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SCHOLARLY REVIEW

Nutrition and Gaelic Football: Review, Recommendations, and Future Considerations

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Gaelic football is the second most popular team sport in Ireland in terms of participation. However, very little research exists on the nutritional considerations for elite male Gaelic footballers. Gaelic football is an intermittent type field game played by two teams of fifteen players. Although amateurs, elite players may train and compete 4–5 times per week and may play for several teams. Research suggests that elite footballers are similar anthropometrically and in fitness to professional soccer players. Work-rate analysis shows that footballers experience longer durations of high-intensity (HI) activity (5–7s) and shorter rest durations than soccer players. Recent data suggests that half-forward/backs perform a greater amount of HI work during games than players in other positions. Fatigue is apparent between the first and second halves and the first and fourth quarters. The limited amount of nutritional studies conducted implies that footballers may be deficient in energy intake and may be at the lower end of recommended carbohydrate intakes to support training. A wide variety of sweat rates have been measured during training, demonstrating the importance of individual hydration strategies. Ergogenic aids such as creatine and caffeine may prove beneficial to performance, although data are extrapolated from other sports. Due to the lack of research in Gaelic football, further population specific studies are required. Future areas of research on the impact of nutrition on Gaelic football performance are examined. In particular, the creation of a test protocol mimicking the activity patterns and intensity of a Gaelic football game is warranted.

Keywords: carbohydrate, protein, caffeine, creatine, energy intake.

Gaelic football is an intermittent type field game played by two teams of fifteen players. It is one of a family of sports indigenous to Ireland. The other sports include hurling, camogie, handball, and rounders. It is the second most popular team sport in Ireland, in terms of participation, after soccer (Irish Sports Council, 2011) and its rules and competitions are governed by the Gaelic Athletic Association (G.A.A.). The G.A.A. is an amateur organization, and at the elite level, football players represent their county. Intercounty games are often played in front of attendances of eighty thousand people and television pictures are broadcast around the world to the Irish diaspora.

Although an amateur sport, elite Gaelic footballers follow a quasi-professional training regimen. Players may be required to attend pitch-based sessions up to three times a week, gym-based resistance-training sessions twice a week, squad meetings and workshops. Traveling to and from and participating in competitive and friendly games can mean several hours travel to and from venues and overnight stays. All this must be balanced with the demands of their professional lives (work/study) and the obligations of their personal lives (relationships and family).

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Despite its popularity, there is very little scientific research into Gaelic football. In particular, the nutritional requirements of Gaelic footballers have received very little consideration. The purpose of this review is to assess the literature in the area, gain a clearer understanding of how nutrition might impact on different factors (e.g., type of training, game), and, due to the absence of specific research in the sport, offer recommendations for future research. This review will focus on elite male footballers due to the greater popularity of the male game compared with the female, and bias in published papers toward males. Papers were sourced on PubMed online search engine (http://www.ncbi.nlm.nih.gov/pubmed) using the following search query—"Gaelic football." Criteria for inclusion were: male participants; investigated at least one of the following: training, nutrition, anthropometry, fitness; reported anthropometric data. In addition, reference lists were studied to discover relevant papers not published in a journal (e.g., conference proceedings).

Rules

Football is played on a pitch of between 130–145m in length and 80–90 m in width (Gaelic Athletic Association, 2013), being approximately 40% larger in area than a soccer pitch. A typical formation is one goalkeeper, three fullbacks, three halfbacks, two midfielders, three half-forwards, and three full-forwards. The time limit for a senior intercounty league or championship game is two 35-min halves, with a 15-min interval. In all other adult games the playing time is two 30-min halves. Points are scored by putting the ball over the crossbar and between two posts (one point) or by scoring a goal by kicking the ball between the posts and under the crossbar (three points).

Competition Calendar

The two major competitions in elite male Gaelic football are the National League and the All-Ireland championship, with the championship considered the more prestigious. The league consists of four divisions, each containing eight teams, with promotion and relegation between divisions. Teams are guaranteed a fixed number of games in this format and the league typically runs from the beginning of February to mid-April. The All-Ireland championship runs from mid-May to mid-September. The time interval between competitive games in this competition differs depending on various factors, but can be as frequent as several consecutive weekends or as much as 6 weeks apart.

Elite underage players (U-21 or younger) may also compete for their university in the Sigerson Cup as well as competing in the All-Ireland under-21 championships. Dual players also exist who compete for their counties and/or universities in both football and hurling. Finally, all elite players compete with their club teams in intra-county and sometimes national competitions.

Training

There is scant peer reviewed scientific data available on the type of training performed by elite Gaelic footballers. Collins, Doran and Reilly (2011a) examined the effects of small sided games (SSG) (4 v 4; 6 × 4 min at performed at greater than 90% HR_{max}; 3 min active recovery between games) on a number of fitness parameters in seventeen club level players. After twenty sessions, significant improvements were seen in 5m sprint (1.14 ± 0.08 vs 1.08 ± 0.05 s; $p < .05$), three indices of repeated sprint ability ($p < .05$) and $\dot{V}O_2$max (56.9 ± 1.9 vs 59.4 ± 2.2 $mL.kg^{-1}.min^{-1}$; $p < .05$). A limitation of this study was that no control group was employed to determine if normal training would have had a similar effect.

King and O'Donoghue (2003) examined the effects of an 11-week periodized interval-training program on a variety of fitness parameters. Training progressed from aerobic training (20–30 min continuous running) at the beginning (weeks 1–3), to bursts of running ranging from 3–15 s duration with variable recovery times of 5–60 s (weeks 8–11). A control group continued with normal skill-based training at moderate intensity. The subjects in the experimental group demonstrated a greater improvement in performance in a multistage fitness test ($p < .05$), agility test ($p < .01$) and vertical jump (VJ) ($p < .05$) than the control group. Both groups showed significant improvements in 20m sprint performance ($p < .05$). It must be recognized that this study has major limitations. The subjects were members of an elite U-14 training squad. The authors acknowledge this when they state that psychological factors may have played a part in the improvements measured.

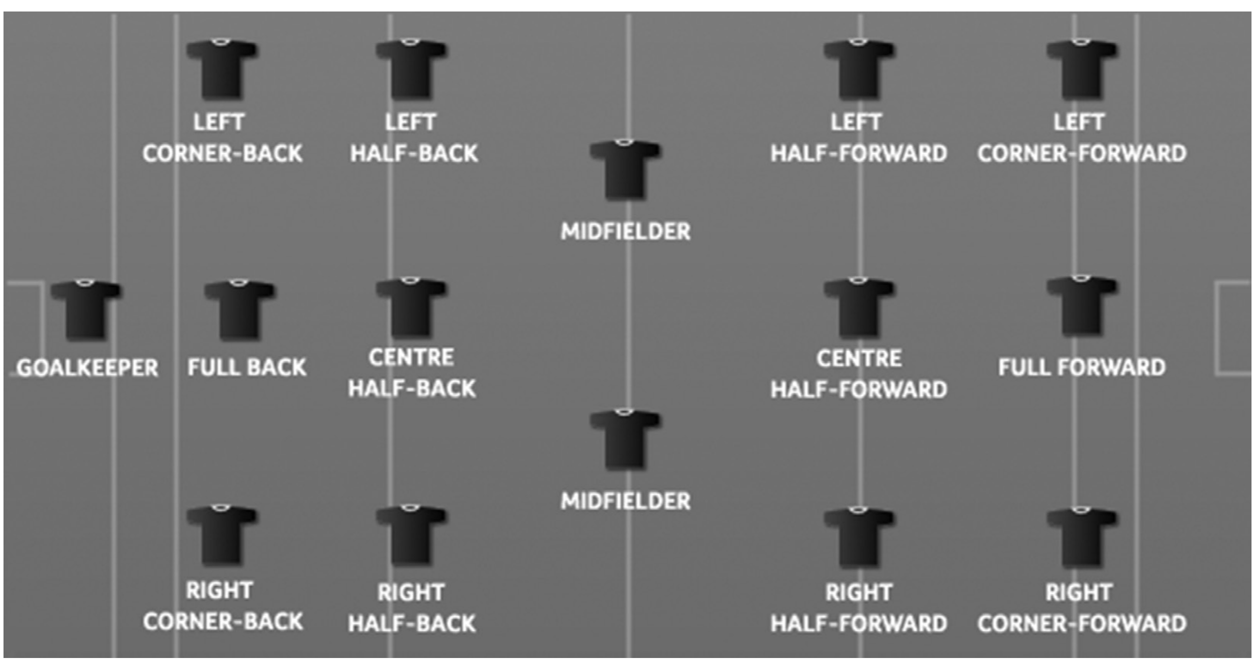

Figure 1 — Player Positions in Gaelic Football

Collins et al. (2013a) compared the effects of high-intensity interval training (HIIT) and normal training over an 8-week period. While the groups were matched by playing position, they were not matched by fitness such that the control group had significantly higher percentage body fat (%BF) and slower 5, 10, and 20m sprint times at the outset ($p < .05$). Nevertheless, there was no initial difference in the Yo-Yo Intermittent Recovery Test 2 (YYIRT2). After the 8-week training period, the experimental group showed a significantly greater improvement in performance in the YYIRT2 test compared with the control group (23 vs 9% respectively; $p < .05$).

Cregg et al. (2013) compared the effects of a 6-week (3 days/week) training program of either HIIT or high volume endurance training (HVET) on various fitness parameters. There was a significant and similar improvement in $\dot{V}O_2$max (7%) in both groups, with no changes in counter-movement jump (CMJ), CMJ flight time or 5m speed. The authors concluded that HIIT was a time efficient method of improving and maintaining fitness in Gaelic footballers.

The data presented suggests that elite Gaelic football teams may use SSG and HIIT interval sessions as a means of developing fitness over the course of a season. Notwithstanding the limitations of King and O'Donoghue (2003), their study suggests that elite teams may also employ a perioidized training paradigm, moving from developing a general aerobic base at the start of the season to more game specific movement patterns and exercise intensities later on. This is in line with the concept of periodization as outlined by Bompa (1999), who describes it as a framework for planned and systematic variation of training variables to reach a high level of performance at a given time in the year. Athletes should focus on developing general fitness at the start of the training year while improving skill-related aspects of performance as they move toward the competitive phase.

Reilly and Keane (2002a) examined the variations in the fitness of a successful intercounty team from January to September (i.e., a full season) at six discrete time intervals. They reported improvements in sprint time for 50, 100, 200, and 400m as well as a mean reduction in bodyweight of 3.3kg over the course of the season. While no information is given with regards the type of training, this may be evidence of a periodized fitness program that results in gradual improvements in speed and anaerobic power parameters over the course of a season.

It is acknowledged that nutrition plays an important part in the acute and chronic adaptations to a variety of training stimuli (Hawley et al., 2011). A proper understanding of the different types of training undertaken by elite Gaelic football teams will allow nutritionists to devise appropriate strategies to promote adaptations to training. As the training focus changes over the course of a season, so too will the nutritional requirements for the players.

Anthropometric Characteristics of Elite Male Gaelic Footballers

When comparing elite and club level players, there appears to be anthropometric differences between the two groups. Keane, Reilly, and Borrie (1997) compared the characteristics of elite and club players. Elite players were taller (181 ± 4 vs 175 ± 6.4 cm) and had a higher body mass (BM) (82.6 ± 4.8 vs 76.5 ± 6.7 kg) than the club players ($p < .001$), although there was no difference in Body Mass Index (BMI). Reeves and Collins (2003) reported that elite footballers were taller than club players (182 ± 4 vs 181 ± 3 cm, $p < .05$). The elite players had a greater BM (83 ± 2.8 vs 80.9 ± 4 kg) and had lower %BF (11.3 ± 1 vs 18.3 ± 3%) than the club level players, but these differences were nonsignificant. Being tall, muscular, and lean appears to be a prerequisite for competing at the elite level.

