trial, participants received a milk protein-based supplement on match days consumed at three intervals after the game (PRO). The first was consumed right after the game ended (25g), the second was 3 hours later (30g), and

the third was another three hours later (25g). This took the total protein intake on game days to 2.35g/kg once the drinks were consumed. The protein split was 80% casein and 20% whey. On training days they received a similar protein drink supplying 20g of protein with breakfast, taking the total intake to 1.5g/kg. The other trial was a placebo (PLA) where all procedures were the same except instead of protein, it was a carbohydrate-dense drink of maltodextrin concentrate which increased the total carbohydrate intake instead (8.11g/kg on game days and 5.44g/kg on training days). The increased amount of total daily protein intake consumed in the pattern followed by this study has been proven to be effective in stimulating protein synthesis according to Areta et.al. (2013), and Moore et.al. (2012). Poullois et.al. (2018) showed improved results in PRO compared to PLA. The principal results suggested that increased protein intake, especially after the first game tends to enhance football locomotor activity in the second game. It prevents a decline in knee extension and flexion torque during recovery and may promote antioxidant protection after the second game. Total distance covered and average heart rate remained unchanged in the two games played during the PRO trial which supports the finding of attenuation in the decline of locomotor activity. High-intensity running actions also did not drop in PRO in the last fifteen minutes of each half in the second game which suggests increased resistance to fatigue. Overall, PRO improved neuromuscular performance and skeletal muscle healing and attenuated an inflammatory response showing a result of decreased DOMS in PRO. A protein-induced anti-inflammatory response can be seen as the driving factor behind improvement in performance recovery. Limitations pertain to the small sample size. The results as explained in the study come across as overly complicated when comparing both trials. The results were too driven by statistics, did not provide much definitive comparison between the two trials, and were rather vague.

Abbott et.al. (2019) conducted research to determine the effects of casein protein ingestion on recovery mechanisms in professional soccer players when consumed half an hour before bed. Ten male soccer players made up the population for this study. Two trials were conducted, where after a night match, players consumed either 40 grams worth of casein protein (CP), or a carbohydrate control (CON) 30 minutes before going to bed. Muscle soreness (MS), countermovement jump height (CMJ), and reactive strength index (RSI) were measured at baseline. These measurements were thereafter taken at 12, 36, and 60 hours after each match. Abbott et al. (2019) showed that casein protein had a positive effect on muscle protein synthesis and time to recovery. Results indicated that overnight muscle protein synthesis increased by 22%. CMJ height had returned to pre-match baseline by 36 hours in CP whilst for the CON group it remained under baseline at the 60-hour mark. For RSI, changes were significant at the 12 and 36-hour mark with the CP group showing better results as compared to CON. In muscle soreness, both groups went through their peaks at the 12-hour mark, however, the CON group had higher values at the peak compared to CP at the 12-hour mark. Differences at the 36 and 60-hour mark were moderately small but CP showed better results here as well in terms of how severe the soreness was. The findings in this study showed that consuming 40 grams worth of CP before sleep enhanced overnight muscle protein synthesis in the first 36 hours following a soccer match played at night. Deficits in muscle function were brought back to pregame fitness levels or baseline at a more accelerated rate. The authors of this study believed it could be possible for this to have happened because CP had added to the total protein intake in the 24 hours of that day which enhanced muscle synthesis. This could imply that the 40 grams could be consumed in any manner of protein and not necessarily by just CP, suggesting for more research to be done to determine the effectiveness of casein protein specifically, and the timing of consumption as well.

Limitations here could be sample size and number of trials, perhaps testing this after more than just two matches could have provided more of an understanding of CP and its effectiveness.

