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Linear Sprint Testing Methods in Gaelic Games: A Systematic Review

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ABSTRACT

Background: The most common method used to monitor acceleration and maximum sprinting speed performance is via a linear sprint test. When conducting linear sprint monitoring it is important to ensure the relevant methodologies are all considered and standardised to ensure valid and reliable results. **Objectives:** The aims of this review are 1) to systematically search the Gaelic games literature and identify studies that have assessed linear sprint performance, 2) to report the methodological variables employed in each study, and 3) to report normative values for linear sprint performance. **Methods:** This systematic review searched for literature in five databases. Key details (i.e., playing standard, timing technology, split times over various distances), were extracted. A methodological reporting rating tool was created to grade each study. **Results:** Twenty-two studies; one in camogie, twelve in hurling and ten in men's Gaelic football were included. No study monitoring ladies Gaelic football was identified. Sprint times over 10 m ranged from 1.71 ± 0.08 to 2.11 ± 0.77 s between hurlers and men's Gaelic footballers. The mean rating for methodological reporting was 42%. All included studies failed to report some key methodological variables. **Conclusions:** This review highlights the importance of utilising and reporting the methods used to conduct accurate sprint performance monitoring across time and allow comparison between studies. The methodological rating tool can be used by practitioners as a 'checklist' to ensure sprint monitoring is conducted in a valid and reliable manner. Future research should seek to examine linear sprint performance in ladies Gaelic football.

Key words: Gaelic football, Hurling, Camogie, Speed, Monitoring, Sprint Performance

INTRODUCTION

Gaelic games are comprised of four primary native Irish field-based team sports; Ladies Gaelic football, Male Gaelic football, camogie, and hurling. Camogie and hurling are the female and male versions of the same sport. The two primary playing levels are club (sub-elite) and inter-county (elite). Elite teams are comprised of the most talented club players. Games within all four sports are contested by two teams of fifteen players. All games are sixty minutes in duration except for the two elite male sports (70 minutes). Games are typically played on a natural grass rectangular pitch typically 140 m x 90 m (Cullen et al., 2017). Gaelic football is played with a leather football slightly bigger and heavier than a soccer ball. Hurling and camogie have a similar objective to Gaelic football, however both sports use a stick and ball. The objective of the four games is to kick or strike the ball either between and above the crossbar of H-shaped goalposts (1 point) or under the crossbar (3 points) (Young et al., 2019).

All of the four Gaelic game sports are comprised of high-intensity short duration efforts intermingled with low- to moderate- intensity passages of play (Duggan et al., 2020; Kelly et al., 2021; Young et al., 2018). For successful performance positions require appropriately developed levels of multiple physical qualities i.e., strength, speed, power, anaerobic and aerobic endurance (Byrne et al., 2018; Connors et al., 2021; Duggan et al., 2020; Kelly & Collins, 2018). The importance of speed in Gaelic games can be observed in the volume of sprinting performed during competition (ladies Gaelic football 630 ± 287 m; men's Gaelic football 445 ± 69 m; camogie 162 ± 102; hurling 415 ± 140 m) (Malone, Solan, & Collins, 2017; Malone et al., 2023; O'Grady et al., 2022; Young et al., 2019). One goal of training is often to improve these physical qualities simultaneously to enhance on-field performance (Duggan et al., 2020). Longitudinal monitoring of physical qualities is regularly conducted at specific times during the season to assess training adaptation (Kelly & Collins, 2018). Consid-

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ering practitioner experience and equipment available it is important that appropriate tests are selected.

The assessment of speed performance is most commonly completed via a linear or straight-line sprint test (Altmann, Ringhof, Neumann, Woll, & Rumpf, 2019). This objective of this test is to run in a straight line for the pre-determined distance in the shortest time possible. Photocells, often referred to as 'timing gates' and will be referred to as such hereafter, are most commonly used to monitor linear sprint performance (Haugen & Buchheit, 2016). Although a simple test to administer, recent reviews have highlighted some methodological variables (i.e., timing gate height, the number of timing gate beams, starting distances, surface etc.) that influence the validity and reliability of the linear sprint performance test (Altmann et al., 2019; Haugen & Buchheit, 2016). Consequently, comparison of normative values in the literature can be difficult when different methods are employed to determine outcomes (Haugen & Buchheit, 2016; Haugen, Tønnessen, & Seiler, 2012). A review of the methodological factors employed during linear sprint performance tests in Gaelic games has yet to be completed. In a Gaelic games context, practitioners and researchers must be cognisant of the influence different methodological factors have on reported sprint performance times. If such details are not reported in sufficient detail, comparison between results from different studies is difficult. Furthermore, observation of 'true' changes in sprint performance requires precise monitoring using appropriate methods longitudinally. This review will improve practitioners' awareness of the different factors which affect sprint monitoring and can thus allow them to make more informed decisions concerning the selection of the various factors.

Therefore, the aims of the current review are 1) to systematically search the Gaelic games literature and identify studies that have assessed linear sprint performance, 2) to report the methodological variables employed in each study, and 3) to report normative values for linear sprint performance.

METHODS

Literature Sources and Search

A systematic search of the literature was conducted in accordance with the PRISMA 2020 guidelines for systematic reviews (Page et al., 2021). Five electronic databases were searched using the selected combination of the keywords and phrases in CINAHL with full-text, PubMed, Scopus, SPORT Discus with full-text, and Web of Science. The selected keywords and phrases were identified via the pilot searching of keywords utilised in eligible studies known to the authors. All fields were searched in each database from inception to the 10th May 2022. The final search phrases were combined as follows: «Ladies Gaelic football» OR "Gaelic football» OR «Gaelic games» OR hurling OR hurlers OR camogie NOT soccer AND "Linear sprint" OR "speed test" OR "sprint test" OR "sprint performance" OR "speed performance" OR "speed profi*" OR "sprint tim*" OR "sprint velocity" OR "physical performance" OR "performance characteristics" OR "performance profile". All timing technologies were permitted provided testing involved a linear sprint performance test. All record types were permitted in the search (theses, conference papers, book chapters etc.). Additional studies were identified from the reference lists of included studies, searched, and imported from Google Scholar.

Eligibility Criteria and Study Selection

To import the search results a reference management software (Zotero, 6.0.8, USA) was used. Duplicate items were identified and removed. Remaining studies were screened over two phases. The first was by title and abstract which led to the removal of non-relevant studies. The second screening involved a full-text review of all remaining studies to assess for eligibility. The inclusion criteria were as follows: a) Any record type (journal articles, books, conference papers etc.,) that assessed linear sprint performance in Gaelic games or training intervention studies that assessed linear sprint performance in Gaelic games; b) Study participants were required to be ladies or men's Gaelic football, camogie or hurling athletes; c) Study participants were required to have a mean age ≥ 16 years old; d) Studies must be available in English. Studies were excluded for the following reasons: a) the same data set from a previous publication was used (salami slicing), or b) studies or authors that did not provide results of sprint performance purportedly assessed.

Data Extraction and Synthesis

Relevant data were extracted from included studies to an appropriately designed Microsoft Excel (Microsoft, 16.62, Redmond, WA, USA) spreadsheet. Relevant data were compartmentalised in the spreadsheet across five tabs; study characteristics, timing technology, starting procedures, extraneous variables, and normative values. The study characteristics tab extracted the following data: author's names, title, year of publication, record type, playing standard/grade, group/position, number of participants, age in years, body mass (kg), and height (m). The timing technology tab extracted the following additional data: timing technology used, brand, model, and other relevant technological information. The starting procedures tab extracted the following additional data: starting position, false start criteria, starting distance from initial timing gate, the number of trials performed, the trial reported (i.e., the fastest, the mean), the length of the inter-trial recovery (minutes), the reliability (i.e., inter-day, inter-trial), and any other additional relevant information (i.e., cone placed beyond final timing gate to discourage early deceleration). The extraneous variables tab extracted the following additional data: time of year/season data was collected, time of day testing was performed, instructions given to participants, clothing worn, footwear worn, surface/location of testing, and environmental conditions (if applicable). The normative values tab extracted the following additional data: position of participants (if applicable) or category (i.e., starter, non-starter etc.), and the sprint performance times across different split distances (i.e., 5 m, 10 m, 20 m, 30 m etc.).

Missing Data

A number of studies eligible for inclusion were missing the results of linear sprint performance. Results were requested from the first author of eligible studies. Studies were removed from the review if the authors did not respond (n = 3).

Linear Sprint Performance Methodological Reporting Rating Tool

A ratings scale was developed to assess methodological variables reported for each study based on previous work (Martin & Beckham, 2020). Ratings of each study were based on methodological variables mentioned in the current review (see results and discussion section for further detail). Ratings per item ranged from 0 to 1, 2, or 3 depending on degree of variability within that specific variable (Table 1). In total sixteen items were included to assess methodological reporting. Items included were discussed between authors (EMcG, RH, KB, ML) and those included were agreed by consensus. One author (EMcG) rated the items for each study.

RESULTS

Search Results

In total, the search of five databases returned four hundred and seventy-nine (n = 479) search results. First, duplicate items of the search results were removed (n = 94). Studies were then screened by title and abstract which led to the removal of three hundred and fifty-eight (n = 358) studies. Twenty-seven (n = 27) studies remained for a full-text review. Fifteen (n = 15) studies were eligible for inclusion after the full text review. Twelve (n = 12) studies remained after three (n = 3) were removed as normative values were absent from the papers and were not provided from the authors upon request. An additional ten (n = 10) eligible studies were identified and included based on screening the reference lists from included studies. In total, twenty-two (n = 22) studies were included in the review (Figure 1).

Study Characteristics

Study characteristics and descriptive statistics of the twenty-two included studies are reported in Table 2. One study assessed linear sprint performance in camogie, twelve in hurling, and ten in men's Gaelic football. None of the included studies assessed linear sprint performance in women's Gaelic football. One study assessed linear sprint performance in both hurling and men's Gaelic football (McIntyre, 2005).

Timing Technologies and starting Procedures Reported for Linear Sprint Performance

Timing technologies and starting procedures used to assess linear sprint performance are reported in Table 3. Two studies failed to report the type of timing technology used. Seven studies used Witty Microgate timing gates to monitor performance. One study stated the number of timing gate lights used i.e., dual-beam, and one study reported the specific height at which timing gates were placed (1 m). Twelve (55%) studies reported using a starting distance of 0.5 m behind the initial timing gate prior to sprinting. One study used a distance of 0.3 m. The remaining nine studies (41%) did not report the starting distance. Nine studies reported assessing linear sprint performance over three trials while the remaining 13 (59%) did not report the number of trials performed. Only three studies (14%) reported the test reliability.

Extraneous Variables Reported for Linear Sprint Performance

Extraneous variables such as time of season or day, instructions/start signal given, footwear/clothing worn, surface/location, and environmental conditions are reported in Table 4. Sprint performance was most commonly assessed during the pre-season period as reported in 45% of studies. Only three papers reported the specific instructions participants were given prior to the test. Ten studies (45%) did not report where testing took place while the remaining twelve studies (55%) stated that tests were performed in an indoor facility.

Linear Sprint Performance Methodological Reporting Rating Tool

Ratings for linear sprint performance tests are reported in Table 5. The mean rating across all included studies was 10.5/25 or 42%. The highest rating was 68% (17/25).

Normative Values for Linear Sprint Performance

Normative values by sport for linear sprint performance are presented (mean ± SD) in Figure 1a, in Figure 1b and in Figure 1c. The most commonly assessed split distance was 20 m which was assessed in 19 studies (86%). Seventeen studies (77%) assessed 5 m splits while 10 m times were assessed in fifteen studies (68%). Split times over 15 m, 30 m, and 40 m were only assessed once each.

DISCUSSION

The current review is the first to investigate linear sprint performance in Gaelic games, report the methods employed in each study, and collate normative values by sport. Ninety-five percent (95%) of the 22 studies included in the review were conducted in either men's Gaelic football or hurling. Linear sprint performance has yet to be investigated in Ladies Gaelic football. Numerous studies failed to report key relevant methodological variables. Collated normative values should be interpreted with caution and are difficult to compare between studies as the outcomes were determined through unknown or different methods.

Methodological Reporting Rating Tool

There is a clear absence of methodological reporting for sprint performance tests as sixteen studies (73%) were given a rating of less than 50% on the reporting rating tool

Table 1. Linear sprint performance methodological reporting rating tool

Item#	Outcome assessed	Ratings
All items		0=not reported
1	Participant competitive level	1=reported vaguely (e.g. club) 2=reported specifically (e.g. club division 1)
2	Timing technology	1=reported vaguely (e.g. timing gates were used) 2=reported generally only (e.g. Witty Microgate timing gates were used) 3=reported specifically (e.g. Single-beam Witty Microgate timing gates)
3	Placement height	1=reported generally only (e.g. radar gun was placed at hip height) 2=reported specifically (e.g. beams were placed at 1.00 and 1.15 m respectively)
4	Starting position	1=reported generally only (e.g. standing start) 2=reported specifically (e.g. staggered crouch start with preferred front in front)
5	False start criteria	1=reported specifically (e.g. trials voided if participants rocked back prior to initiating movement)
6	Starting distance from technology	1=reported specifically (e.g. participants started 0.5 m behind the first timing gate or the radar gun was placed 5 m behind the participants)
7	Number of trials performed	1=reported specifically (e.g. participants performed three trials)
8	Trial used for data analysis	1=reported specifically (e.g. the mean of the three trials was used for analysis)
9	Recovery time between trials	1=reported specifically (e.g. participants were given 3 minutes of passive recovery between trials)
10	Reliability reported	1=reported specifically (e.g. ICC was 0.92, 0.95, and 0.96 for 5, 10, and 20 m times)
11	Time of testing relative to competition calendar	1=reported generally only (e.g. during pre-season) 2=reported specifically (e.g. last week of pre-season in January before league)
12	Testing time of day	1=reported generally only (e.g. testing took place at the same time/in the morning) 2=reported specifically (e.g. testing took place between 0900 and 1400 each day of testing)
13	Instructions given to participants	1=reported specifically (e.g. participants were told to "run as fast as possible")
14	Clothing and footwear reported	1=reported one of two (e.g. trainers were worn on both testing days/ jersey and shorts were worn) 2=reported both (e.g. trainers and a jersey and shorts were worn on both testing days)
15	Location/surface reported	1=reported generally only (e.g. testing took place indoors) 2=reported specifically (e.g. testing took place indoors on a rubberised athletic track)
16	Results reported	1=reported specifically (e.g. table showing all tested split times reported)

(Table 5). The dearth of reporting of methodological variables inhibits replication of studies as the methods employed are not fully clear. Comparison between-studies should therefore be limited if the methods are not similar. In future it is important that practitioners and researchers are aware of these variables and report the methods employed.

