An Investigation into the Role and Function of Athlete Monitoring and its Impact on Training Practice and Performance among Elite Gaelic Football Players

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An investigation into the role and function of athlete monitoring and its impact on training practice and performance among elite Gaelic football players

Jason Hugh McGahan
An investigation into the role and function of athlete monitoring and its impact on training practice and performance among elite Gaelic football players

A thesis submitted to Cork Institute of Technology in fulfilment of the requirement for the award of Doctor of Philosophy

By

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Department of Sport, Leisure and Childhood Studies

Candidate Supervisor(s) of the research:
Dr. Cian O'Neill & Dr. Con Burns

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Abstract

**Background:** Ensuring adequate rest and recovery is critical for the avoidance of overtraining and the achievement of optimal performance, therefore it is recommended that training load and recovery be continually monitored throughout the training year. The purpose of this research was to investigate training load and markers of wellness among elite Gaelic footballers to assist the regulation of such loading to optimise performance in an amateur sports setting.

**Methods:** Participants were selected from two elite Gaelic football teams (Division 1 and 3 respectively) where training load data (global positioning system (GPS), session rating of perceived exertion (s-RPE) and wellness markers) were collected across three seasons (9 months each). External training loads were measured via VX Sport 4 Hz GPS technology. Internal TL (s-RPE X Session Duration) was recorded for each player post-session. Psychometric data were recorded each morning upon rising using the Metrifit athlete monitoring system, calculating a daily readiness to train (RTT) score for each player.

**Results:** Monitoring daily deviations of selected physiological and psychometric variables during a pre-competition training camp found significant daily variations in Total Distance (TD), High Speed Running (HSR) and internal Training Load (TL), yet there were no adverse effects on individual Counter Movement Jump (CMJ) or RTT scores on the following day. The coefficient of variation for the markers of RTT and CMJ across the entire week (CV: 13.87% & 7.98% small to moderate effect size respectively) demonstrated no significant day-to-day variation (p = .369). An investigation into positional running demands of participants found significant relationships between competition and game-based training for mean high speed running and mean speed across each of the 5 positional lines (range r = .811 -.964 & r = .792 -.998 respectively). A comparative analysis of match-play running demands and technical performance between the Division 1 and 3 Teams found a contrast in HSR running demands by rank; the Division 3 team demonstrated significantly greater HSR (p = .001), HSE (p = .024), RHSD (p = .002) and %HS (p = .002) than the Division 1 team. From a technical performance perspective, the Division 1 team made a greater number of total tackles, with significantly more tackles in the middle third (p = .044), while the Division 3 team performed significantly greater number of hand passes (p = .007) and unsuccessful shots per game (p = .007). Analysis of seasonal variation in training load and wellness markers revealed a large difference between the pre-competition training blocks (i.e. Pre-Season 2 and In-Season 4) relative to the primary competition block (In-Season 6) for both external and internal load. Notably, there were significant differences in RTT across the eight seasonal blocks (p = .001, ES= .363).

**Conclusion:** The findings from this series of studies established that a pre-competition training camp can provide a dedicated period of time to develop tactical and team play elements while not adversely impacting levels of neuromuscular fatigue or perceptual ratings of wellness. Results also provide support and value for the application of a game-based training approach as a method of preparing players for the physical demands of competition in elite Gaelic football. Also, it was found that overall technical proficiency, rather than high-speed running profiles, differentiated Division 1 and 3 team performances. Finally, variation in training load was prevalent across the seasonal blocks, with targeted periods of loading and unloading clearly evident across different stages of the season as identified by associated wellness scores. This research provides critical information regarding elite Gaelic football players’ physiological running demands and training loads across competitive seasons, which enables coaches to be more accurate and agile in their planning and practices to optimise performance.
Declaration by author

I hereby declare that the work contained within this thesis is entirely my own work other than the counsel of my supervisors, Dr. Cian O’ Neill and Dr. Con Burns of the Department of Sport, Leisure & Childhood Studies, Cork Institute of Technology. This work has not been submitted for any academic award, or part thereof, at this or any other educational establishment. Where the use has been made of the work of other people, it has been fully acknowledged and referenced.