The primary differentiating factor between whey protein and soy protein is that the former is an animal-based protein and the latter plant-based. Kritikos et.al. (2021) conducted a research study to investigate if protein supplementation can alleviate muscle damage following speed-endurance training to enhance performance recovery in soccer players. Along with this, determining the effects of soy protein (SP) compared to whey protein (WP) was also administered. It was hypothesized that WP would show slightly better results due to its higher leucine contents. Ten well-trained male soccer players were put through three different trials (WP, SP, Placebo). Each trial included a one-week adaptive period (days 1-7), where they followed a dietary plan providing 0.8-1g/kg/day of protein from food sources only. Following this was the second week (days 8-14) where participants consumed either a placebo or protein supplements based on the trial. This took the total protein intake to 1.5g/kg/day. Thereafter, on days 15 and 17, participants took part in a speed-endurance training session, and day 16 was a rest day, allowing for 48 hours of recovery between sessions. The same diet and supplementation protocol was followed during these days as in the past two weeks. Supplement drinks were consumed right after the sessions. The speed-endurance sessions were 60 minutes long. It incorporated a total of eight 30-second maximum intensity sprints separated by 2.5 minutes of rest between each 30-second burst. Soccer-specific drills were carried out as well. Kritikos et.al. (2021) showed that even though speed-endurance performance reduced in terms of maximum speed from session one to two in all trials, WP and SP showed a smaller magnitude of decline (by 2.3%) as compared to the placebo trial. Average speed also dropped in session two across all trials, but WP showed the highest average speed in session two by 5%. High-intensity running

also decreased in all trials in session two, with SP and WP significantly mitigating the decline. Acceleration declined similarly, but supplementation did not affect this factor. Speed over 10m was significantly lower than baseline at the 24-hour mark after session one only in the placebo by 6%, whereas 30m speed was lower in placebo, SP, and WP, by 5.2%, 3.9%, and 3.2% respectively. Countermovement jump height decreased similarly in all trials at the 24-hour mark following session one. Therefore, it was concluded that supplementation by either whey or soy protein could facilitate performance recovery. The effect of supplementation could be seen as an anti-inflammatory prospect rather than the attenuation of exercise-induced muscle damage markers. Limitations here pertain to participant quantity. The players were also consuming much below the recommended value of protein intake (1.6-2.2g.kg recommended) for soccer athletes and athletes in general. During the adaptive period, it was only 0.8-1g/kg/day and, during the supplementation loading period in week two it was 1.5g/kg/day. A higher value of protein consumption could perhaps show a higher magnitude of results. Also, a 48-hour rest period is unlikely to be present in professional and semi-professional soccer schedules between games, hence a slightly longer rest period between the sessions, around 72 hours, would be more realistic.

N-3 PUFA stands for Omega 3 polyunsaturated fatty acids, and one of its principal functions is to aid with regulating inflammation. It enhances muscle anabolic sensitivity to an amino acid source. Leucine, on the other hand, a type of branched-chain amino acid or BCAA, performs functions such as regulating protein synthesis, tissue regeneration, and metabolism. Keeping in mind these specific functions, Philpott et.al. carried out a study in 2018 to understand the impact of adding N-3 PUFA fish oil to a whey protein, leucine, and carbohydrate supplement for six weeks on recovery from eccentric muscle damage. Thirty competitive male soccer players

received one of three supplement conditions, which were fish oil, plus whey, leucine, and carbohydrate (FO), a whey protein leucine and carbohydrate placebo (PRO), or a carbohydrate-only placebo (CHO). Participants consumed two 200 ml drinks daily during the six-week supplementation period. A normal diet routine was maintained. Following the supplementation period, participants reported to the testing site for experimental trials in a fasted state with no pre-exercise meal. On the second day of the visit, eccentric-based exercises were performed after baseline testing was done. Measurements of muscle soreness, muscle function via maximum voluntary contraction, blood markers of inflammation, and muscle damage were collected at every visit. Soccer-specific skills were tested at baseline on the second visit, and 24 and 72 hours after exercise using the Loughborough Soccer Passing Test (LSPT), which included completing a certain number of passes accurately, as quickly as possible. The Yo-Yo Intermittent Endurance Test was used to test anaerobic endurance. Supplementation was continued during the four days of the visit. Philpott et.al. (2018) showed that dominant and non-dominant legs had similar results in terms of soreness. At the 24, 48, and 72-hour mark, muscle soreness was lower in FO as compared to PRO and CHO. Over the entire 72-hour period, general soreness was 58% lower in FO compared to CHO. Performance on the LSPT and Yo-Yo test was not affected by supplementation after the 72-hour recovery period. Creatine kinase, which is a blood marker that indicates muscle damage was lower in FO compared to CHO. Overall, FO demonstrated a decrease in perceived feelings of muscle soreness and serum creatine kinase concentrations, but did not have an impact on the inflammatory response, nor did it enervate the decline in muscle function and soccer-specific performance during exercise recovery. The reduction in perceived muscle soreness by the addition of N3- PUFA however, did not translate into better maintenance of muscle function or soccer-specific performance. However, a limitation to there being no

concrete results in terms of soccer-specific performance could be because soccer-specific skills were not tested at the 48-hour mark when muscle soreness was at peak values. Hence posing a possibility that the researchers missed out on any benefits of FO on soccer-specific performance during peak muscle soreness.