Disparity between Sports Examined

Twenty-two studies met the eligibility criteria to be included in the current review. Nine studies assessed linear sprint performance in Men's Gaelic football, 11 in hurling, one assessed both hurling and Men's Gaelic football, and one in camogie. Notably, linear sprint performance was not assessed in Ladies Gaelic football.

Future research should investigate linear sprint performance in both camogie and Ladies Gaelic football. The apparent dearth of literature on both female sports limits comparison when conducting linear sprint performance testing. Normative values for these athletes allows practitioners to identify potential areas of improvement for their team and/ or individual players.

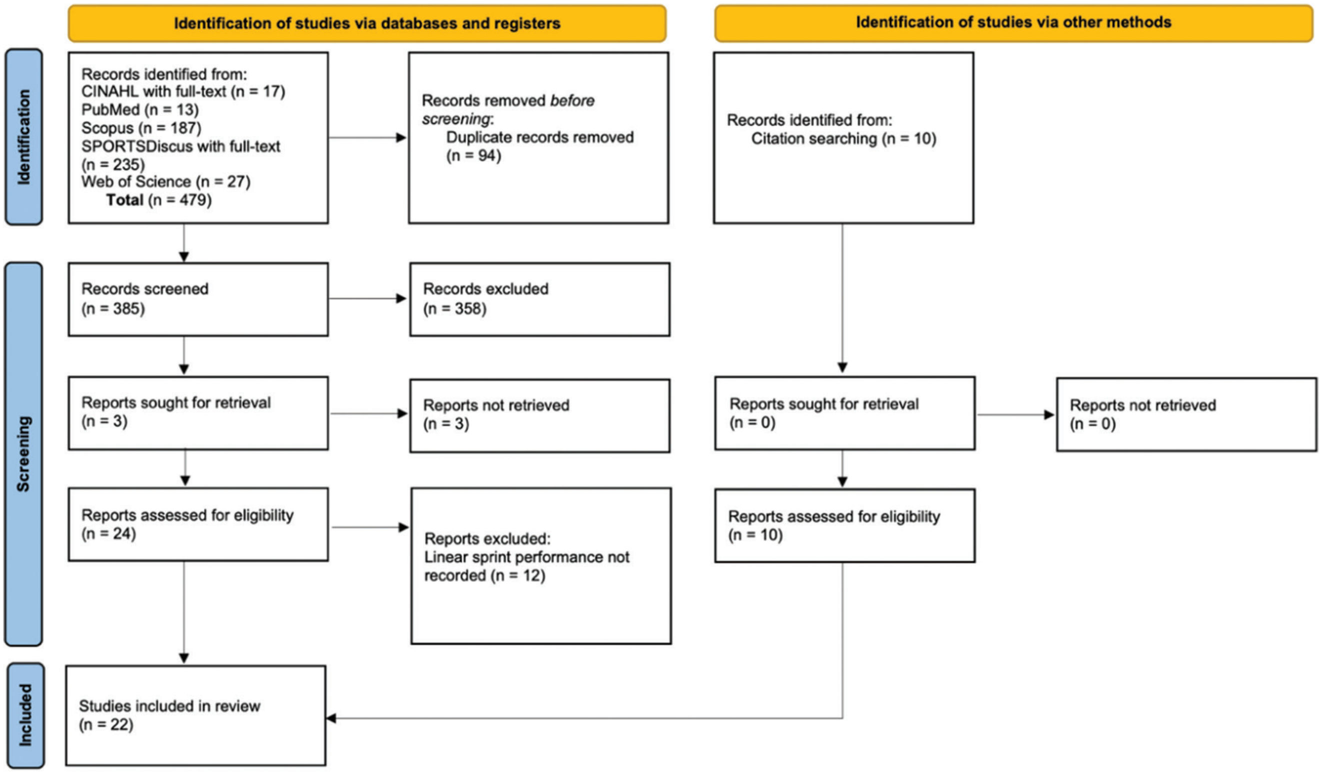

Figure 1. PRISMA 2020 flow chart

Linear Sprint Performance

Linear sprint performance in team sport athletes can be split into short sprint performance (≤ 20 m) and long sprint performance (> 20 m) (Nicholson, Dinsdale, Jones, & Till, 2021). Short sprint performance captured via time to completion is often used as a surrogate measure of acceleration (i.e., 0-5 m, 0-10 m, 0-10 m, 0-20 m) (Nicholson et al., 2021) whereas long-sprint performance can be used as an indirect measure of maximum sprinting speed (Clark, Rieger, Bruno, & Stearne, 2019). Seventeen studies (77%) assessed 5 m performance, fifteen (68%) 10 m while nineteen (86%) assessed 20 m performance. In contrast, only three studies assessed long sprint performance (Duncan, 2006; Loughran et al., 2017; Strudwick et al., 2002).

Acceleration has been argued to be of greater importance than maximum sprinting speed in field-based team sports (Simperingham, Cronin, & Ross, 2016). Examination of match-play demands in male Gaelic football reveals players perform over four times as many accelerations (defined as a change of ≥ 7.2 km·h^{-1}/≥ 2.0 m·s^{-2} in ≤ 1 s) as reported sprints (defined as ≥ 22 km·h^{-1}/≥ 6.1 m·s^{-1}) (181 ± 39 accelerations versus 43 ± 15 sprint efforts) (Malone et al., 2017). The greater number of acceleration efforts performed during men's Gaelic football match-play may help explain why many Gaelic games studies have examined short-sprint performance in comparison to longer sprint performance.

The lack of research undertaken on long-sprint performance may also partly be due to practical limitations. Linear sprint performance assessment is often conducted indoors (Table 4). Assessment of long-sprint performance may not always be feasible in indoor facilities due to limited space. For example, a 40 m linear test requires additional space following the end of the testing zone for the player to decelerate and stop safely. Although timing gates can be positioned to effectively capture long-sprint performance, teams may only have access to a limited number of devices. Consequently, the assessment of short-sprint performance may be prioritised over long sprint performance due to time constraints. Future studies examining the effects of interventions to enhance sprint performance should endeavour to assess long sprint performance in addition to performance over 20 m. Capturing sprint performance over longer distances (i.e., 0-30 or 40 m) ensures the total influence of an intervention can be examined on sprint performance.

Timing Technologies

Speed qualities can be assessed using a variety of different technologies (Haugen & Buchheit, 2016). In Gaelic games timing gates were found to be the most commonly used technology with 91% of studies reporting using them (Table 3). The remaining 9% of technologies used were not reported. Timing gates are typically positioned along a running course with a reflector positioned opposite. Timing gates emit an infrared beam with timing triggered once the beam is broken. Timing gates can consist of single-, split-, double- or triple- light beams. Single-beam timing gates can be problematic as timing can be incorrectly triggered by swinging arms or legs; accuracy and reliability of timing are therefore affected (Haugen & Buchheit, 2016). The development of dual- and triple- timing gates have reduced the prevalence of premature timing (Altmann et al., 2015). Subsequently, dual-beam timing gates have been recommended to researchers and coaches who require timing accuracy to be precise and

Table 2. Characteristics of included studies

Author	Playing Standard	Sample			
		n	Age (years)	Body mass (kg)	Height (m)
		Camogie			
Connors et al., (2021)	Senior inter-county (Division 1)	45	22.3±3.5	68.4±7.4	1.69±0.6
		Hurling			
Byrne et al., (2020)	Club & collegiate	14	20.8±1.3	74.9±6.1	1.77±0.0
		15	20.6±1.0	75.7±6.3	1.78±0.01
Byrne et al., (2020a)	Club & collegiate	13	21.1±2.1	77.8±4.9	1.80±0.04
Byrne et al., (2018a)	Club & collegiate	18	21.2±2.1	79.2±6.5	1.80±0.04
Byrne et al.,(2018b)	Club & collegiate	10 (COMP)	21.80±2.90	76.6±7.4	1.79±0.06
Byrne et al., (2020b)		11 (SPRINT)	21.80±2.90	76.6±7.4	1.79±0.06
Byrne et al., (2019)	Club & collegiate	8	20.3±2.3	80.6±2.5	1.86±0.03
Byrne et al.,(2018c)	Club & collegiate	12	20.3±2.3	80.6±2.5	1.86±0.03
Collins et al., (2014)	Senior inter-county (Division 1)	4[a]	25.0±4.0	88.7±5.7	1.84±0.04
		8[b]	25.0±4.0	84.2±9.0	1.86±0.05
		8[c]	25.0±4.0	79.9±4.9	1.80±0.06
		6[d]	25.0±4.0	80.2±5.8	1.82±0.05
		8[e]	25.0±4.0	75.5±8.6	1.77±0.09
		7[f]	25.0±4.0	79.6±5.6	1.83±0.03
Duncan (2006)	Senior inter-county	1	24	81.2	1.73
Malone et al., (2020)	Senior club (Division 1)	30	24.0±4.0	78.0±3.0	1.80±0.02
Malone et al., (2017)	Senior club (Division 1)	24 (SSG)	25.0±6.4	80.5±3.2	1.80±0.2
		24 (Control)	25.0±6.4	80.5±3.2	1.80±0.2
Malone et al., (2021)	Senior club (Division 1)	25	24.5±2.2	81.5±4.5	1.79±0.03
McIntyre (2005)*	Senior inter-county	30	24.0±5.0	83.0±9.0	1.77±0.06
		Men's Gaelic football			
Boyle, Warne, & Collins (2021)	Senior inter-county	12[a]	26.3±4.3	89.9±5.8	1.87±0.06
		34[b]	24.3±3.8	83.7±6.8	1.84±0.06
		28	25.2±3.9	85.9±8.3	1.82±0.06
		20	23.8±3.3	85.9±8.3	1.86±0.04
		34	23.9±3.1	83.7±7.6	1.83±0.06
		34	24.2±4.1	85.8±8.9	1.83±0.06
		80	24.6±3.6	85.6±9.1	1.84±0.06
		82	24.2±3.5	84.0±6.5	1.84±0.06
Cullen et al., (2013)	U18 Secondary School 'A' level	13[a]	17.2±0.8	72.1±8.7	1.83±0.04
		113[bc]	17.0±0.7	81.6±13.7	1.77±0.06
		30[d]	17.3±0.7	71.0±6.9	1.86±0.06
		109[ef]	16.8±0.7	69.7±7.4	1.77±0.06
Kelly et al., (2021)	Club	13 (SIT)	26.5±4.9	79.7±9.6	1.79±0.08
	Club	12 (ET)	25.4±2.6	76.6±9.7	1.79±0.05
Kelly & Collins (2018)	Senior inter-county (Division 1)	26	26.0±6.6	85.4±10.2	1.84±0.07
Loughran et al., (2017)	Collegiate & inter-county	17	20.9	79.9±10.9	1.79±6.4
McIntyre (2005)*	Senior inter-county	29	24.0±6.0	81.0±9.0	1.79±0.06
Mooney et al., (2019)	U20 inter-county	40	19.10±0.63	78.1±6.6	1.81±0.05
	U20 club	14	19.22±0.55	82.1±9.6	1.81±0.04
	U20 inter-county starters	15	19.3±0.7	78.6±7.8	1.82±0.10
	U20 inter-county non-starters	22	19.0±0.6	78.0±5.5	1.81±0.05

(Contd...)

Table 2. *(Continued)*

Author	Playing Standard	Sample			
		n	Age (years)	Body mass (kg)	Height (m)
O'Leary (2016)	Senior inter-county	24	NR	NR	NR
	Collegiate & club	20	NR	NR	NR
	Secondary school	27	NR	NR	NR
Shovlin et al., (2018)	Senior inter-county	28[b]	26.0±6.0	84.0±6.3	1.82±0.07
		33[c]	26.0±6.0	81.8±8.0	1.81±0.04
		24[d]	26.0±6.0	84.2±5.8	1.87±0.05
		33[e]	26.0±6.0	81.6±6.0	1.84±0.05
		30[f]	26.0±6.0	86.9±12.6	1.84±0.07
Strudwick et al., (2002)	Senior inter-county	33	23.0±5.0	79.2±8.2	1.79±0.07

[a]goalkeeper, [b]full-back line, [c]half-back line, [d]midfield, [e]half-forward line, [f]full-forward line, [g]starters, [h]non-starters, *COMP* Composite training, *ET* Endurance training, *NR* Not reported, *SIT* Sprint interval training *SPRINT* Sprint training, *SSG* small-sided games, *Players assessed in hurling and men's Gaelic football

reliable (Haugen, Tønnessen, Svendsen, & Seiler, 2014). Only one included study reported using a dual-beam timing gates (O'Leary, 2016). Work by Haugen et al. (2014) reported time differences of -0.05 to 0.06 seconds over 20 m between single- and dual- beam timing gates in a mixed group of junior elite track and field athletes. Evidently, comparison between single- and dual- beam timing gates may be misleading. In the current review comparison between results is difficult due to the lack of technological information included.

Post-processing technology (error-correction technology) has been developed to attempt to correct the false time triggering common in single-beam timing gates. This technology analyses the length of time the infrared light beam(s) are broken. Timing is triggered the instant the longest break in the beam is initiated based on the assumption that the athlete's torso will break the beam for the longest period of time (in comparison to arms or legs). Although one study used a brand and model of timing gates with post-processing technology inbuilt (i.e., SmartSpeed, Fusion Sport) it was not reported (Kelly et al., 2021). Earp and Newton (2012) reported that post-processing technology successfully removed all false signals during sprint performance over 10 m. Consequently, timing gates with post-processing technology have been recommended as an accurate and reliable means of assessing sprint performance for single-beam timing gates (Earp & Newton, 2012).

Timing gates height has been shown to influence timing accuracy and reliability in single- and dual- beam timing gates (Altmann et al., 2017; Cronin & Templeton, 2008). When using single-beam timing gates placement at a height where only one body part typically breaks the beam has been recommended (i.e. hip or head height) (Haugen & Buchheit, 2016; Yeadon, Kato, & Kerwin, 1999). However, timing gate height has only been reported in two studies. Connors et al. (2021) used a height of 1 m whereas Loughran (2017) reported placing timing gates at participant's relative hip height. Comparison between single-beam timing gates placed at different heights revealed a mean difference of 0.07 s over 10 m (Cronin & Templeton, 2008). Consequently, times recorded via single-beam timing gates placed at different heights are not comparable (Cronin & Templeton, 2008).

Placement of single-beam timing gates at relative hip or head height for individual participants has been recommended to avoid premature time triggering (Yeadon et al., 1999). However, this adjustment of timing gates would be time consuming and practically challenging in a team-sport setting. Devices enabling measurement from initial movement during a sprint such as pressure-sensitive floor pods or infrared photoelectric systems have been shown to be valid and reliable (Altmann et al., 2017; Healy, Norris, Kenny, & Harrison, 2016). High-speed video cameras with an appropriate sampling rate can be used to precisely measure short sprint performance, however, the use of these devices is also time consuming (Healy et al., 2016). Radar and laser devices have become popularised for monitoring velocity and their use has been recommended as a means of monitoring the magnitude of velocity decrement in resisted sled training (Cahill et al., 2020). Bezodis, Salo and Trewartha (2012) found that laser had a mean bias of +0.41 $m{\cdot}s^{-1}$ at 1 m when compared to the criterion high-speed video but distances of 30 m and 50 m had mean biases of +0.06 and +0.08 $m{\cdot}s^{-1}$, respectively. This suggests laser devices may be appropriate to use when assessing maximum sprinting speed (Bezodis et al., 2012; Haugen & Buchheit, 2016) but not acceleration.

Starting procedures

To reduce premature timing gates time-triggering athletes must assume a starting position behind the initial timing gate. Hence, the athlete passes the initial timing gate already moving at a certain speed. This is termed a 'flying start'. Up to a certain point sprint time decreases as a function of flying start distance due to the exponential nature of a typical sprint-velocity curve (Haugen, Tønnessen, & Seiler, 2015). When measuring performance over Altmann and colleagues (2015) reported significantly faster 5 m sprint times using

Table 3. Technology used and starting procedures reported for linear sprint performance assessment

Author	Model (Brand)	Athlete Starting Position	Instructions given to Participants/ Start Signal	False Start Criteria	Timing Gate Height	Starting Distance (m)
			Camogie			
Connors et al., (2021)	Witty (Microgate)	Staggered stance, preferred foot forward	"Don't rock back"	NR	1.0 m	0.5
			Hurling			
Byrne et al., (2020a)	Kit Race time 2 Light Radio (Microgate)	Static upright position	"3, 2, 1, go"	NR	NR	0.5
Byrne et al., (2018a)	Model NR (Microgate)	Static upright position	NR	NR	NR	0.5
Byrne et al.,(2018b)	Model NR (Microgate)	Static upright position	NR	NR	NR	0.5
Byrne et al., (2020b)	Witty (Microgate)	Static upright position	NR	NR	NR	0.5
Byrne et al., (2019)	Witty (Microgate)	Two-point sprint start	NR	NR	NR	0.5
Byrne et al.,(2018c)	Witty (Microgate)	Two-point sprint start	NR	NR	NR	0.5
Collins et al., (2014)	Model NR (Newtest)	NR	NR	NR	NR	NR
Duncan (2006)	Model NR (Brower Timing Systems)	NR	NR	NR	NR	0.5
Malone et al., (2020)	NR	NR	NR	NR	NR	NR
Malone et al., (2017)	Witty (Microgate)	NR	NR	NR	NR	NR
Malone et al., (2021)	NR	NR	NR	NR	NR	NR
McIntyre (2005)*	Model NR (Pacesetter)	Two-point start	NR	NR	NR	NR
			Men's Gaelic football			
Boyle et al., (2021)	Witty (Microgate)	NR	NR	NR	NR	0.5
Cullen et al., (2013)	Model NR (Fusion Sport)	NR	NR	NR	NR	0.5
Kelly et al., (2021)	Smartspeed (Fusion Sport)	NR	NR	NR	NR	NR
Kelly & Collins (2018)	Powertimer (Newtest)	Stationary	NR	NR	NR	NR
Loughran et al., (2017)	Speedtrap II (Brower Timing Systems)	NR	NR	NR	Approx. hip height	0.5
Mooney et al., (2019)	Model NR (Brower Timing Systems)	Two-point start	"Run as fast as possible"	NR	NR	0.5
O'Leary (2016)	Witty (Microgate)**	NR	NR	NR	NR	0.3
Shovlin et al., (2018)	Model NR (Microgate)	NR	NR	NR	NR	NR
Strudwick et al., (2002)	Model NR (Eleiko)	NR	NR	NR	NR	NR

*Players assessed in hurling and men's Gaelic football, **Dual-beam timing gates, NR Not reported

a 1.0 m (0.98 ± 0.06 s) starting distance compared to 0.5 m (1.05 ± 0.07 s) and 0.3 m (1.09 ± 0.08 s) starting distances. In the current review 40% of studies did not report the initial starting distance from the timing gate and thus comparison of these studies should be limited (Table 3).

Various starting positions can be assumed during a sprint. Track and field sprinting events employ a four-point (block start) position in events up to 400 m while American football athletes typically assume a three-point stance during the NFL combine. In soccer, rugby and Australian football a two-point stance (standing start) is frequently used (Haugen, Tnnessen, Hisdal, & Seiler, 2014; Johnston, Black, Harrison, Murray, & Austin, 2018; Roe et al., 2017). However, variation exists and different standing stances have shown to influence 5 and 10 m sprint performance (Cronin, Green, Levin, Brughelli, & Frost, 2007). Sixty percent (60%) of studies failed to report the starting position athletes assumed prior to sprinting. The remaining 40% of studies reported

Table 4. Extraneous variables reported for linear sprint performance

Author	Time of Year/ Season	Testing Time of Day	Number of Trials/Trial Reported	Clothing/ Footwear	Surface	Rest	Reliability
Camogie							
Connors et al., (2021)	Pre	0900-1200	NR	Jersey & shorts	Indoor artificial track	3 min	NR
Hurling							
Byrne et al., (2020a)	Pre	1400-1600	NR	NR	Indoor	NR	NR
Byrne et al., (2018a)	NR	NR	NR/Fastest	NR	Indoor	NR	NR
Byrne et al.,(2018b)	Collegiate season	1400-1600	NR	NR	Indoor	NR	Inter-day: 5 m (SEM 0.06, CV% 2.04), 10 m (SEM 0.08, CV% 1.65), 20 m (SEM 0.10, CV% 1.06)
Byrne et al., (2020b)	Pre	NR	NR/Fastest	NR	Indoor synthetic track	3 min	NR
Byrne et al., (2019)	Pre	NR	3/Fastest	NR	Indoor synthetic track	3 min	NR
Byrne et al.,(2018c)	Pre	1400-1600	3/Fastest	NR	Indoor synthetic track	3 min	NR
Collins et al., (2014)	In (Jun)	NR	NR	NR	Indoor	NR	NR
Duncan (2006)	Pre	NR	NR/Fastest	NR	NR	NR	10m: TEM=0.8 s, 30m: TEM=0.2 s
Malone et al., (2020)	In (Jun)	1400-1900	NR	NR	NR	NR	ICC: 5 m (0.91), 10 m (0.95), 20 m (0.96)
Malone et al., (2017)	In (Mar/ May)	0900-1900	NR	NR	NR	NR	NR
Malone et al., (2021)	Pre (Nov - Dec)	NR	NR	NR	NR	NR	NR
McIntyre (2005)*	In	NR	3/Fastest	NR	NR	NR	NR
Men's Gaelic football							
Boyle et al., (2021)	In (May, 2014-19)	1800–2000	3/Fastest	NR	Indoor	5 min	NR
Cullen et al., (2013)	2 wks post-season	1400-1800	3 trials	Loose clothing/ Appropriate footwear	Indoor sports hall	3 min	NR
Kelly et al., (2021)	Pre	NR	3/Fastest	NR	NR	NR	NR
Kelly & Collins (2018)	Pre (Nov) In (Jan/ Mar)	NR	3/Fastest	NR	NR	5 min	NR
Loughran et al., (2017)	In	NR	NR	NR	Indoor rubberised athletic track	NR	NR
Mooney et al., (2019)	Pre	1700-2100	3/Fastest	NR	Indoor wooden sprung floor	≥3 min	NR
O'Leary (2016)	Pre and In	NR	3/NR	NR	NR	NR	NR
Shovlin et al., (2018)	In (June)	1800 – 2100	NR	NR	Indoor	NR	NR
Strudwick et al., (2002)	In	NR	NR	NR	NR	NR	NR

*Players assessed in hurling and men's Gaelic football, *Pre* Pre-season, *In* In-season *Post* Post-season, wks Weeks, *CV*% Coefficient of variation %, *ICC* Intraclass correlation coefficient, *NR* Not reported, *SEM* Standard error of measurement, *TEM* Typical error of measurement

Table 5. Scoring of studies using the linear sprint performance (LSP) test procedure reporting rating tool

Study	Item for LSP testing scoring tool																Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Connors et al., (2021)	2	2	2	1	0	1	0	0	1	0	1	2	1	1	2	1	17
Byrne et al., (2020a)	1	2	0	1	0	1	0	0	0	0	1	2	1	1	1	1	12
Byrne et al., (2018a)	1	2	0	1	0	1	0	1	0	0	1	1	0	0	1	1	10
Byrne et al.,(2018b)	1	2	0	1	0	1	0	0	0	1	0	2	0	1	1	1	11
Byrne et al., (2020b)	1	2	0	1	0	1	0	1	1	0	1	0	0	0	2	1	11
Byrne et al., (2019)	1	2	0	1	0	1	1	1	1	0	1	1	0	0	2	1	13
Byrne et al.,(2018c)	1	2	0	1	0	1	1	1	1	0	1	2	0	0	2	1	14
Collins et al., (2014)	2	2	0	0	0	0	0	0	0	0	2	1	0	0	1	1	9
Duncan (2006)	1	2	0	0	0	1	0	1	0	1	1	0	0	0	0	1	8
Malone et al., (2020)	2	0	0	0	0	0	0	0	0	1	2	2	0	0	0	1	8
Malone et al., (2017)	2	2	0	0	0	0	0	0	0	0	2	2	0	0	0	1	9
Malone et al., (2021)	2	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	6
McIntyre (2005)*	1	2	0	1	0	0	1	1	0	0	1	0	0	0	0	1	8
Boyle et al., (2021)	1	2	0	0	0	1	1	1	1	0	2	2	0	0	1	1	13
Cullen et al., (2013)	2	2	0	0	0	1	1	0	1	0	1	2	0	1	1	1	13
Kelly et al., (2021)	1	2	0	0	0	0	1	1	0	0	1	0	0	0	0	1	7
Kelly & Collins (2018)	2	2	0	0	0	0	1	1	1	0	2	1	0	0	0	1	11
Loughran et al., (2017)	1	2	1	0	0	1	0	0	0	0	1	1	0	0	2	1	10
Mooney et al., (2019)	2	2	0	1	0	1	1	1	1	0	1	2	1	0	2	1	16
O'Leary (2016)	2	3	0	0	0	1	1	0	0	0	1	0	0	0	0	1	9
Shovlin et al., (2018)	1	2	0	0	0	0	0	0	0	0	2	2	0	0	1	1	9
Strudwick et al., (2002)	1	2	0	0	0	0	0	0	0	0	1	0	0	0	0	1	5
Mean scores across studies as a percentage of maximum score=42%																	

*Players assessed in hurling and men's Gaelic football, 1 Competitive level, 2 Timing technology, 3 Placement height, 4 Starting position, 5 False start criteria, 6 Starting distance from technology, 7 Number of trials participants performed, 8 Trial used for data analysis, 9 Length of recovery time between trials, 10 Reliability reported, 11 Time of testing relative to competition calendar, 12 Time of day of testing, 13 Instructions given to participants, 14 Clothing and footwear reported, 15 Location/surface reported, 16 Results reported

using a two-point start (Table 3). Although it may seem self-evident that Gaelic games athletes would assume a two-point start as it is most similar to the starting posture prior to sprinting during match-play, the starting stance should be explicitly detailed in future research.

It has been reported that some athletes perform a 'rocking motion' and backward or 'false' step or backward step from a standing position prior to beginning an assessment (Altmann et al., 2015; Haugen, Tnnessen, et al., 2014). By performing a rocking motion prior to sprinting an athlete can gain momentum potentially leading to improved performance. While the influence of a rocking motion is yet to be empirically determined, Schwenzfeier et al. (2022) found that participants who utilised a 'false' step prior to initiating a sprint were 0.23 s faster over 10 m than when they took a forward step. Furthermore, reliability may be affected if different starting procedures are used between or within athletes or trials. No included study stated false start criteria during any speed assessment although one study did instruct participants not to rock back (Table 4). It is recommended that coaches and researchers instruct athletes to avoid this rocking motion and 'false' step and void trials in which it is performed prior to starting.