Watson (1995) reported that a group of successful players (received national awards or professional contracts with Australian Rules teams) in an elite team had lower %BF (average of 12.4%) compared with their less successful teammates. Goalkeepers were reported to have the highest %BF levels (18.4%). While not conclusive, this data suggests that low %BF levels may aid performance and success in Gaelic football. When compared with players of other codes, footballers were similar anthropometrically to League of Ireland (LOI) soccer players (McIntyre, 2005), English Premier League (EPL) soccer players (Strudwick, Reilly, & Doran, 2002) and rugby union backs (Brick & O'Donoghue, 2005).

An important question to examine is if there are position-specific anthropometric differences between players. This will help in determining position specific dietary requirements and training targets. McIntyre and Hall (2005) conducted a study on 28 college footballers and reported that midfielders were taller than defenders and forward, and were significantly heavier than defenders ($p < .05$). Horgan and Collins (2013) reported differences in anthropometric characteristics with respect to playing positions in a group of 27 elite Gaelic footballers. Midfielders were significantly taller and had lower skin-fold thickness (SFT) compared with players in other positions.

In contrast to the previous two studies, Shortall, Doran, and Collins (2013) reported BM, SFT and %BF did not differ between defenders, midfielders and forward in a group of 21 elite Gaelic footballers. Goalkeepers had significantly higher BM than defenders ($p = .006$) and forward ($p = .007$) but not midfielders, and significantly higher SFT ($p < .001$) and %BF ($p < .001$) than all other positions. The data suggests that apart from midfielders and goalkeepers, Gaelic footballers share homogenous anthropometric characteristics. The reasons for goalkeepers having higher %BF is not apparent, but can possibly be attributed to a larger body mass being beneficial for the position as well as differences in training between goalkeepers and outfield players.

Table 1 Anthropometric Characteristics of Elite Footballers in Comparison with Nonelite Footballers and other Team Sport Players

Authors	Level	Age	Height (cm)	Body Mass (kg)	% Body Fat	Prediction Equation	Muscle Mass (kg)	Endomorphy	Mesomorphy	Ectomorphy
Keane et al. (1993)	intercounty (n = 35)	23.5 ± 4.9	181 ± 4.0	82.6 ± 4.8	-	Not stated	-	-	-	-
	senior club (n = 34)	26.8 ± 3.9	175 ± 6.4	76.5 ± 6.7	-		-	-	-	-
Kirgan and Reilly (1993)	UK club players (n = 15)	20.6 ± 1.5	174 ± 5	73.3 ± 9.3	14.5 ± 2.2	Durnin and Womersley (1974)	-	3.0 ±0.7	3.1 ± 0.8	1.6 ± 1.6
Florida-James and Reilly (1995)	UK club players (n = 11)	21.3 ± 2.3	176 ±5.8	70.7 ± 7.7	12.2 ± 2.1	Durnin and Womersley (1974)	-	2.4 ± 0.4	4.2 ± 1.4	2.4 ± 1.0
Watson (1995)	intercounty (n = 32)	25.5 ± 4.1	181.4 ± 8.2	81.9 ±6.9	15.0 ± 4.2	Watson (1983)	-	2.6 ± 0.7	5.6 ± 0.5	3.1 ± 0.7
Strudwick et al. (2002)	intercounty (n = 33)	-	179 ± 7.0	79.2 ± 8.2	12.3 ± 2.9	Martin, Spenst, Drinkwater and Clarys (1990)	60.7 ± 2.4	-	-	-
	english premier league soccer players (n = 19)	-	177 ± 6	77.9 ± 8.9	11.2 ± 1.8		62.4 ± 73.3	-	-	-
Donnelly et al. (2003)	intercounty (n = 33)	-	179 ± 7.0	79.2 ± 8.2	12.3 ± 2.9	Not stated	60.7 ± 2.4	2.7 ± 0.5	5.7 ± 0.8	1.9 ± 0.6
	intercounty Hurlers (n = 7)	-	174 ± 5	73.4 ± 7.7	13.1 ± 1.4		-	2.5 ± 0.4	4.57 ± 0.53	1.85 ± 0.55
Reeves and Collins (2003)	intercounty (n = 12)	25 ± 3.5	182 ± 4	83 ± 2.8	11.3 ± 1	Durnin and Womersley (1974)	-	-	-	-
	Club (n = 13)	24 ± 2.1	181 ± 3	80.9 ± 4	18.3 ± 3		-	-	-	-
	english premier league soccer players (n = 21)	20 ± 3.1	179 ± 5	74 ± 10	15.3 ± 3		-	-	-	-
Brick and O'Donoghue (2005)	intercounty footballers (n = 25)	23.6 ± 3.4	-	86.5 ± 8.6	12.0 ±4.3	Not stated	-	-	-	-
	intercounty hurlers (n = 20)	26.6 ± 3.5	-	84.5 ± 10.1	15.8 ± 5.3		-	-	-	-
	semiprofessional soccer players (n = 22)	24.6 ± 5.0	-	81.4 ± 8.0	12.1 ± 3.6		-	-	-	-
	rugby union forward (n = 9)	28.8 ± 3.9	-	100.2 ± 9.2	17.5 ± 4.0		-	-	-	-
McIntyre (2005)	intercounty footballers (n = 29)	24 ± 6	179 ± 6	81 ± 9	13.4 ± 3	Durnin and Womersley (1974)	-	-	-	-
	intercounty hurlers (n = 29)	24 ± 5	177 ± 6	83 ± 9	18.4 ± 3		-	-	-	-
	league of ireland soccer players (n = 21)	23 ± 6	177 ± 5	78 ± 5	12.2 ± 2		-	-	-	-
McIntyre and Hall (2005)	elite college (n = 28)	21 ± 1.7	181 ± 5	81.6 ± 6.5	14.5 ± 3.1	Durnin and Womersley (1974)	-	-	-	-
Collins et al. (2011)	Intercounty footballers (n = 15)	26 ± 5	187 ± 7	85 ± 6	11 ± 1	Durnin and Womersley (1974)	-	-	-	-
	rugby union backs (n = 5)	21.1 ± 2.2	-	84.5 ± 4.7	12.1 ± 3.7		-	-	-	-
Collins (2013)	intercounty footballers (n = 21)	N/A	178.0 ± 22.1	85.0 ± 7.1 (midseason)	10.9 ± 1.7 (midseason)	Reilly et al. (2009)				

Cullen et al. (2013) examined the anthropometric profile of a large cohort ($n = 265$) of elite U-18 footballers. Midfielders and goalkeepers were taller and heavier than players in other positions ($p < .001$). The %BF was higher in goalkeepers than players in all other positions ($p < .01$) and goalkeepers had a higher BMI than defenders ($p < .05$) and forward ($p < .01$). The total distance covered in the Yo-Yo Intermittent Recovery Test 1 (YYIRT1) was lower in goalkeepers than players in other positions ($p < .01$). Given that this study was conducted on adolescent players, it may suggest that biological factors may help to determine position specialization at an early age.

A number of limitations should be acknowledged when interpreting published anthropometric data. Doran et al. (2013) compared %BF from six different prediction equations to body fat measurements from a Dual-energy x-ray absorptiometry (DXA) scan on a group of 35 sub-elite Gaelic games players. All equations demonstrated 95% prediction intervals ranges exceeding 10% and failed to predict %BF relative to DXA within an accepted ±3.5% anthropometric error rate. It should be noted that one of the prediction equations analyzed was Durnin and Womersley (1974). This equation is used by many of the previously cited studies reporting %BF in Gaelic footballers and the margin of error reported casts doubt on the accuracy of these studies. The author's state that alternative methods of measuring body fat (i.e., SFT) or presumably DXA be used in future studies. Several of the studies are not published in peer reviewed journals but are part of conference proceedings (Brick & O'Donoghue, 2005; Collins et al., 2011b; Donnelly et al., 2003; Horgan & Collins, 2013; Keane et al., 1997) and therefore may not have been subject to rigorous peer review. Finally, the vast majority of the studies were published before 2006 and thus may not be relevant to the modern elite player.

The previous concerns notwithstanding, a number of trends can be observed. Elite players are taller and heavier than their club counter-parts (Keane et al., 1997). Looking at the earliest (Watson, 1995) and the most recent (Shortall et al., 2013) studies which report BM and %BF, it appears that modern players are slightly heavier (81.9 ± 6.9 vs 85.0 ± 7.1 kg), have a lower %BF (15.0 ± 4.2 vs 10.9 ± 1.7%) and are slightly smaller in stature (181.4 ± 8.2 vs 178.0 ± 22.1 cm). While McIntyre and Hall (2005) reported position specific differences in club level players, recent data from Shortall et al. (2013) suggest that elite modern players are a homogenous group, with the exception of goalkeepers who tend be heavier and have a higher %BF. Horgan and Collins (2013) suggest that elite midfielders differ from players in other positions, being taller and leaner. The inconsistencies in the data may be as a result of strategic or tactical aspects of game play.

A number of recommendations can be suggested based on available anthropometric data. The use of prediction equations may not be valid for Gaelic footballers and alternative measurements (SFT and DXA) should be used. The reporting of fat-free mass should be encouraged in future studies. This will give a more accurate picture of body composition changes over time and can help to determine the efficacy of various training and dietary strategies. Future studies should examine changes in anthropometric characteristics at several time points over the course of a season rather than at one instance. The period during the season when teams are studied should also be reported as body composition may change over the course of a season (Shortall et al., 2013).

Nutritional strategies that impact on %BF and BM may be necessary for players in certain positions if they are outside of expected anthropometric norms. Specific nutritional strategies may be devised for midfielders to enable to them to "bulk up". Having a high BM may be advantageous for midfielders, enabling them to contest possession, break tackles and distribute the ball. It is not known if high %BF is particularly advantageous for goalkeepers or whether it is a result of position-specific training, but it may warrant further study.

Physiological Characteristics of Elite Male Gaelic Footballers

Elite footballers are characterized by moderate $\dot{V}O_2$max with estimated values in the literature ranging from 48.7 (McIntyre, 2005) to 59.4 ml/kg/min (Strudwick et al., 2002). Maximal oxygen uptake values are similar to those reported for EPL soccer players (58.8 ± 3.8 vs 59.4 ± 6.2 ml/kg/min, Strudwick et al., 2002) and rugby backs (57.0 ± 3.9 vs 59.6 ± 4.7 ml/kg/min, Brick & O'Donoghue, 2005). McIntyre (2005) reported higher $\dot{V}O_2$max values among a group of Gaelic footballers compared with League of Ireland (LOI) soccer players (48.7 ± 7 vs 57.6 ± 5 ml/kg/min). Brick and O'Donoghue (2005) recorded greater one repetition maximum bench press (1RM-BP) in Gaelic footballers compared with semiprofessional soccer players and rugby union forward (93.6 ± 12.3 vs 80.0 ± 11.7 vs 88.6 ± 7.0 kg respectively, $p < .05$), although lower values have been published for Gaelic footballers (73.7 ± 12 kg; McIntyre, 2005).

Lower body power values for footballers, as measured by VJ, range from 50.3 ± 5.8 cm (Watson, 1995) to 65 ± 4 cm (McIntyre & Hall, 2005). Brick and O'Donoghue (2005) highlighted similar VJ values for rugby union backs, semiprofessional soccer players and Gaelic footballers. Strudwick et al. (2002) published higher VJ values for EPL players compared with Gaelic footballers (63.4 ± 5.7 vs 58.3 ± 6.7 cm, $p < .01$). McIntyre (2005) reported no differences between Gaelic footballers, hurlers and League of Ireland (LOI) soccer players over 15m speed (2.53 ± 0.1 vs 2.49 ± 0.1 vs 2.48 ± 0.1 s), while Strudwick et al. (2002) recorded similar 10m (1.89 ± 0.17 vs 1.75 ± 0.08 s) and 30m (4.60 ± 0.30 vs 4.28 ± 0.12 s) sprint times between Gaelic footballers and EPL soccer players. Keane et al. (1997) reported superior performance for elite players in horizontal jump, VJ, estimated $\dot{V}O_2$max, Cooper 12 min run and 100m sprint time when compared with club level players.

McIntyre and Hall (2005) compared fitness profiles of different playing positions in college footballers and reported that midfielders had greater VJ, handgrip strength and aerobic fitness compared with backs and forward. Horgan and Collins (2013) reported differences in fitness characteristics with respect to playing positions in a group of 27 elite Gaelic footballers. Midfielders were faster over 5m compared with players in other positions. They were also faster over 10m and 20m compared with fullbacks and halfbacks. The authors suggest that there may be biological factors that influence selection and suitability for the position of midfielder.

Analysis of the evidence suggests that elite Gaelic footballers compare favorably with players from other football codes with respect to various aspects of fitness and may give an insight into the type of training undertaken. The data of Brick and O'Donoghue (2005) suggest a program of resistance training to improve upper body strength. Strudwick et al. (2002) report similar speeds over 10 m and 30 m when comparing elite Gaelic footballers and professional EPL players. Training modalities which might be used to improve speed include plyometrics (Rimmer & Sleivert, 2000) and power based resistance training (Harris et al., 2000). Elite intercounty footballers perform better in several fitness tests when compared with club-level players. This demonstrates that there may be a minimum fitness requirement for elite selection.

Finally, there appear to be position specific fitness requirements. This is evident for the position of midfielder. While the data are from college level footballers, McIntyre and Hall (2005) reported greater lower body power, grip strength and aerobic fitness in midfielders compared with other positions. Horgan and Collins (2013) reported superior speed in midfielders compared with players in other positions. Whether this is a result of specific fitness training for midfielders or the existence of a specific phenotype to be successful as a midfielder is unknown. If midfielders undergo different training to players in other positions then this will have nutritional implications.

Physiological Demands of Gaelic Football

Keane, Reilly, and Hughes (1993) examined the match demands in footballers over four championship and four national league games. The mean distance covered was 8594 ± 1056m. The majority of the distance covered (66%) was accounted for by low intensity activities (walking and jogging). High intensity (HI) activity (striding and sprinting) accounted for 12.4% and 3.7% of the total distance covered respectively. No fatigue was evident between the first and second halves as determined by distance covered. The total distance covered was 8523 ± 1175m for defenders, 9131 ± 977m for midfielders and 8490 ± 673 m for forward, which was not significantly different between positions.

McErlean, Cassidy, and O'Donoghue (2000) performed a time motion analysis of 40 male elite Gaelic footballers. The mean time for HI activity ranged from 4.1sec for forward to 6.8sec for midfielders, with an average of 15.9% of the game being performed at HI. This ranged from 10.7% for forward, to 22.1% for midfielders. Work-to-rest ratios were lowest for midfielders (1:3.6 ± 0.6) and highest for forward (1:13.0 ± 6.6). There was no difference in the amount of HI activities performed between the first and second halves. Time spent in game related activity (soloing and contesting possession) amounted to 2.7% of game time. It should be noted that the soloing a football leads to an increase in physiological responses such as heart rate, lactate accumulation, oxygen consumption and Rating of Perceived Exertion, when compared with running at the same speed (Hulton, Ford, & Reilly, 2005). It is not clear if a greater time spent soloing the ball leads to a significant increase in energy expenditure and greater fatigue.

O'Donoghue and King (2005) analyzed the activity profile of a group of university footballers. They reported longer mean HI activity durations (5.7sec vs 3.2sec) and shorter recovery periods compared with premier league soccer games. Fifty one percent of recoveries were less than 20sec, with 8% of recoveries lasting 90 sec or longer. A positional effect was also reported, with central players performing 50% greater number of bursts, with shorter recovery periods than any of the other positional groups ($p < .001$). Central players spent a significantly higher portion of match time performing HI activities than the other groups ($p < .01$).

The previous three studies used a manual, vision based notation analysis to determine activity profiles. This type of motion analysis has several limitations including the validity and reliability of the data entry procedure, the number of and experience of the observers and their perspective of the game area (Barris & Button, 2008). Therefore, the accuracy and validity of this data may be questionable. The age of the data also questions its relevance to the modern game as coaches and teams are employing more sophisticated tactics than in the past (e.g., blanket defense). More recent data using Global Positioning System (GPS) data over four competitive games has shed light on the effect of tactical changes in the game (Collins, Solan, & Doran, 2013). Significant differences were noted in relation to previous studies. Half-backs/forward covered a greater distance (absolute and HI) compared with players in other positions. Differences were also observed in the HI distance covered in the first and second halves (876 ± 298 vs 819 ± 246m, $p = .001$) and between the first and fourth quarters (479 ± 178 vs 379 ± 107m, $p = .028$). The maximum speed attained was 30 ± 1.4 kph and the average speed was 7 ± 1 kph These activity profiles suggest that football has a high anaerobic component. Phosphocreatine degradation and anaerobic glycolysis are most probably the main energy pathways used to generate ATP during periods of high-intensity activity. An understanding of the types of substrate used and the causes of fatigue will help determine pregame macronutrient-intake targets and supplementation to attenuate decrements in performance.