Candidate:

Jason Hugh McGahan

Date
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Conducting this research within two Elite Gaelic football teams has given me a number of experiences, high and low, both as a practitioner and as a person for the rest of my life. I have been involved with Gaelic football since I was 6 years old; I went to my first All-Ireland Final when I was 9 years old. I followed my Dad around the country supporting the Armagh footballers through the highs and lows. It has been a part of my life for as long as I can remember. I have enjoyed the camaraderie and the banter through playing, and now coaching. It only made sense that I conduct a PhD in a sport that I grew up playing and subsequently studying so that I can, in some small way, give something back to the game I love and to those who share my passion. I could not have achieved the completion of this thesis without the help of a variety of people:

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Ronan and Thando, throughout the 4 years it has taken to complete this thesis you have always been there to support me in whatever way possible, a roof over my head or to let off steam with a beer in Johnny’s, for that I would be forever grateful to you both. Thank you.

To the people of Douglas GAA, Tony Leen, Eoin Cadogan & family, for making my transition in the first few months/year a home from home. Thank you.

Participants

I would like to express my sincere gratitude to the players and management of the Kerry and Kildare Senior football teams for their ultimate bye in, time and commitment to my research.
Colleagues

I would have never have thought that back in 2012 when I was frantically trying to win myself a post graduate place on the MSc Sports Performance programme at UL, that I would be in the position I am now. I am privileged to have met and worked with a variety of people during my academic years in CIT, in particular my colleagues in the Department of Sport, Leisure and Childhood Studies and my PhD colleagues Lisa and Linda Bolger for their I.T. efficiency skills whom I would like to thank. I would like to thank Metrifit and VX Sport for all their support over the four years in particular Ann Bruen and Peter Larkin (Metrifit), Paul Clarke (VX Sport).

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Finally, my sincerest thanks go to my supervisors Dr. Cian O’ Neill and Dr. Con Burns. I would like to thank Cian for the opportunities you have given me to develop my applied work for the last 4 years. You have been a constant source of support throughout that time and I know you still will be in the future. Con, I hope you feel your investment in the countless visits to the Bistro over the years has paid off! You have taught me a great deal throughout our time and I will be forever grateful for that. I hope that the thesis is fitting to the guidance you have both given me over the years. I am really looking forward to seeing what we can achieve in the future.
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Berenice

Where do I start? When things were looking unbearable, you picked me up and kept encouraging me to drive forward. I want to thank you for the countless hours you’ve sat as a source to offload. Making sure I am constantly reminded of all that is good and I am lucky to have outside of work! Thank you for the love, support and patience you have given me to allow this thesis to be accomplished. I really could not have achieved this without you. Sláinte to the future!

Finally, I hope that having this collection of studies in one document may assist skills coaches, strength and conditioning coaches, physiotherapists and sports scientists in the field. I am never going to walk the steps of Croke Park as a player but doing the best I can as a sport scientist/coach, I may well do.

Thank You

Jason
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Chapter 1: Introduction
1.1 Introduction

Gaelic football is an amateur field-based contact sport involving 15 players per team. It is the most popular sport in Ireland (Delaney & Fahey, 2005) and is governed by the Gaelic Athletic Association (GAA). The best club Gaelic footballers in each of the 32 counties in Ireland are selected to represent their county team (i.e. elite level), who train up to five times per week (2-3 pitch sessions 1-2 gym sessions) in a high performance environment (Malone, Solan, Collins, & Doran, 2015). County teams compete in the National League (played across the months of February and March) and the All-Ireland Championship (played across the summer months of May - September) competitions. For the League competition, teams are categorised into four rank ordered divisions with 8 teams in each division, where they have the possibility of being promoted or relegated from their respective division based on their performance across the 7 games. In contrast, the All-Ireland Championship competition, the most prestigious competition in Gaelic football, is played in a knock out cup format.

The amateur status associated with Gaelic football means that the athletes playing at elite level (County) do not receive payment for their performance, regardless of the professional approach taken in preparation for training and competition. Due to this amateur status, Gaelic football coaches have limited access to players across a training week (maximum 2-3 collective pitch sessions). As a result, performance improvement in such a limited training environment is a major challenge. Therefore, careful planning of the training program and associated macrocycle, mesocycle and microcycle sessions is imperative to ensure that technical skill and tactical awareness are developed in conjunction with physical fitness.

Elite Gaelic football players have reported significantly higher levels of emotional and physical exhaustion in comparison to their non-elite (i.e. Club) counterparts (Burns, 2014). The management of this fatigue is compounded by the fact that these athletes are involved in multiple teams (e.g. Club, U20, County and in some cases University). With most players either students or in full time employment, the frequency of, and travel associated with, matches and training means that players rarely have adequate time to fully recover (O’Neill et al., 2007). There is an accumulation of evidence suggesting that ‘burnout’ in talented young Gaelic football players is a serious issue that needs to be urgently addressed by the GAA (O’Neill et al., 2007). This issue of burnout is most
prevalent in the youth population playing Gaelic games and is defined by O’Neill et al. (2007) as the result of the psychological and physiological demands associated with excessive training and the number of games. Therefore, this area is not merely an area of interest in the field of coaching science and performance, but is also a core area within the GAA’s strategic research plan.

The primary objective in training competitive athletes is to provide training loads that are effective in improving performance and aiding the prevention of injury (Meeusen et al., 2013). Season long competition schedules in sport create challenges for coaches in balancing the requirements of developing and maintaining physical fitness, optimizing recovery as well as adjusting the training load before, and between, games (Gastin, Meyer, & Robinson, 2013). Previous research has highlighted the importance of appropriate and tailored seasonal variation in training load to enhance athletic performance, with varying periods of intense and light training (Gabbett & Jenkins, 2011; Lambert & Borresen, 2010). Ensuring adequate rest and recovery is important in the avoidance of overtraining and the achievement of optimal performance, therefore it is recommended that training load and recovery be continually monitored throughout the training year (Kellmann, 2010). Endurance athletes generally use standard training volume (km’s per week) as an index of training with reasonable effectiveness (Lambert & Borresen, 2010). However, measurement of training volume alone ignores the crucial training variable of ‘intensity’ (Lambert & Borresen, 2010), as high-intensity exercise training is particularly difficult to quantify. The demands of different sports vary and therefore the methods of measuring training load need to vary accordingly. The utilization of advancements in various subjective player monitoring tools, in addition to objective GPS measurement tools such as GPS devices, has become more prevalent in the recording and monitoring of athlete training load and wellness.

While there is limited investigation into training loads and its relationship with wellness in other sports (Gastin et al., 2013), there has been no research conducted with elite GAA players to date. While specificity is considered a fundamental principle of training, it is difficult to replicate the demands of competition if those demands are poorly understood. This may lead some coaches to engage in the ‘over training’ of their players due to their acute lack of awareness of what training loads and levels of intensity are required to optimally prepare their players for competitive performance.
The time has come to examine training loads specific to Gaelic football using evidence-based methods. Advances in sports technology have resulted in the development of cutting-edge player monitoring tools (e.g. online platforms) to provide coaches with subjective information detailing the internal load (i.e. rate of perceived exertion and wellness markers) of athlete’s training in response to the external load measured by objective tools such as GPS (Killen, Gabbett, & Jenkins, 2010).

1.2 Aims of the Thesis:

The Aims and Hypotheses of this research process were as follows:

1. To investigate the impact of internal and external training load in a pre-competition training camp on wellness markers and CMJ among elite GAA athletes

H01: There will be no significant relationship between training load (internal & external) and readiness to train on the following day (wellness markers (RTT) and CMJ) in a pre-competition training camp among elite Gaelic footballers

2. To examine the relationship between training-based positional running demands and related match-play demands in an elite Gaelic football team

H02: There will be a significant relationship between the running demands recorded between training sessions and match-play in an elite Gaelic football team

3. To compare the match-play high-speed running demands and technical performance variables of Division 1 and Division 3 players in elite Gaelic football

H03: There will be no significant differences in the high-speed running demands and technical performance variables during match-play between Division 1 and Division 3 players in elite Gaelic football
4. To investigate the variation in training load and markers of wellness of elite Gaelic footballers across a season

HO4: There will be no significant differences in training load and markers of wellness in elite Gaelic footballers across a season

1.3 Significance of the Research

The research literature has emphasized the importance of monitoring training response and exploring the relationship between training load and training outcomes (e.g. fatigue, performance) within the sporting environment via the measurement of external and internal loads accumulated during training and competition. What is apparent is the dearth of research in the field of athlete monitoring within elite Gaelic football with no evidence of relevant literature that has examined the relationship between internal and external training loads. An increased understanding of this relationship will assist coaches in (i) planning optimum training loads between games and training sessions and (ii) developing appropriate monitoring strategies.

Currently, no published research has examined the individual running demands of training activities and their relationship with competition demands within Gaelic football. The primary purpose of training is to prepare athletes for competition and ensure that they receive a training stimulus that reflects the demands of the game. Gaelic football players tend to use a combination of traditional conditioning-based training (high intensity running without the ball), game-based training (small-sided game activities progressing to full-game scenario’s) and skills-based training (open and closed skill activities to develop technical competence). The physical running demands of each of these activities is unclear, with limited research detailing whether game-based training is superior to other methods of training as a method of preparing players for the movement demands of competition. Within other sports, research has been conducted (Gabbett, 2010a; Gabbett, Jenkins, & Abernethy, 2012; Gabbett & Mulvey, 2008) suggesting that game-based training activities can elicit similar running demands to those of competition (Gabbett & Mulvey, 2008). However, it has also been found that without thorough game-based design, such activities may not effectively prepare athletes for the more high intensity passages of play, with fewer sprint efforts found in comparison to competition (Gabbett,
2010a). Similarly, traditional conditioning-based training programs have reported fewer sprint efforts (Austin, Gabbett, & Jenkins, 2010) and greater running-based demands (total distance) than have been found in competition (Gabbett, Jenkins, et al., 2012).

Previous research has examined the positional demands in Gaelic football (Malone et al., 2015; Reilly, Akubat, Lyons, & Collins, 2014), however no studies have differentiated teams by success rates or divisional status. Studies in Australian Football (Aughey, 2013; Brewer, Dawson, Heasman, Stewart, & Cormack, 2010), rugby league (Gabbett, 2013) and soccer (Mohr, Krustrup, & Bangsbo, 2003) have reported that elite players record greater running demands when compared to their counterparts playing at the sub-elite level. However, in contrast to these studies, it has been reported that soccer and rugby league teams competing in higher divisions of competition cover less total distance and less high-speed running distance than teams competing in lower divisions (Di Salvo, Pigozzi, González-Haro, Laughlin, & De Witt, 2013; Hulin, Gabbett, Kearney, & Corvo, 2014). It has been hypothesized that this is due to their increased technical abilities. Furthermore, Di Salvo, Gregson, Atkinson, Trodoff, and Drust (2009) found that the bottom 5 teams in the English Premier League covered greater high-speed running distance than the teams in the top 5 positions. However, it is unclear whether similar patterns exist within elite Gaelic football match-play. To date, there is no published literature that has investigated the differences in high-speed running and technical performance variables between different divisional teams in elite Gaelic football. Analysis of such variation would serve to assist coaches in identifying the key characteristics of performance and could help to increase prospects of promotion to higher divisions.

Finally, the ability to monitor both subjective and objective measures of training loads is critical to the process of quantifying training periodization plans, maintaining physical fitness and optimizing recovery. While previous research has examined the external and internal TLs across phases of seasons in other sports (Malone, Di Michele, et al., 2014; Moreira et al., 2014; Ritchie, Hopkins, Buchheit, Cordy, & Bartlett, 2016), there is a dearth of such examination within Gaelic football. Therefore, the following series of research studies documents the relationship between training load and markers of wellness, quantification of the positional running demands in training and competition,
analysis of high intensity running demands of match play across divisions and the variation in training and competition load across a season within elite Gaelic football.

1.4 Overview of the Study

This study consists of eight sections, each with its own specific purpose and focus.

Chapter 1: Introduction

This chapter provides a background to the overall theme of this research, i.e. athlete monitoring in elite Gaelic football incorporating the use of GPS, s-RPE and an online platform to monitor wellness. An overview of the research conducted in this area to date, both worldwide and more specifically in Gaelic football, is provided. The aims and hypotheses of the current research are also outlined. This section highlights the importance and significant impact that this research may have in the field of Gaelic football and athlete monitoring on a global level.

Chapter 2: Literature Review

This chapter serves to provide a detailed literature review of the research that has been completed in the Gaelic football domain, but also highlights the significant gaps in the related body of literature. This literature review is divided into 3 main sections with Section 1 providing an overview of the physical and physiological demands of Gaelic football. This provides a context with regard to how the training modes of the sport can be evaluated. Section 2 examines the role of training load monitoring, with special reference to the influence of both external and internal load on the outcomes of training. Finally, Section 3 provides an overview and analysis of the current literature relating to training load and its impact on both performance and fatigue.

Chapter 3: Research Methods

This chapter provides a detailed description of the methods adopted to examine the internal and external training load as well as markers of wellness among the research cohort. This incorporates the design, content and implementation of each of the 4 studies. The procedures used in the collection of all data (i.e. GPS, s-RPE, RTT and CMJ) are
outlined, while a detailed account of each of the protocols used in the collection of same is presented in each respective experimental chapter (i.e. