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Applied Sport Science of Gaelic Football: A Review

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Abstract

The current review focuses on Gaelic football literature providing an insight into the physical characteristics of players, the demands of match-play, the injury profile, and nutritional considerations within the game. Since the first review of Gaelic football in 2001, an increased understanding of match dynamics has taken place through the application of movement analysis technology. In recent years, the evolution of the application of sport science provisions within Gaelic football has increased. This has resulted in researchers attempting to bridge the gap between the scientific laboratory and the applied practitioner. Overall, intermittent aerobic fitness remains important during competition, along with upper and lower body strength, speed and jump based characteristics, with positional and seasonal variations present in Gaelic football. The stochastic nature of Gaelic football means distances covered during match-play will have an inherent positional profile, with gradual reductions in match-play running performance frequently observed. Monitoring training loads in combination with response variables, such as wellbeing, can allow practitioners to achieve optimal dose and response characteristics via training regimes. The risk of injury to elite Gaelic football players is significantly greater during match-play, compared to during training. 70% of injuries occur to the lower limb region, with hamstring and knee injuries being the most common. Furthermore, specific findings show that training days elicit the greatest deficits between intake and expenditure, as such practitioners should target specific nutritional interventions to ensure that players are optimally loaded for the energetic requirements of these sessions. The current review can provide information to coaches and practitioners around position-specific physical qualities, match-play demands, and concurrently, support the training process within Gaelic football.

Performance | Match-Play Demands | Injury | Positional Variation | Nutrition

1. Introduction and Structure of Gaelic Football

Gaelic football is an intermittent, high-intensity, team sport [25]. It is competed by two teams, each having 15 players on a pitch (130 – 145 m long, 80 – 90 m wide) at any one time [78]. Elite Gaelic football consists of inter-county players, whereas sub-elite Gaelic football comprises of club level footballers. The average length of an elite Gaelic football season is 26 weeks, with a sub-elite season lasting 4-6 months. Being amateur in status, it is common for adult Gaelic footballers to work full time jobs or be enrolled as full time students in addition to having other personal responsibilities. An elite level match has a 70 minute duration (2 x 35 min halves), with a sub-elite game being 60 minutes in total (2 x 30 min halves), additional time is at the discretion of the officials [56]. Earlier research divided the positions of Gaelic football into three brackets – back, midfield and forward [65]. Current literature now considers the five outfield positional lines (full back, half back, midfield, half forward and full forward) due to three middle positions having an increased involvement in match-play [56, 58, 93]. Where possible, the current review will communicate data per the line of the field. The literature search process was conducted across a number of search engines such as Pubmed, SPORTDiscus and Scopus with key author names and text search terms such as 'Gaelic football' and 'nutritional demands', 'running performance' and 'physiological demands', used to find peer reviewed investigations pertaining to Gaelic football. The current review aims to primarily focus on research since the last Gaelic football review in 2008. The current review will focus on the male Gaelic football population, specifically discussing the elite and sub-elite populations at the adult and adolescent (age 15-20 years, underage teams) grade. It is not within the scope of the current review to delve into all aspects of Gaelic football. The authors will focus on the characteristics of the competing athletes, the demands of match-play and training, the injury profile and nutritional considerations of Gaelic football players.

Figure 1 near here

2. Anthropometric and Performance Characteristics

Anthropometric Profile

The mean age of elite male adult Gaelic footballers is 24 – 26 years [53, 56, 93]. An elite adult Gaelic footballer's height typically ranges from 178 – 187 cm [65, 81, 91, 93], with sub-elite adults 180.4 cm [88], elite adolescents 178.1 – 181.0 cm [17, 67] and sub-elite adolescents 181.0 cm (see Table 2) [67]. The body mass of elite adult Gaelic footballers is 81.0 – 83.6 kg [91, 93], with sub-elite adults 78.8 kg [88], elite adolescents 72.1 – 78.1 kg [17, 67] and sub-elite adolescents 82.1 kg [67].

The body composition of elite Gaelic footballers when communicated as an estimated body fat percentage (BF%) is reported to be 10.9 ~ 11.3% [35, 81], with higher values reported for collegiate footballers (14.5 ± 3.1%) [65]. The application of Dual Energy X-ray Absorptiometry (DXA) to identify the body composition of Gaelic footballers has become an increasingly popular method. Gaelic football research comparing commonly utilised skinfold prediction equations to DXA-derived BF% identified that five out of six equations underestimated BF% compared to DXA-BF% values [25]. Research involving sub-elite collegiate players reported higher DXA-derived BF% values (15.7 ± 3.8%) [25] when compared to elite players (14.5 ± 3.1%) [21].

Positional differences regarding stature are frequently observed in Gaelic football [17, 42]. Midfielders tend to be taller compared to all other outfield positions [42], often followed by the goalkeeper [17]. However non-significant stature variations among the five outfield positions can occur [65]. Midfielders tend to have a higher body mass than half backs [65], and half forwards [42]. However, more recent literature observed no body mass variations across positions to be present [93]. Body composition is an important characteristic of Gaelic football players with lower BF% associated with increased speed, improved power to weight ratio, jumping ability and economy of movement across match-play [25, 42]. Positional variations in adiposity can occur, with the general trend showing the middle three positional lines possessing lower BF% values compared to full backs and full forwards [42, 93]. However, this trend is not always consistent, with no positional adiposity differences also previously reported within the literature [35, 92]. A seasonal effect has been observed across body mass within elite Gaelic footballers [42, 85, 92]. Indeed, literature examining seasonal changes in body composition of elite Gaelic footballers found the highest recordings for body mass in pre-season (January; 86.0 ± 5.3 kg), and the lowest at the end of season (September; 82.7 ± 5.0 kg) [85]. A more recent investigation similarly reported a reduction in sum of eight skinfold (-21.5%) and body fat % (~11.8%) from pre-season to mid-season [42], in line with decreases observed by Shortall, et al [92].