Table 2 Positional Work Rate Variations in Elite Players Over Four Competitive Games (Collins et al., 2013b)

Position	Distance Covered (m)	High-Intensity (> 17 km.hr-1) Distance(m)
average	8815 ± 1287	
fullbacks and full-forward	7427 ± 689 *#	1318 ± 265 *#
halfbacks and half-forward	9419 ± 1204	1934 ± 551
midfield	9159 ± 321	1589 ± 186

*$p < .01$ Significant difference between fullbacks/forward and halfbacks/fowards
#$p < .01$ Significant difference between fullbacks/forward and midfield

Nutrition Studies in Elite Men's Gaelic Football

Reeves and Collins (2003) performed a dietary intake study over a 7-day period of elite and club footballers, professional soccer players and a control group. The results revealed significant differences ($p < .05$) in diet. Compared with soccer players, elite footballers consumed less carbohydrate, both absolute (432 ± 23 vs 437 ± 40g) and as a percentage of energy intake (52.2 ± 5 vs 57.0 ± 4.1%). Gaelic footballers also consumed less fat expressed as a percentage of energy intake (25.9 ± 4 vs 27.5 ± 3.4%) and less alcohol than the soccer players (0 vs 1.4 ± 1g). Dietary protein accounted for 16% of total energy intake. More recent data from Collins, Doran, and Reilly (2011b) reported carbohydrate, fat and protein intakes (as a percentage of total energy intake) of 54 ± 4, 29 ± 3 and 17 ± 3% respectively in a group of fifteen elite Gaelic footballers. The macronutrient intake ranges from the two cited studies are within the ranges reported for other team sports such as soccer, basketball and Australian Rules football (Burke, 2007).

When energy intake was expressed in terms of body mass, soccer players consumed 173 ± 11 kJ/kg BM/day, whereas intercounty footballer's players consumed 151 ± 11 kJ/kg BM/day. A wide range of energy intake values are reported in the literature and the values published for Gaelic footballers are at the lower end of the spectrum when compared with professional team-sport athletes (Burke, 2007). While elite Gaelic footballers may not have the same energy intake as professional athletes, this could be as a result of lower energy expenditure. Mean daily energy expenditure was not calculated for the elite footballers, so it is not known if they were in energy balance, surplus, or deficit.

Extrapolating the data from Reeves and Collins (2003), a daily carbohydrate intake of 5.2 g/kg BM/day and daily protein intake of 1.5 g/kg BM/day was calculated for the elite players. The carbohydrate intake was at the lower end of the recommended intake for a moderate exercise program (5–7 g/kg BM/day; Mujika & Burke, 2010). The protein intake was within the intake for strength and power athletes (1.2–1.7 g/kg BM/day; Tarnapolsky, 2010) and should cover the protein needs for most situations (i.e., strength/power training, field based training). Mean carbohydrate and protein intakes of 5.3 and 1.7 g/kg BM/day respectively were calculated from Collins et al. (2011b). This supports the contention that elite players may not be ingesting sufficient carbohydrate, especially if undertaking HI training.

Reilly and Keane (2002b) examined the effect of ingestion of a carbohydrate supplement and placebo before a game and at half time on player's work rates. There was no difference in any of the work-rate indices between the experimental and control group. It should be noted that the bolus (5% glucose solution in 150ml liquid, approximately 7.5g of carbohydrate) may have been too small to elicit an ergogenic effect, given the high rates of exogenous carbohydrate oxidation that can be attained with sufficient carbohydrate feeding (Jentjens & Jeukendrup, 2005). Another interpretation may be that glycogen depletion may not be a limiting factor in football performance. However, the effect of carbohydrate on psychological factors such as mood, RPE and task persistence (Backhouse et al., 2007) and skill execution (Russell et al., 2012) as opposed to physiological parameters should not be discounted.

Newell et al. (2008) investigated fluid intake and loss during a training session in a warm environment (16–18 C°, 82–88% humidity) with a squad of 20 elite Gaelic footballers. Urine analysis (urine specifc gravity (USG) as measured by refractometer) was used to determine pretraining hydration. The majority of players ($n = 15$) were hydrated before training (USG < 1.010) although three players were minimally dehydrated (1.010 < USG < 1.020) and two were significantly dehydrated (USG > 1.020). Sweat rate was determined using the following formula: sweat rate = (preexercise body mass—postexercise body mass) + fluid consumed—urine output. The mean sweat rate per hour was 1.39 L/hr and mean body mass loss was 1.1%, ranging from one player who gained 0.5% body weight to another who lost 2.4% body weight. There was a wide variation in fluid intake (300–2000ml) among the squad. The results of this study indicates the individual sweating variation in response to training and the importance of measuring individual sweat rates and developing individualized hydration strategies.

Vitamin D is a nutrient that has important biological functions, including bone morphology, Calcium metabolism, muscle function, and athlete susceptibility to injury (Hamilton, 2010). In Ireland (latitude 51–56°N), UVB radiation from sunlight over the winter months (October–March) is too weak to promote cutaneous vitamin D production (Webb, Kline, and Holick, 1988). A study by Magee et al. (2013) reported that 94% of a cohort of 34 elite Gaelic footballers were classified as vitamin D insufficient/deficient. Close et al., (2013) reported an increase in serum Vitamin D concentrations (29 ± 25–103 ± 25 nmol/L, $p = .0028$) when deficient athletes were supplemented with 5000 IU/day vitamin D(3) for 8 weeks. In addition, the supplemented athletes improved 10m sprint time and VJ compared with a placebo group who received no supplementation. This data suggests that the majority of Gaelic football players are Vitamin D deficient over the winter months and that supplementation is a viable method to prevent deficiency and improve physical performance.

Nutritional Recommendations

Carbohydrate

The value of a high carbohydrate diet on initial muscle glycogen stores and subsequent performance are well established in soccer players (Balsom et al., 1999). It is difficult to know if glycogen is limiting in football due to the shorter match duration compared with soccer (70 vs. 90 min). Collins et al. (2013b) reported a reduction in HI exercise between the first and fourth quarters suggesting that glycogen depletion may play a role. It may be speculated that the longer HI work periods and shorter rest durations in football compared with soccer may result in greater muscle glycogen utilization. However, no experimental evidence exists to support this assertion.

In the event that muscle glycogen depletion is not limiting, adequate pregame carbohydrate intake is still essential as low pregame muscle glycogen effects performance in soccer players (Saltin, 1973). Carbohydrate intake during a game is likely to benefit both peripheral and central nervous system function (Winnick et al., 2005) compared with placebo, attenuate decrements in blood glucose and shooting skill (Russell et al., 2012), attenuate rise in Rate of Perceived Exertion (Backhouse et al., 2007) and attenuate performance reductions in the latter stages of a simulated basketball game (Welsh et al., 2002). Aggressive posttraining and postcompetition refueling should be encouraged in elite footballers, as it has been demonstrated that replenishment of muscle glycogen can be impaired in elite soccer players with suboptimal carbohydrate intake (Jacobs et al., 1982).

Carbohydrate-protein (CHO-P) ingestion (24g whey, 4.8g leucine, 50g maltodextrin) immediately before repeated sprint training (RST) has been shown to increase myofibrillar synthesis in the post training period to a greater extent (?48%) than a noncaloric placebo (Coffey et al., 2011) which may improve recovery during periods of heavy training. The ingestion of a CHO-P beverage (4.8% CHO, 2.1% protein) appears to be beneficial in attenuating the decrement in performance compared with an iso-caloric carbohydrate beverage. Using a randomized, cross-over study design, Alghannam (2011) compared the effects of these two beverages, and a taste and color matched placebo on run to fatigue (RTF) at 80% $\dot{V}O_2max$ after a soccer simulation test. Ingestion of CHO-P allowed a greater RTF than the protein and placebo beverages (23.02 ± 5.27 vs 16.49 ± 3.25 vs 11.00 ± 2.80 min; $p < .05$). In addition, consumption of CHO-P attenuated the increases in RPE toward the end of exercise ($p < .05$) and maintained blood glucose at the end of exercise to a greater extent than carbohydrate or placebo (4.68 ± 0.64 vs 3.92 ± 0.29 vs 3.66 ± 0.36 mmol/L respectively, $p < .05$). While caution should be taken when assessing this study due to the small sample size ($n = 6$) and lack of confirmation studies, it may open a promising avenue of performance enhancement in intermittent-type sports.

Protein

The importance of the quality (i.e., high leucine content) and timing of protein ingestion, especially around strength training sessions, should be conveyed to players to ensure maximal adaptations to the training stimulus. Pre- and postexercise protein supplementation may increase type I and type II muscle fiber size, and squat jump performance over carbohydrate intake alone (Andersen et al., 2005). Whey protein may be more beneficial immediately after exercise in promoting muscle protein synthesis (Boirie et al., 1997). Casein protein ingestion immediately before sleep will provide a more sustained release of amino acids and improve whole body protein balance (Res et al., 2012).

Table 3 Carbohydrate Requirements (Mujika & Burke, 2010)

Training Type	Recommendations
moderate exercise (1 hr per day)	5–7g/kg/day
1–3 hr of moderate to high-intensity exercise	6–10g/kg/day
speedy refueling—less than 8 hr between two demanding workouts	1–1.2 g per kg immediately after first session repeated each hr until the normal meal schedule is resumed
pregame fueling	1–4g/kg eaten 1–4 hr before the game
during game	30–60g per hr including mouth rinsing

Table 4 Protein Requirements (Tarnapolsky, 2010)

Training Type	Recommendations
resistance training (early training)	1.5–1.7 g/kg
resistance training (steady state)	1–1.2g/kg
game specific/pitch based training	1.4–1.7g/kg

Hydration

The detrimental effects of dehydration on exercise performance are well established (American College of Sports Medicine, 2007). Athletes should be monitored regularly before training to ensure that they are adequately prehydrated. This can be accomplished through the use of urine specific gravity, osmolality and reagent strips. Players should be proactive and monitor urine color and volume, and thirst as a means of determining hydration status. A wide variety of sweat rates have been reported for footballers (Newell et al., 2008). Instead of issuing generic recommendation, the measurement of individual sweat rates in a variety of environmental conditions can be used to determine individual hydration strategies for players. Pre- and posttraining weighing should be used to determine fluid loss and optimal rehydration rates.

Ergogenic Aids: Creatine

If we consider the anaerobic activity profile (4–6 s HI bursts with recovery ranging from 20–90 s; O'Donoghue & King, 2005) and the importance of muscle mass, upper body strength and VJ height in performance, then the use of creatine may have an ergogenic effect on performance. Mujika et al. (2000) examined the effect of acute creatine supplementation on various fitness parameters in a group of amateur soccer players. Following initial testing, players were separated into a placebo (maltodextrin) and creatine (20g/day) supplementation group for 6 days and were retested 7 days later. The creatine group performed significantly better in a 5m and 15m RST after supplementation, and demonstrated a limited rate of decay in a counter-movement jump test. The creatine group also reported a significant increase in body mass whereas the placebo group showed no change.

Bishop (2010) reported that creatine supplementation is ergogenic in repeated sprint activities when recovery ranges from 50–90s. O'Donoghue and King (2005) reported that 24% of recovery periods lasted 45s or longer in a senior football match. Supplementation may be ergogenic in these recovery periods. Ferrauti and Remmert (2003) concluded that creatine supplementation during periods of resistance and sprint conditioning training improves strength and power above training alone, providing a basis for creatine supplementation during training.

Anecdotal evidence suggests that many football coaches believe that creatine is a substance that is potentially harmful. Few longitudinal studies exist on the long-term effects of creatine supplementation. Schröder, Terrados, and Tramullas (2005) examined the effects of three years of daily creatine supplementation (5g/day) on professional Spanish basketball players Sixteen blood parameters were measured 5 times each year. Only creatine kinase was elevated above normal at each measurement point. The authors previously reported similar creatine kinase activity patterns in noncreatine supplemented athletes (Schröder et al., 2001). They suggested that this may be as a result of high eccentric loading due to basketball practice and game play and thus increased muscle damage. Kim et al. (2011) warn against high-dose creatine supplementation (> 3–5 g/day) in individuals with preexisting kidney disease. Adverse effects have been reported in an individual taking a combination of steroids and high doses (200g/day) of creatine (Revai et al., 2003). However, as stated by Gualano et al. (2012) "after hundreds of published studies and millions of exposures creatine supplementation maintains an excellent safety profile."