Many studies apart from the ones reviewed above have been carried out along the same lines of performance enhancement and recovery expedition using different nutritional strategies. As expressed by Anderson et.al. (2016, 2017), periodization is a strategy used by professional players and is something that can be incorporated into the diet routines of athletes aspiring to enhance their performance and be consistent with it. Of the various combination strategies studied above, caffeine along with a higher concentration of carbohydrates proved to be beneficial in order to speed up carbohydrate oxidation and be more effective during the course of a game (Kinglsey et.al., 2014). Protein combinations with carbohydrates also showed positive results in improving multiple sprint performance (Highton et.al. 2013). However, the addition of L glutamine and L carnitine to this formula proved to be inconsequential, with limitations of this study playing a role in why L carnitine did not have any significant effect, given its benefits (Naclerio et.al., 2015). Iglesias-Gutierrez et.al. (2012) went on to evaluate the positional differences in soccer via physical load tests on the players. The authors found a positive correlation between positions that endure more running and physical load, and total energy and carbohydrate intake, even though the values were below the recommended values. This review also looked over different percentage concentrations of carbohydrates, ranging from 6-12%. All these studies had similar protocols in the fact that the match was either simulated, players either ran through an intermittent test, or played an actual game. However, almost all studies that had participants consume the solution or gel before and during the trials showed that blood glucose

levels dropped after the onset of the second half of playing time. Not even a concentration as high as 12% helped eradicate this phenomenon. The physiology behind this has been explained by Russell et.al (2014) previously in this paper. On the contrary, Foskett et.al. (2008) showed positive results and no drops in blood glucose levels using similar procedures. The major difference in this study existed where the participants were carbohydrate loading in the 48 hours before the testing, and on test day consumed a 6.4% carbohydrate solution. Wynne et.al. (2021) showed that there were no significant differences between consuming a mixed macronutrient meal compared to a high carbohydrate meal 4 hours before a game. However, Souglis et.al. (2013) showed opposing results when players consumed a high-carbohydrate diet for three days before the game. When used alongside carbohydrate loading, the strategy of carbohydrate solutions and beverages before and during games might be more beneficial. Nevertheless, it might be a point to consider that instead of carbohydrate gels and solutions, a low glycemic index nutrient or energy bar could be of more benefit to athletes. As shown by Kaviani et.al. (2020), compared to a higher glycemic index bar, lower indexes showed better agility and jumping performance toward the end of a game without compromising blood glucose at the start of the second half. In terms of protein for recovery, all studies reviewed above showed that protein does indeed assist in muscle soreness, recovery, and returning to match fitness at a quicker rate. Different types of protein such as whey, soy, casein, and leucine were reviewed. Similar to how carbohydrates were tested with other products in this review, protein was also combined with fish oil by Philpott et.al. (2018) which showed a very high magnitude of results in terms of mitigating muscle soreness, however, it did not translate to improved performance. Poulouis et.al. (2018) showed that higher protein consumption after games enervated inflammation and decreased DOMS. Similarly, Abbott et.al. (2019) showed that casein protein

consumption before bed enhanced overnight muscle protein synthesis by taking the total protein consumed to a higher amount on game days. Kritikos et.al. (2021) assessed that while there may not be many differences between whey and soy proteins, both these types of proteins show positive results on muscle tissue regeneration. However, limitations in this study such as lower than recommended values being consumed might have restricted a higher magnitude of results. This review showed that to see increments in performance, preparation in terms of diet needs to be an acute strategy. It cannot be given importance only on game days. It needs to be something followed in the days leading up to when one needs to be at their peak performance and reap the benefits of recovering at a much faster rate.

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