In addition to position and time of season, the competitive level of players tends to have an impact on the anthropometric characteristics of Gaelic footballers [3, 41, 81]. Elite Gaelic footballers tend to be taller and have a greater body mass index compared to their sub-elite counterparts [41]. Furthermore, elite players (11.3 ± 1.0%) are reported to have lower estimated BF% compared to sub-elite players (18.3 ± 3.0%) [81]. Due to the more robust nature of top level competition, the anthropometric characteristics of Gaelic footballers appears to be an important factor in determining the level of competition one competes at. Recent literature has also examined the DXA-derived, off-season changes in body composition of elite adult male Gaelic football players with specific reference to player role (starter vs non-starter). Although there were no significant differences in body mass, fat-free mass, lean tissue mass or BF% when comparing starters and non-starters across the two time points (mid-season and off-season), independent of player role, all four body composition variables observed a significant change over time [7]. This study was the first of its kind within elite Gaelic football to assess the off-season changes in body composition when comparing player role. The findings highlight that players may require further education on the impact of reduced work load and off-season lifestyle choices on their body composition. DXA is considered the gold standard for analysis of body composition [34], however it can be an expensive methodology. Although a study comparing commonly used adipose tissue body composition equations underestimated BF% relative to DXA-BF% for five of the six skinfold equations examined [25], this method and the 'sum of skinfold' procedure are more feasible options for practitioners. The importance of skinfold or adiposity assessment (DXA) should not be underestimated by practitioners, these assessments should take place at least four time points throughout the season. If using the skinfold assessment approach, practitioners may engage in these processes more consistently given the cost-effective nature of these assessments. Consistent collection of these data will allow the performance department of Gaelic football backroom teams to create specific positional standards, while also providing specific priority interventions for nutrition and strength and conditioning staff. It must be remembered that the earlier the assessment, the longer the specific intervention window will be with priority players. Therefore, it may be suggested that at elite inter-county level, players are assessed after the club window ahead of a new season to provide an elongated intervention window.

Strength, Power and Speed

The limited available research regarding strength profiles suggests elite Gaelic footballers are relatively homogenous regarding lower-body strength. Further investigations are warranted within this area to further elucidate these initial findings. Overall, half backs (154.1 ± 17.5 kg) have been shown to outperform midfielders (142.7 ± 18.9 kg), with this being the only reported positional difference in 1 repetition maximum deadlift (1RMDL) [42]. In terms of upper-body strength, full backs (111.0 ± 14.2 kg) displayed a greater 1 repetition maximum bench press (1RMBP) when compared to half forwards (90.7 ± 5.1 kg) and full forwards (84.5 ± 8.0 kg) [42]. Seasonal trends also appear within strength profiles, with a 19.7% increase in 1RMDL observed between pre-season (November) and mid-season (March) [42]. Future research should aim to identify the changes in strength and power profiles of these players across multiple seasonal periods to understand if these profiles change dramatically during the off-season period.

Gaelic footballers are required to contest the ball in the air for possession during competitive match-play, thus the need to possess adequate jump characteristics. The mean countermovement jump (CMJ) height, and squat jump (SJ) height for elite Gaelic footballers ranges from 38.0 – 38.6 cm and 36.1 – 37.0 cm, respectively [42, 93]. Elite adolescents reported a mean CMJ height of 43.3 – 51.0 cm [17, 67], with sub-elite adolescents at 45.9 ± 3.3 cm [67]. Elite players scoring the lowest may be explained by different jump protocols being implemented (Selected arm swing [67], hands on hips [17]) and varying jump readers (Takei Jump Reader [42], Optojump Photocell System [67]) used across investigations. It should be noted that there is limited research regarding Gaelic football jump performance, and thus, further investigations are required to determine if these values are reflective of these populations. The mean CMJ height of sub-elite adult Gaelic footballers is 43.1 ± 6.5 cm [15]. Regarding positional variations, full forwards were found to have a greater CMJ height compared to midfielders, with no other positional differences observed [93]. Midfielders were observed to have a significantly lower SJ height compared to full backs, half backs and half forwards, with half forwards seen to have superior CMJ height performance [42]. In contrast, earlier research comparing across three positional lines reported midfielders to outperform back line and forward line players in vertical jump height [65]. Contradictory findings regarding CMJ peak power (CMJ PP) are also evident. Full forwards have been found to have a significantly greater CMJ PP compared to all other positions [93], while another investigation indicated half backs to outperform all other positional lines [42]. Variations between earlier research and contemporary studies may be related to several factors such as a change in game dynamics or increased levels of strength and conditioning training within elite and sub-elite populations. In addition to positional differences, time of season appears to impact jump performance, with SJ height (10.1%) and CMJ (9.8%) improvements reported when comparing pre-season (November) to mid-season (March) [42].

Speed and acceleration are crucial characteristics of Gaelic football [31]. During match-play it is often these short bursts of anaerobic activity that have an important bearing on match outcome [43]. The mean acceleration times for elite Gaelic footballers over 5-, 10- and 20 m are 1.10 ± 0.11 s, 1.82 ± 0.12 s and 3.09 ± 0.16 s, respectively [93]. Regarding 5 - and 20 m sprint times for elite adolescent Gaelic footballers, ranges from 0.92 –1.13 s and 2.86 – 3.22 s are reported, respectively [17, 67]. Sub-elite adolescents reported 5- and 20 m sprint times of 0.94 ± 0.04 s and 2.95 ± 0.10 s, respectively [67]. As identified in the previous section, there is a research gap regarding speed characteristics in sub-elite adult footballers. The majority of existing literature reports that Gaelic footballers are relatively homogenous in terms of acceleration variables (5-, 10-, 20 m), with no positional differences reported during performance testing [93] or match-play for maximal velocity capabilities [54, 56]. Although uncommon, it should be noted that some positional speed differences have been reported at elite adult level, with midfielders outperforming all other positions over 5 m [35], but underperforming over 20 m compared to all other positional lines [42]. Similar to other capacities, time of season has also been found to impact speed variables, with a 7% improvement in 5 m sprint time reported when comparing pre-season to mid-season [42]. Improvements in sprint speed over the course of a season may be linked to observed increases in SJ and CMJ [42], with strength being a critical characteristic for jump performance, as well as overall player robustness [28]. Therefore, it is recommended that practitioners aim to capture upper and lower limb, push and pull strength characteristics, in conjunction with jump, power and speed based profiles across 3 – 4 time points in a given season. Pre-season, in-season during league, pre-Championship and pre-All Ireland finals are suitable testing time points in order to understand the effectiveness of a specific intervention utilised across a training period. Practitioners should utilise these data points to provide guidance to any player-specific intervention.