Gaelic footballers thinking of supplementing creatine should take reasonable precautions beforehand. Before commencement, they should be checked by medical staff for preexisting kidney conditions. Regular blood tests throughout the supplementation period should be performed by medical staff to check for any abnormalities. Athletes should follow standard creatine loading procedures (1 week of 25g/day loading phase, 3 weeks of 5g/day maintenance phase; Powers et al. (2003)). Individuals should also be made aware of the existence of responders and nonresponders to creatine supplementation (Syrotuik & Bell, 2004) so as to manage expectations. If these recommendations are followed then it is reasonable to assume that players will be at minimal risk of adverse health effects.

Ergogenic Aids: Caffeine

Several studies have demonstrated the ergogenic effects of caffeine in soccer. Foskett, Ali, and Gant (2009) demonstrated greater passing accuracy and VJ performance after consuming 6mg/kg BM of caffeine in a soccer simulation running and passing skill test compared with placebo. Del Coso et al. (2012) demonstrated that consumption of a commercially available caffeinated sugar-free energy drink (3mg/kg BM) allowed better performance in a jump test, greater mean running speed during a RST (7 × 30m with 30sec recovery); more distance covered at a speed greater than 13km/h and a greater number of sprints during a simulated soccer game compared with placebo ($p < .05$). Consumption of caffeine in conjunction with carbohydrate has also been demonstrated to improve performance in physical and soccer-specific tests to a greater extent than carbohydrate alone (Gant, Ali, & Foskett, 2010; Ranchordas & Pattison, 2011).

Using a model similar to Gaelic football (2 × 36 min halves; 18 × 4s sprint with 2 min active recovery per half; cycle ergometer), Schneiker et al. (2006) demonstrated that consumption of 6mg/kg BM of caffeine improved sprint work performance by 8.5% in the first half and 7.6% in the second half compared with placebo ($p < .05$).

Table 5 Caffeine Recommendations (Hespel et al., 2006)

Playing Position	Recommendations
goalkeeper	2 mg/kg BW taken 60 min before game. Smaller dose improves visual information processing, reaction time and alertness.
outfield	5 mg/kg BW taken 60 min before game.

Mean peak power was also improved by 7% and 6.6% respectively in the first and second halves compared with placebo ($p < .05$). A review by Davis and Green (2009) state that caffeine is beneficial in RST of 4–6s duration, similar to HI burst durations in football.

Limitations

It must be acknowledged that the nutritional recommendations for Gaelic footballers are taken from other field sports such as soccer. With the exception of Reilly and Keane (2002b), there has been no research into the acute or chronic effects of different dietary strategies on Gaelic football performance. Many of the studies that demonstrate the efficacy of a particular nutritional intervention are taken from laboratory based studies on cycle ergometers (Schneiker et al., 2006) or use soccer specific test protocols (Alghannam, 2011). However, due to the lack of research in Gaelic football and the broadly similar activity patterns to soccer, these recommendations may be used as general guidelines for Gaelic footballers until such time as Gaelic football specific requirements can be established.

Conclusion

Gaelic football is the second most popular team sport in Ireland. Activity profiles and fitness parameters are broadly similar to soccer. Due to a lack of research, nutritional recommendations must be interpreted from studies carried out in soccer and other team sports. Body composition, upper body strength, and lower body power may be important factors in discriminating elite from nonelite players. Differences in fitness, body composition, and game work rates are evident between various playing positions. Many of these factors can be influenced by nutrition. Elite footballers may not be eating sufficient dietary carbohydrate to support HI training. Several recommendations can be made to further advance the understanding of nutrition and Gaelic football performance for the modern day game.

Methodological Recommendations

Standardized units should be used to allow comparisons to other studies, sports, and recommended macro-nutrient intake for different types of training.

- g/kg/BM for carbohydrate and protein intakes
- kJ/kg BM or kCals/kg BM for energy intake

The use of body fat prediction equations is discouraged until a population specific equation can be determined. The sum of skinfolds and/or DEXA scan should be used to report changes in body composition. Where feasible, %BF and fat-free mass should be reported. When conducting nutritional intake studies, it is recommended that the type or phase of training be reported as this will have an impact on whether nutrient intake is optimal for the mode of training.

Research Recommendations

The creation of a standardized, valid and reliable field-based or laboratory based protocol (similar to the Loughborough Intermittent Shuttle Test; Nicholas, Nuttall, & Williams, 2000) which mimics the activity patterns of elite Gaelic football is essential to test the efficacy of various nutritional interventional strategies on performance. These should include: carbohydrate-loading; ingestion of CHO or CHO-P; supplementation of caffeine, creatine, sodium bicarbonate, beta-alanine, carnosine, nitrates and Vitamin D. Food intake studies would determine if players are eating the correct combination of macro- and micronutrients to support different phases of training.

Knowledge of the activity profiles required to compete at the elite level are important when devising training programs and dietary strategies. Global Positioning Systems data can be used to provide a greater understanding of position-specific activity profiles as well as the effect of game preparation nutritional strategies on distance covered, number of HI activities, fatigue etc. The use of muscle biopsy and blood sampling using a Gaelic football specific activity protocol or during match play may help to determine if low muscle-glycogen, lactate accumulation, pH or other factors are implicated in fatigue. Identification of fatiguing agents may help scientists in devising nutritional strategies to maintain performance levels.

Finally, further research is warranted into the work-life balance of elite Gaelic footballers. Because of its amateur status, most players are in full-time employment or education and may also have family commitments. Traveling to and from training and games, the pressure of work or education, the type of job (physically active versus sedentary), family responsibilities and the stresses of everyday life may have an impact on the ability to recover and adapt to training and may impair the enjoyment of competing and participating at the elite level.

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