Trials/Trials Reported

Thirteen studies (59%) failed to report the number of trials participants performed during linear sprint performance testing. The appropriate number of trials to perform will depend on the sprint distance being performed although it is recommended that this number is reported. Work in junior soccer players reported faster sprint performance over 20 m (0.02 s) on the final trial of fifteen in comparison to the first trial whereas 40 m performance began to decrease after three or four trials even with a recovery period of up to 6 minutes (Haugen & Buchheit, 2016). Over (Haugen & Buchheit, 2016). Furthermore, the trial used for statistical analysis should be reported. Ten studies reported using the fastest trial for analysis while the remaining 55% of studies did not report the trial used (Table 3).

In the current review eight studies reported the recovery period given between trials (Table 3). The eight studies involved sprint trials over 20 m; five studies stated three minutes recovery, one stated a minimum of three minutes (Mooney et al., 2019) while the remaining two studies gave five minutes of recovery were given between trials (Boyle et al., 2021; Kelly & Collins, 2018). For every 10 m sprinted,

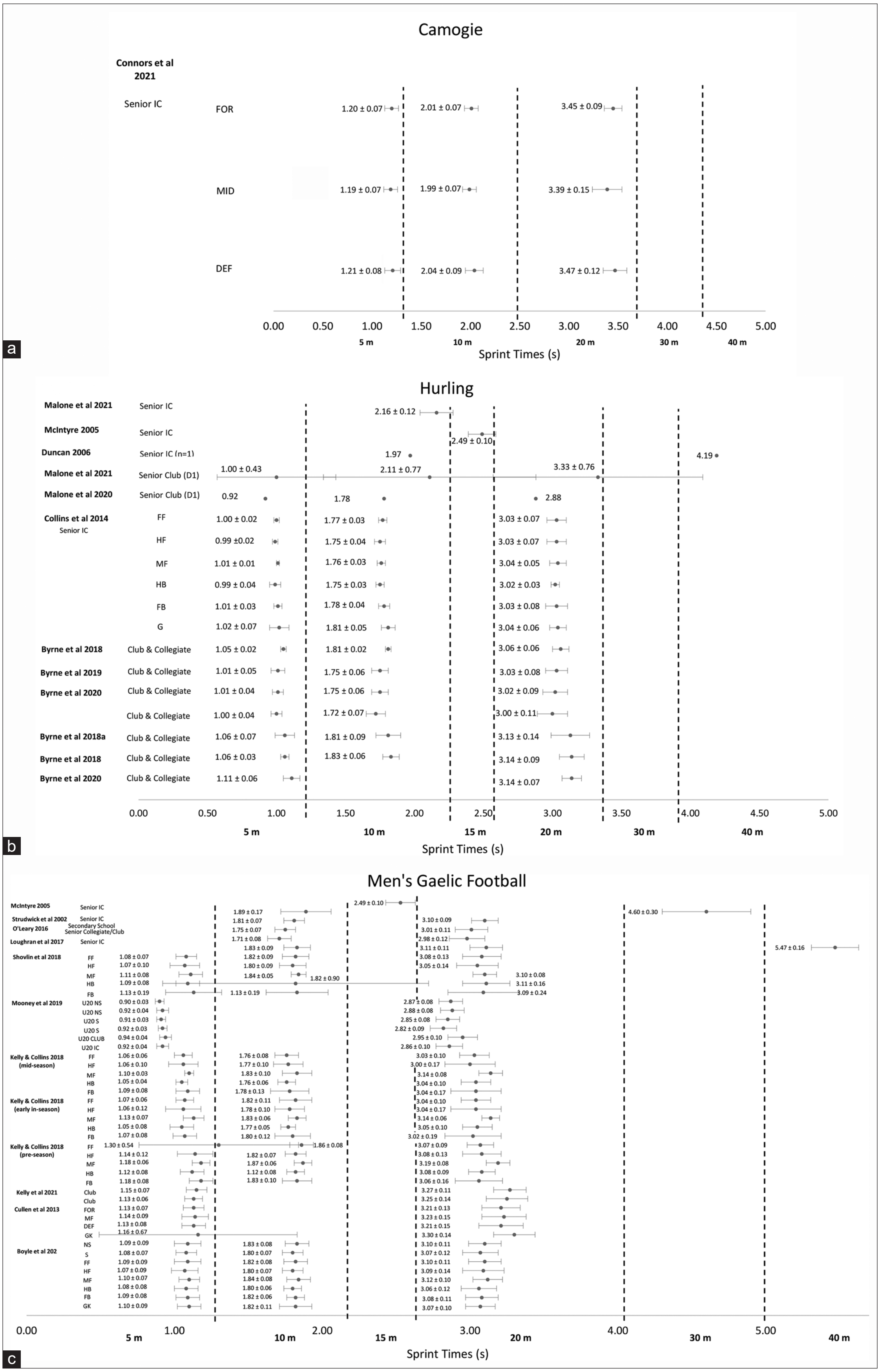

Figure 1. Normative values for sprint performance in Camogie, Hurling and Men's Gaelic football
GK Goalkeepers, *DEF* Defenders, *FOR* Forwards, *FB* Full-backs, *HB* Half-backs, *MF* Midfielders, *HF* Half-forwards, *FF* Full-forwards, *IC* Intercounty, *S* Starters, *NS* Non-starters

it has been recommended that one minute of recovery is given (DeWeese & Nimphius, 2015; Hansen, 2014)

Reliability

Test reliability refers to how repeatable the performance of a test is (McGuigan, 2014). Reliable monitoring in sports performance is crucial as apparently small changes in performance can be the difference between success and failure (Haugen et al., 2012). Therefore, it is important to establish the reliability of a test. Coaches and researchers can use correlations, typical error of measurement, and changes in the mean to determine whether a method is reliable. Of all the studies included in this review, only three reported the reliability for linear sprint performance (Byrne et al., 2018; Duncan, 2006; Malone et al., 2020). In future it is recommended that studies report the reliability of performance testing.

Extraneous Variables

Time of season

Gaelic games playing seasons are typically 6-12 months in duration. Kelly and Collins (2018) examined seasonal changes in sprint performance in senior inter-county male Gaelic football. From November (pre-season) to January (early in-season) there was a mean improvement of 7 ± 22% in sprint time over 5 m across all positions (1.15 ± 0.09 to 1.07 ± 0.07 s) (Kelly & Collins, 2018). Similar seasonal changes for 10 m times have been found in male (2.03 ± 0.15 to 1.96 ± 0.11) and female (1.97 ± 0.14 to 1.90 ± 0.16 s) soccer players (Emmonds, Sawczuk, Scantlebury, Till, & Jones, 2020; Magal, Smith, Dyer, & Hoffman, 2009). Accordingly, it is important to state the time of year and season performance testing was undertaken as comparisons between studies without context (time of season) may be misleading.

Time of day of testing

Many physiological functions are diurnal and thus fluctuate during the day (Souissi et al., 2007). Research has shown that high-intensity short duration exercise is influenced by time of day with morning nadirs and afternoon peaks (Pavlović et al., 2018; Souissi et al., 2007). Pavlović (2018) reported slower 5 and 20 m sprint performance in elite male handball players in the morning (08:00 – 09:30) compared to the evening time (18:00 – 18:30) (1.19 ± 0.10 vs. 1.06 ± 0.07 s; 3.50 ± 0.25 vs. 3.18 ± 0.19 s. In the current review ten studies stated the time of day linear sprint performance testing were conducted which ranged 09:00 to 21:00 (Table 4). Practitioners should be cognisant of these diurnal variations when and caution is therefore advised when interpreting and/or comparing data collected during different times of the day within- and between- studies.

Instructions given to participants

Performance tasks can be influenced by instructions given to participants prior to task execution (Wulf, 2013). Attentional focus is the conscious effort of an individual to focus attention on their bodily processes or movements, or to focus on the effect of their movement on the environment (Wulf, 2013). Specifically, internal focus is concentrated attention on one's own body movements (e.g., "move your arms as fast as possible"), whereas external focus is concentrated attention on the effect of movement on the environment (e.g., "push the ground away explosively"), (Wulf, 2013). Faster 10 m sprint times (small effects) were found when external focus and control instructions were given to male soccer players compared to internal focus instructions (Winkelman, Clark, & Ryan, 2017). In the current review, one study instructed participants to "run as fast as possible" (Mooney et al., 2019). Although external instructions may improve performance all participants should receive standardised instructions between trials and these instructions should be reported. Only one study reported the start signal given to participants prior to trials being initiated. Participants in a study by Byrne *et al.,* (2020) initiated trials under the starting signal "3,2,1, go". Limited research exists on the influence of start signals in team-sport athletes when assessing linear sprint performance (Haugen & Buchheit, 2016).

Surface, footwear and location

The type of attire, equipment, and footwear used by participants should be standardised and reported. Regarding footwear, Cullen et al. (2013) stated participants wore 'appropriate footwear' during an observational study while footwear was 'the same for all tests' in other studies (Table 4).

A recent systematic review and meta-analysis concluded that playing surface is a factor influencing sprint performance (Sanchez-Sanchez et al., 2020). Thirteen studies reported that testing was performed in an indoor facility with five stating the type of surface (Table 4). Gaelic games are played on natural grass and/or artificial turf pitches. Although assessment of linear sprint performance on a natural grass pitch was not reported it is important to note that there is a large degree of variability between and within natural grass pitches (Sanchez-Sanchez et al., 2020) and climate in Ireland (Walsh, 2012), which subsequently influences the condition of natural grass pitches. Speed assessments may be best performed indoors on the same surface. Artificial grass is a viable option, however, environmental conditions (wind, rain, temperature) will have greater influence outdoors, are likely to change within- and between- testing sessions and may affect performance.

Environmental factors

Environmental factors are an important consideration when assessing speed performance. The international governing body for athletics (World Athletics) studies environmental factors such as wind speed, air density, air temperature, humidity, and altitude during track and field events (Haugen & Buchheit, 2016). For example, during a 100 m sprint event, a tailwind of 7.2 km·h^{-1} (2.0 m·s^{-1}) can yield 0.10 and 0.12 s faster times for male and female international-standard sprinters respectively, in comparison to negligible wind speeds (Linthorne, 1994). In team-sports, minimal research has examined the influence of environmental factors on speed performance. Therefore, it is not surprising environmental factors were not reported in any included study (Table 4). Reducing extraneous variables by conducting speed assessments indoors may be the most appropriate approach.

Normative Values

Comparison or aggregation of normative values obtained between-studies is only appropriate when similar procedures are employed. For example, club and collegiate hurling players recorded a time of 1.82 ± 0.05 s over 10 m (Byrne et al., 2018). Comparably, Norwegian national team male soccer players completed the same distance in 2.01 ± 0.05 s (Haugen, Breitschädel, & Seiler, 2019). By failing to consider methodological differences one may mistakenly conclude that sub-elite amateur players are markedly faster than elite professionals over 10 m. In this example, the soccer team was assessed via split-beam timing gates with timing initiated via a start pad once the front foot moved (Haugen et al., 2019). The hurling team was evaluated via timing gates (number of beams not stated) and begun their trial 0.5 m behind the first timing gate (Byrne et al., 2018). Evidently, comparing sprint times measured using differing methods yields misleading conclusions.

Examination of positional differences within-studies reveals mixed findings between playing grade and sport (Figure 1). Cullen et al., (2013) found no significant differences in sprint times over 5, 10, and 20 m between positional groupings in U18 'A' schools provincial boy's Gaelic football champions (Cullen et al., 2013). In contrast, Kelly and Collins (2018) found a significant main effect of position, with midfielders found to be slowest over 20 m; whereas Shovlin et al., (2018) found no statistically significant differences between positions over 5, 10, and 20 m although half- and full-forward players were fastest. In inter-county hurling sprint performance over 5, 10 and 20 m was unable to differentiate between positions (Collins et al., 2014). Overall, these findings suggest that positional differences can exist, however, it may depend upon the cohort and the number of players per positional group being assessed (Kelly & Collins, 2018). Similar to positional grouping differences, differences may exist between playing standards. A study by Mooney et al. (2019) compared starters and non-starters at male U20 Gaelic football inter-county level performance over 20 m. It was found that inter-county players were 3 ± 11% faster in comparison to club players (Mooney et al., 2019). Future research should seek to examine if positional and playing standard differences exist in ladies Gaelic football and camogie during linear sprint performance.

Future Research

There is a considerable dearth of literature conducted on ladies Gaelic football and camogie. Future research should seek to establish normative values for both short- (≤ 20 m) and long- (≥ 20 m) sprint performance. All future research should report the methodological variables mentioned in the current review when investigating linear sprint performance. This will aid comparison between studies as well as provide practitioners with normative values.

Limitations

This is the first systematic review to examine the linear sprint performance and methodological considerations in Gaelic games. However, this review has its limitations. As four Gaelic games team-sports were included, this macro-level view of research limits the scope of examination within each sport. For example, focusing on one sport would allow for a more detailed examination of the individual nuances within a sport in greater detail (i.e., influence of age grade, playing standards, position). However, assessment methods and their limitations transcend a specific sport and the findings of this review are applicable across many sports, particularly Gaelic games.

CONCLUSION

Inaccurate data can misinform the training priorities and prescriptions of athletes by practitioners. To ensure valid and reliable data are captured when monitoring linear sprint performance, practitioners need to be cognisant of the influence of utilising and reporting methodologies. The methodologies mentioned in the current review can be used as a 'checklist' for practitioners to ensure accurate and standardised monitoring practices are employed across time. This will help ensure that practitioners and researchers are precise in their monitoring of sprint performance and enables them to track 'true' changes longitudinally accurately.

This review provides various linear sprint performance results in camogie, hurling and men's Gaelic football, although results should be interpreted with caution. These data span across various age grades, playing standards, times of season, positional standards etc. This systematic search highlighted the minimal number of studies conducted on camogie and ladies Gaelic football. Future research should seek to investigate linear sprint performance in both sports. These normative data will give greater context to practitioners in relation to the performance capacities of their players and help inform training priorities and prescription.

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DATA AVAILABILITY

The datasets utilised in this review are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTION

All the authors contributed to the conception and design of the study. EMcG drafted the manuscript and all authors contributed to editing and revising the manuscript. All authors read and approved the final manuscript prior to submission.

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