Aerobic and Anaerobic Profiles

The intermittent nature of Gaelic football can result in short recovery periods in between moderate- to high-intensity bursts [73]. It's common for Gaelic footballers to undergo indirect measures of aerobic fitness via tests such as the Yo-Yo Intermittent Recovery Test (Yo-YoIRT). The Yo-YoIRT is a test and not a characteristic measure. It is used to assess the ability to perform repeated bouts of high intensity running, with these tests reported to be a reliable measure of changes in performance [2]. Yo-Yo Level 1 (Yo-YoIRTL1) is a largely aerobic test that assesses the ability to repeat high-intensity efforts, while significantly stressing the anaerobic energy system [97]. Therefore, Yo-YoIRTL1 induces physiological demands similar to those experienced during match-play [2, 83]. The mean Yo-YoIRTL1 distance for elite adult Gaelic footballers is 2,335 ± 453 m [22]. The mean Yo-YoIRTL1 distance for elite adolescent Gaelic footballers is found to be 1,464 ± 370 m [17], with a mean distance of 2,365 ± 489 m reported for adult sub-elite players [88]. With the minimal differences between elite and sub-elite populations, it appears these groups may have a similar aerobic/anaerobic capacity regarding the Yo-YoIRTL1. However, more recent research found variations in Yo-YoIRT1 performance were evident regarding playing status, with starters covering a significantly greater distance compared to non-starters [8]. It should be noted that there are limited research available regarding playing status and playing level variations, and further investigations are required to clarify these findings. Gaelic football is an intermittent sport that is stochastic in nature [91], as such, variances observed within the Yo-YoIRTL1 performance may have an impact on match performance. Unsurprisingly, elite adolescent goalkeepers were found to cover a lower Yo-YoIRTL1 distance compared to all outfield positions [17]. An enhanced aerobic system in starters as measured by Yo-YoIRT1 may result in quicker recovery from high-intensity running, and therefore allow players to impact match-play to a greater extent. Understanding such differences across position and playing status will allow practitioners to enhance player preparation for competitive match-play based on role-specific characteristics. The data may also aid coaches to individualise training plans based on position and playing role. With further research, the role-specific characteristics may become a significant factor regarding team selection.

In addition to the Yo-YoIRTL1, the Yo-YoIRT Level 2 (Yo-YoIRTL2) is another field test conducted in Gaelic football [36, 42, 93]. Yo-YoIRTL2 has a faster starting speed compared to Yo-YoIRTL1, and similarly assesses an athlete's ability to perform high-intensity intermittent exercise. Due to its shorter duration, the Yo-YoIRTL2 tends to be utilised more with elite athletes than the Yo-YoIRTL1 [35, 36]. Peak Yo-YoIRTL2 distance for elite Gaelic footballers is reported to be 1,751 ± 398 m [36], with full forwards and full backs tending to cover a lesser distance compared to the three middle positional lines, with a bell-shape curve evident within the analysis [45, 93]. Kelly and Collins (2018) observed significant performance improvements in Yo-YoIRTL2 from pre-season to mid-season, with a 34.9 % increase evident. This performance increase is most likely explained by the conditioning of players and match-play game minutes compiled across the season, in addition to any reductions of aerobic fitness during the off-season. To the author's knowledge, there is currently no published Yo-YoIRTL2 research involving sub-elite adult Gaelic footballers. A comparative investigation may provide a rationale to coaches and players on the determination of playing status, in addition to understanding any transitional requirements in players who are called up from sub-elite to elite level competition during the season. Finally, it must be noted that there is a lack of research within Gaelic football on the utility and application of tests such as the 30-15 intermittent fitness test and time trial assessments, such as the 1,000 m – 1,600 m time trial, and Bronco 1,200 m shuttle test, despite anecdotal use of these assessments regularly. Therefore, researchers should endeavour to publish studies on the validity and reliability of these tests, in addition to further positional standards with respect to these assessments.

Early literature characterized elite Gaelic footballers aerobic power ($\dot{V}O_{2max}$) values to range between 52.6 mL·kg^{-1}·min^{-1} [27] to 59.4 mL·kg^{-1}·min^{-1} [95]. Positional differences are frequently observed, with midfielders often found to have the greatest aerobic power due to the specific running demands in linking offensive and defensive situations during match-play [42, 65, 93]. More recent literature has reported positional differences across a case study analysis of one team, with half forwards (64.7 ± 7.8 mL·kg·min^{-1}) found to have the greatest VO_{2max}, followed by midfielders (62.2 ± 3.5 mL·kg·min^{-1}), half backs (58.3 ± 6.8 mL·kg·min^{-1}), full forwards (57.8 ± 2.1 mL·kg·min^{-1}) and full backs (56.8 ± 4.6 mL·kg·min^{-1}) [49]. The importance of improved aerobic performance profiles should not be underestimated by Gaelic football coaches, considering that these profiles have been associated with running performance during match-play [2, 14]. Given the above, it may be suggested that practitioners regularly assess players aerobic power profiles across the season. Furthermore, there is a requirement to understand the key positional fitness variations in Gaelic football. These data would allow coaches and practitioners to effectively compose specific testing batteries that are representative of match-play while also guiding the development of player specific training regimes.

Table 1 near here

3. Running Performance and Physiological Profile

Running Performance Profile

Time motion investigations now use global positioning system (GPS) to quantitatively examine levels of physical stress, assess performance and different positional workloads, establish training intensities, and monitor changes in player physiological requirements [66]. Current GPS devices have the greatest validity and reliability in terms of measuring movement during low to moderate speeds, and over increased distances [39, 45]. It appears that higher sampling frequency units [38, 39, 80] and limited change in direction movements also reduce measurement errors in these devices [39]. Considering the stochastic nature of Gaelic football, these limitations must be considered by practitioners prior to use.

The typical total distance covered by an elite Gaelic footballer to range between 8,160 ± 1,482 m and 9,222 ± 1,588 m (see Table 1). Values between 1,677 ± 419 m and 1,731 ± 659 m are reported to be completed at high-speed (≥ 17 km·h^{-1}), depending on positional requirements, equating to a range of 18.8% to 20.6% of match-play distance [55, 56]. The stochastic nature of Gaelic football means distances covered during match-play will have an inherent positional profile. Movement requirements will be influenced by a player's specific role and actual field position, which may vary depending on possession of the ball, chosen tactics, and formation [13, 14, 60]. Gaelic football also imposes high acceleration requirements on the competing athletes. Elite Gaelic footballers were observed to complete 166 – 184 accelerations during match-play, with very high-speed running (m; > 22 km·h^{-1}) reported to be 445 – 524 ± m, respectively [54, 57, 91]. The mean total acceleration distance observed was 267 ± 45 m [91], with the peak speed achieved during match-play being 30.3 ± 1.2 km·h^{-1} [54]. Regarding sub-elite match-play, players are reported to cover a mean total distance of 7,145 m during a 60 min game. Due to differences in match duration in sub-elite and elite Gaelic football (60 min vs. 70 min), comparisons are most appropriate using relatives figures [100]. All sub-elite positions are found to cover less relative total distance compared to elite footballers (full back, 95 vs. 112 m·min^{-1}; half back, 113 vs. 137 m·min^{-1}; midfield, 117 vs. 151 m·min^{-1}; half forward, 122 vs. 144 m·min^{-1}; full forward, 92 vs. 112 m·min^{-1}) [55, 58]. The mean total distance of elite adolescent (15.0 ± 0.66 years) Gaelic footballers during a 60 min game is reported to be 5,732 ± 1,047 m, with the three middle positions covering a significantly greater distance compared to full backs and full forwards. The mean high-speed running (m; >17 km·h^{-1}), and very-high speed running (m; >22 km·h^{-1}) for elite adolescent players is 851 ± 297 m, and 198 ± 147 m, respectively [82].

Table 2 near here

Regarding positional variations, the middle three positions cover the greatest distance, and perform a greater volume of high-speed running in comparison to full backs and full forwards [56, 57]. Midfielders are reported to cover the greatest distance (10,245 ± 1,972 m), followed by half forwards (9,464 ± 1,612 m), half backs (8,758 ± 1,543 m), full forwards (7,766 ± 2,173 m) and full backs (7,310 ± 1,163 m). A similar hierarchal trend was evident for high-speed distance with midfielders running the greatest distance (1,921 ± 719 m), followed by half forwards (1,780 ± 507 m), half backs (1,780 ± 507 m), full backs (1,404 ± 533 m) and full forwards (1,248 ± 564 m) [61]. Gradual reductions in match-play running performance is frequently observed in Gaelic football [56, 57], with the three middle positions experiencing the largest percentage decrease in total running performance between halves (midfielder (11%), half back (10.3%) and half forward (8.2%) [56]. Midfielders are reported to have a significantly greater high-speed distance decrement in comparison to all other positions, with half forwards having a greater decrement compared to full forwards and full backs. Half backs and midfielders also had greater sprint distance (m; > 22 km·h^{-1}) reductions compared to all other positions [56]. Decrements in running performance are also present across quarters of play (see Figure 2), with significant reductions in relative total distance (RTD) present in the second and third quarters when compared to the first [56, 57].

Figure 2 near here

Team sport athletes such as Gaelic football players, should be conditioned towards the maximal running requirements of match-play [20, 57, 79]. Understanding these requirements allow players to compete during these short duration periods of increased running, while reducing the risk of non-contact injuries during match-play [29]. Malone, Solan, & Collins (2017) investigated the time dependant "worse-case" (maximal distance that can be expected to be covered over a specified duration) movement requirements (m·min^{-1}) across a season, with differences observed between average, and duration specific running performances. These running performances, irrespective of duration, maintained a positional profile. Specifically, the half back (242 m·min^{-1}), midfield (255 m·min^{-1}) and half forward (241 m·min^{-1}) positions covered increased distances compared to full-backs (194 m·min^{-1}) and full-forwards (196 m·min^{-1}), with similar trends observed for high-speed and sprint based running performances [57]. Further literature is required to understand the impact of contextual variables on duration-specific running performances within elite Gaelic football, in addition to understanding how coaching staff utilise these data daily within training contexts. In contrast, when the average running performance of Gaelic football match-play is considered, this tends to range from 116 to 131 m·min^{-1} [45, 54, 56], with half backs (124 – 141 m·min^{-1}), midfielders (136 – 158 m·min^{-1}) and half forwards (127 – 145 m·min^{-}

^{1}) covering increased distances compared to full backs (98 – 113 m·min^{-1}) and full-forwards (101 – 113 m·min^{-1}). From a practical perspective, sport scientists should attempt to provide both average and duration specific running performance profiles, across key timing points of match or training to key stakeholders within the support staff. We suggest that practitioners understand the specific levels of data [11] within external load analysis, while also respecting the validity, reliability, and sensitivity of specific data points from movement-based technologies.

Figure 3 near here

Physiological Profile

While monitoring movement profiles allows practitioners to understand the external workloads Gaelic football players complete across training and match-play, athletes may experience vastly differing physiological requirements [56]. Therefore, the monitoring of player specific heart rate (HR) responses to exercise provides a universal measure of the physiological strain for a given external workload [48]. Gaelic football match-play places a high physiological strain on the players, approaching 80 % of a player's HR maximum for elite adult footballers [85] and 85 % for elite adolescent players [82], with no variation in beats-per-minute (b·min^{-1}) reported when comparing the first and second half, or the first 10 minutes versus the last 10 minutes of play [84]. The mean peak HR of elite footballers during match-play is reported to be 192 ± 9 b·min^{-1}, with average HR found to be significantly lower in the second half compared to the first [30]. Training sessions have been shown to produce lower HR responses compared to that of matches. The intensity of match-play was only approached periodically in the training regimes of elite players, in that the mean HR exceeded 160 b·min^{-1} for 43% of matches but only 26% of training [84]. Approaching the HR observed in matches for a greater percentage of training will allow players to be more prepared for the physiological demands of match-play. Internal responses to match-play can also be measured through O_2 kinetics. No variation has been observed between the O_2 cost of Gaelic football players expressed at %VO_{2max} between the first and second halves of a Gaelic football match [19]. In agreement with previous team sport literature [5, 94], the %VO_{2max} observed during minor (aged 16 - 18 years) match-play was 70.1 ± 7.8%, [19].

4. Training Load Analysis

Training load can be defined as how a physical task involved within a training or match session creates stress and fatigue, and how well the body adapts and improves fitness per se [30]. Typically, this is measured via internal (physiological and psychological stress imposed by an applied load) and external measures (work done independent of the athlete's internal characteristics) [33]. Technological advancements have provided the opportunity for wearable internal and external load monitoring tools, including GPS and HR monitors [32]. A commonly measured psycho-physiological internal load variable is session-rate of perceived exertion (s-RPE; Borg CR-1-10), the rate of perceived exertion multiplied by the session duration in minutes [74]. Currently within Gaelic football literature a typical training week within elite Gaelic football ranges from 1,705 ± 950 – 3,475 ± 596 AU depending on seasonal periods, weekly context, and team dynamics [46]. The breakdown of this internal load will vary across different constructs of the training process such as match-play, training, individual skills, and other conditioning elements. Typically, s-RPE load is greater when elite players return to club and during the provincial championship, when compared to all other phases of the season [46]. External training load variables are more commonly measured through the use of GPS devices of varying sample rates within elite Gaelic football (4 – 18 Hz). Measures such as total distance (m), high-speed distance (m; > 17 $km \cdot h^{-1}$), sprint distance (m; > 22 $km \cdot h^{-1}$), number of accelerations (n) and metabolic power are commonly monitored [47], with perceived rating of wellness used as a response measure [49]. Typically Gaelic football players will cover between 18,417 ± 1,276 m – 22,369 ± 2,300 m across a training week, with 2,813 ± 890 m – 3,700 ± 722 m at high-speed [46]. These external load variables commonly have a positional profile [13, 14, 60], and may be influenced by time of season and competition phase [42].

Training load has also been reported as a modifiable risk factor for injury within elite Gaelic sports [16]. Specifically, the injury-workload association within Gaelic football has been examined [51]. From an external load perspective, multiple models of external loading have shown associations with injury risk within elite Gaelic football players. These include strong associations (AUC > 0.50) for one weekly loading for total distance, relative distance, high-speed running, sprint distance and accelerations, with similar trends observed for two, three and four weekly which showed a strong positive association within injury risk for all external loading metrics (AUC > 0.50). When intensity measures were considered, relative distance showed an associated risk for injury across one- and two weekly models, but not across three- and four weekly models. When odds risk association was considered, a consistent trend towards moderate loading across external loading measures was apparent within the observed cohort. When total distance was considered, players with low weekly volumes (10,000 – 14,000 m) resulted in increased risk. When compared to moderate (≥ 14,000 – 22,000 m) and high weekly loading (≥ 22,000 m), interestingly, two-, three- and four weekly loading showed a U-Shaped curve with moderate weekly loading resulting in reduced odds risk of injury when compared to the reference groupings. Further, higher chronic training loads have been shown to reduce risk of injury while also allowing for the attainment of increased exposures to higher velocities within training and match-play. Indeed, players who had higher chronic loads tolerated increased distances and exposure to maximal velocity when compared to players exposed to low chronic training and game loads [43]. The determination of individualised optimal workloads would appear prudent within squads to allow for optimal training construction with reduced injury risk. Further investigations will allow practitioners to better understand the accumulation of load across the training week within Gaelic football. This in turn may improve the management of players internal and external training loads across the season.

Injury Profile

Epidemiology of Injury

Gaelic footballers have a reported injury rate of 55.9/1000 h in matches, and 4.6/1000 h in training. 70% of all injuries were sustained to the lower limbs, with hamstring injuries accounting for 22-24% of all injuries (see Table 3) [23]. In elite male adolescent Gaelic football, hamstring injuries were the most common injury (13.3%), with over a quarter (26.7%) of injuries related to overuse mechanisms [72]. A match injury rate of 25.1/1000 h was observed in male collegiate footballers, with lower limb injuries predominant (71.1%), particularly in the hamstring, knee and ankle [71]. Re-current- (47.3%) and early re-current (< 2 months) injuries (14.9%) are frequent in Gaelic football [72], which suggests players may be returning to games without adequate rehabilitation, consequently increasing their injury risk [31, 44]. Elite soccer research examining injury risk when returning to play (given clearance by medical staff to participate fully in team training and match-play) suggested a 7% reduction in risk of injury (odds ratio) with each training session completed between return to play and the first subsequent match appearance [4]. To the authors knowledge, no such investigation has taken place to date within Gaelic football. In addition to re-injury, age appears to increases the incidence of injury, with a positive stepwise relationship between age and injury evident [68]. Mean time loss following injury is 16 [75] to 26 days, varying with age, injury type and seasonal cycle [89].

Table 3 near here

Injury Prevention

Factors to reduce injury rates within Gaelic football have been adopted, including the injury prevention programmes such as a structured warm up known as "GAA 15". Recent literature has examined the impact of the GAA 15 program on neuromuscular outcomes in Gaelic football and Hurling players [76]. The study found that the players allocated to the intervention group recorded greater Y-Balance test scores, and Landing Error Scoring System (LESS) scores than the control group, post intervention [76]. Although the positive effects of the GAA 15 program have been displayed, further research is required to validate the benefits of this warm-up protocol with respect to injury rate.

Optimal pre-season training may be another consideration for managing injury risk. 17% of all hamstring injuries occurred in the initial 7 weeks of the season [89], which may be explained by an increased susceptibility to fatigue due to deconditioning in the off season period. In elite Australian football, players with reduced pre-season eccentric hamstring strength were 2.7 times more likely to sustain an injury than players above this threshold [26]. Therefore, ineffective pre-season training stimuli may impair the readiness of players for competitive cycles, thereby increasing in-season injury risk. Elite Gaelic football literature found that greater aerobic fitness capacity reduced injury risk [50]. Furthermore, as highlighted above the monitoring of external and internal workloads through variables such as the acute: chronic workload ratio (ACWR), percentage change in loading, session to session variance, alterations within wellbeing have all been associated with reduced risk [18, 47, 53].

Practitioners must not forget to be informed by the data and not driven by data, they should utilise multiple measures for understanding in order to develop the most prudent conditioning and injury mitigation strategies.

5. Nutritional Profile

The performance effects of nutritional practices in team sports have been widely examined [1, 12, 37]. Previous literature reported that the average energy intake of elite Gaelic football players was 2,995 ± 236 kcal·d^{-1}. These values equate to a mean carbohydrate (CHO) intake of 5.20 ± 0.2 g·kg^{-1} body mass, a protein intake of 1.45 ± 0.6 g·kg^{-1}, and a fat intake of 1.03 ± 0.01 g·kg^{-1} body mass [81]. A more recent investigation reported that the average energy intake (2,968 ± 533 kcal·d^{-1}) of elite Gaelic football players was significantly less than the average energy expenditure (3,944 ± 527 kcal·d^{-1}), with a mean daily deficit of 976 Kcal. Training days have been shown to elicit the greatest deficits between intake and expenditure [77]. Mean CHO intake was 3.5 ± 0.7 g·kg^{-1} body mass, protein intake was 2.1 ± 0.5 g·kg^{-1}, and fat intake was 1.4 ± 0.3 g·kg^{-1} body mass [77]. The notable in difference in CHO intake reported in the studies discussed highlights the requirement for further education and support regarding nutritional intake by Gaelic footballers. Analysis regarding Gaelic football game preparation (2 days pre-game and match day) and recovery (2 days post-game) indicate that both elite and sub-elite players consumed inadequate amounts of CHO to support optimal performance and recovery [70]. Adequate energy intakes are necessary to allow Gaelic footballers to meet the energy requirements of match-play and training. CHO intakes of 5-7 g/kg/day are recommended for moderate intensity training (~ 1h per day) [98]. The findings of Gaelic football literature suggests that the current recommendations of 7 g /kg of body mass/day of CHO may be sufficient to fuel training and achieve energy balance during the pre-season training period [77]. The current literature available suggests that the dietary practices of sampled players are insufficient to meet nutritional recommendations, especially relating to energy and carbohydrate intake [3, 77]. Dietary analysis of elite and sub-elite adult Gaelic footballers reported a significant energy deficit at group level, with CHO intakes also significantly below the guidelines highlighted above for moderate intensity training [62]. In particular, it appears that training days are of concern, with players not adjusting energy intake to cope with the increased energy cost [77]. The nutritional practices reported for elite Gaelic football players may explain the decreases in running performance across both halves and quarters, as players' energy substrate levels become depleted [54, 57]. Gaelic football research examining a high CHO diet (7 g·kg^{-1}) versus an energy-match low CHO diet (3.5 g·kg^{-1}) in a simulated match-play protocol discovered HSD to be significantly greater in the second half for the high CHO group [78]. These findings indicate that a high CHO diet can reduce declines in physical performance during simulated Gaelic football match-play. As such, an increase in education on nutritional strategies for elite Gaelic footballers should be recommended relative to training and match-play demands to prevent detrimental reduction to performance. Analysis of the nutritional knowledge of Gaelic footballers via an online survey demonstrated that 44.3 ± 12.7% of elite and sub-elite adult male footballers (n = 152) classified as "poor" regarding nutritional knowledge, with those with previous nutritional education scoring significantly higher [86]. The nutritional practices of the majority Gaelic football players remain relatively unknown, and require additional research to improve practitioners understanding as to the nutritional status of players prior to training and match-play.

6. Future Directions

While numerous investigations have taken place since 2001, we are still only beginning to understand the training process within Gaelic football. Firstly, further understanding is required with respect to the principles and methodologies employed from a coaching and conditioning perspective within Gaelic football. These studies may elucidate the time allotted to specific coaching and conditioning methodologies within the typical Gaelic football team preparation process across the totality of a season. Although a positional profile exists within the sport across physical capacities and match-play [13, 14, 60], further evidence of positional variations across physical and physiological profiles would allow coaches and practitioners to effectively compose specific training regimes to suit positional demands. With more research, the link between athletic profiles and match-play performance can be understood. Further, understanding the impact of different seasonal periods on the anthropometric and performance profiles across playing roles may aid player development. If role-specific variations exist and are understood, such knowledge may enhance the transitioning process of sub-elite to elite status, and non-starter to starter status. Such research may also aid profiling the key developmental stages, and allow for the development of a standardised understanding of the progression of strength, power and performance profiles from underage to senior level. To gain this understanding, more applied interventions across Gaelic football cohorts from aerobic fitness development to strength-based interventions is required. In addition, the need for more objective information regarding internal loading and its association with variations in fitness parameters is required. In other field team sports, such as soccer [40, 96] and Australian football [10], the impact of detraining has been well examined. To date, an off-season detraining intervention is yet to be completed within the sport. Understanding the impact of cessation of training on performance will aid future coaches on how to manage player wellness during this period. Additional intervention studies are required to understand if current training practices are effective at improving Gaelic football players from a physical, technical, and tactical perspective. Aligned with this, it would appear prudent to further understand the movement profile of the game and how this is changing year on year. Further, researchers need to begin to link movement demands and performance analysis data together to paint a more representative picture of the game of Gaelic football. Understanding around the contextual factors of performance within Gaelic football needs to be appraised. The increased adherence of teams to a national injury database for Gaelic games may also help practitioners understand the key injury epidemiology within the sport across training and match environments and allow for the development of strategies to mitigate against future injuries. It is well documented that Gaelic footballers tend to prepare inadequately for match-play and training regarding nutrition [77], with previous research highlighting that these athletes may benefit from evidence-based nutrition education interventions [87]. Therefore, further educational work is required from governing stakeholders to address the gap between nutritional knowledge and the practical application of this knowledge.

7. Conclusion

Gaelic football players are amateurs, with a professional ethos; training between three and five times per week, with weekly training and playing loads similar to professional players. Since the publication of the last review in 2008, Science and the Gaelic Sports: Gaelic Football and Hurling, the examination of the physical and physiological demands of Gaelic football has increased exponentially. Coaches now have a greater insight into the typical anthropometric and performance profile of Gaelic footballers at various grades and ages. Medical practitioners have been provided with more information on the epidemiology and risk factors of injury within Gaelic football cohorts. The professional ethos of modern-day Gaelic football has highlighted the lack of knowledge and education regarding the nutritional recommendations of competing athletes. Nutritional strategies relative to training and match-play demands are required to prevent detrimental reduction in performance. At elite level, the inclusion of a sports scientist as a member of staff is becoming increasingly common, and thus, many of the queries arising from this review will begin to be addressed.

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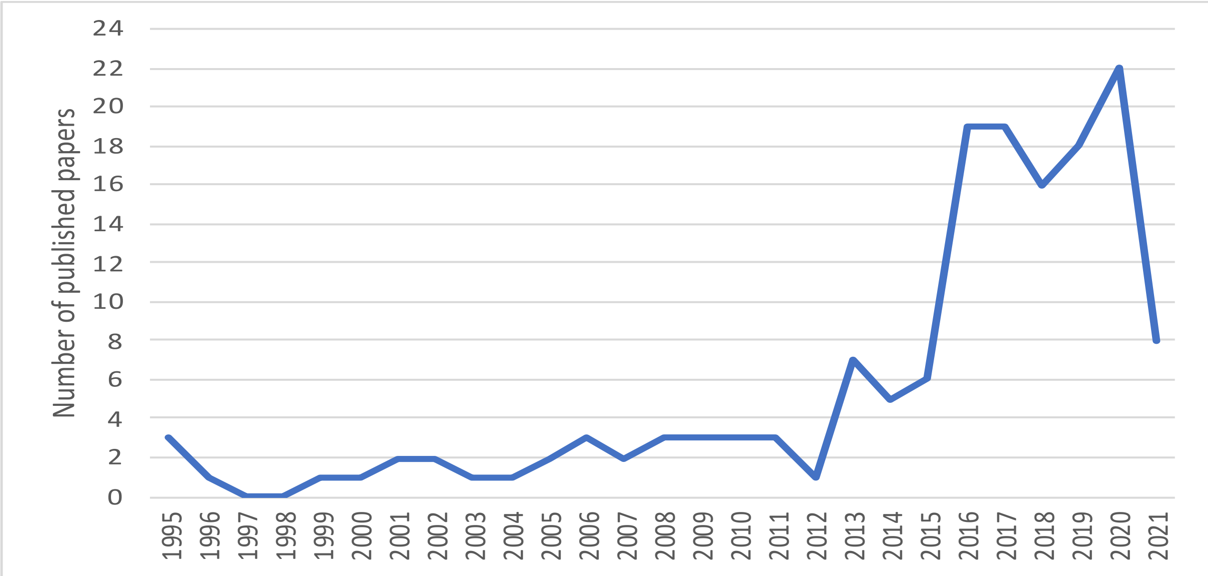
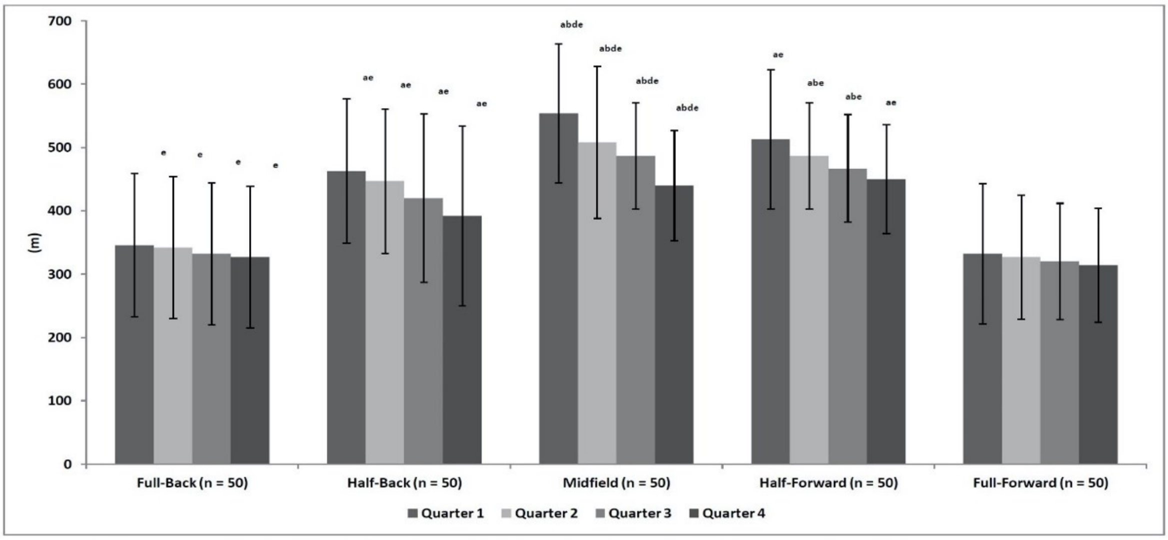
Figure 1. The number of published papers in Gaelic football by year.



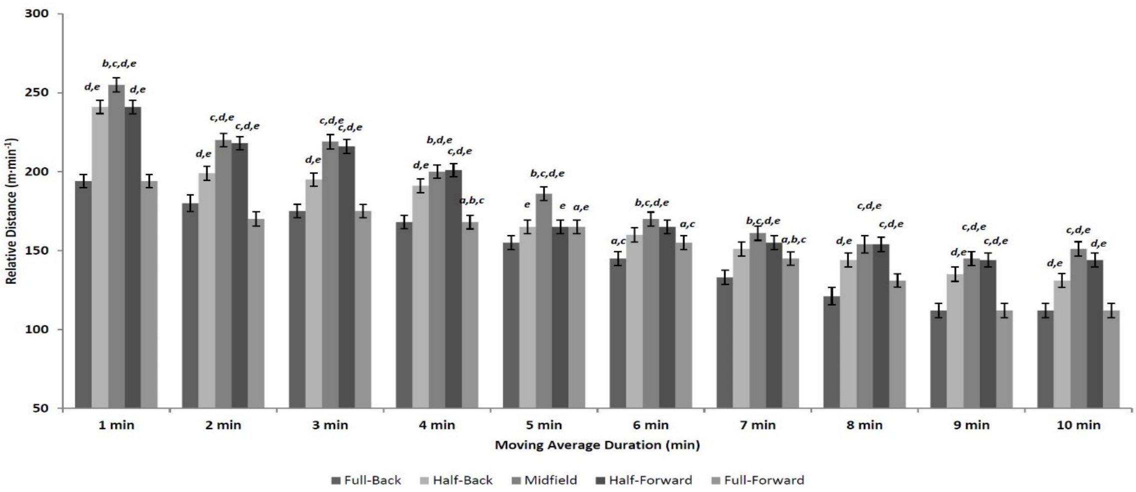
Note – Papers by year obtained from Pubmed.gov and Scopus.com, searching “Gaelic football” AND ‘nutritional demands’, ‘running performance’ and ‘physiological demands’. The result includes peer-reviewed studies only. 2021 result is January - October included.

Figure 2. Positional match-play variations in high-speed running distance across quarters [54].



Significantly different from a- full-backs, b - half-backs c - midfielders, d - half-forwards, e - full-forwards (all p<0.001).

Figure 3. Duration specific running performance of elite Gaelic football players [57].



Significantly different from ***a*** Midfielders, ***b*** Half-Forwards, ***c*** Half-Backs, d Full-Forwards, e Full-Backs (all $p < 0.001$)

Table 1. Anthropometric and performance profile of male Gaelic footballers. Data are presented as a range of mean.

	Anthropometric characteristics				Performance characteristics					
Description of population	Stature (cm)	Body mass (kg)	Σ7 Skinfold (mm)	Adiposity (%)	CMJ height (cm)	5 m sprint (sec)	10 m sprint (sec)	20 m sprint (sec)	Yo-YoIRT1 (m)	Yo-YoIRT2 (m)
Elite, adult [9, 21, 36, 64, 81, 93, 95]	179.0 – 183.7	79.2 – 86.5	81.3	11.3 – 14.9	38.0	1.10	1.82	3.09		1,450
Elite, adolescent [17, 67]	178.1 – 182.0	72.1 – 78.1	56.9 – 66.8	8.7 – 10.0	43.3 – 51.0	0.92 –1.13		2.86 – 3.22	1,465	593
Sub-elite, adult [15, 81, 88]	180.4 – 181.0	78.8 – 80.9		11.6 – 18.3	45.4	1.08	1.86	3.13	2,365	
Sub-elite, adolescent [67]	181.0	82.1	79.6	14.0	45.9	0.94		2.95		483
Collegiate [65]	181.0	81.6		14.5						

Abbreviations: Σ7 = sum of seven skinfold, CMJ = countermovement jump, Yo-YoIRT = Yo-Yo Intermittent Recovery Test

Sum of seven skinfold sites = abdomen, supraspinal, subscapular, bicep, tricep, quadricep, gastrocnemius

Table 2. Match-play running demands of male Gaelic footballers

Description of population	TD (m)	RTD ($m \cdot min^{-1}$)	HSD (m; > 17 $km \cdot h^{-1}$)	RHSD ($m \cdot min^{-1}$; 17 $km \cdot h^{-1}$)	SD (m; > 22 $km \cdot hr^{-1}$)	Max velocity ($km \cdot h^{-1}$)	Mean velocity ($km \cdot h^{-1}$)	Number of accelerations (n)
Elite, adult [55, 56, 63, 91]	8160 – 9222	116	1145 – 1731	15 – 25	445 – 524	29.1 – 30.3	6.5	166 – 184
Sub-elite, adult [59]	7145 ± 1175	109 ± 17		14 ± 5		29.1 ± 1.5	6.6 ± 1.0	
Elite, adolescent [82]	5732 ± 1047		851 ± 297		198 ± 147			

Abbreviations: TD = total distance, RTD = relative total distance, HSD = high-speed distance, RHSD = relative high-speed distance, SD = sprint distance

Table 3. Incidence of injuries in male Gaelic football. Data are presented as a range of mean.

Description of population	Injuries per 1000 hours			Regional distribution of injuries (%)					Type of injury (%)	
	Total	Game	Training	Thigh	Knee	Ankle	Pelvis/Groin	Other	Contact	Non-contact
Elite, adult [6, 24, 51, 52, 68, 69, 75, 90]	12 – 13	30 – 97	2 – 7	17 – 43	8 – 16	10 – 11	9 – 13	28 – 45	11 – 32	68 – 89
Sub-elite, adult [99]	14	51	6	24		13				
Sub-elite, adolescent [72, 74]	5 – 21	9 – 44	3 – 8	13	19	12	8	48	36	64
Collegiate [71]	13	25	7	22	14	11	6	47	21	79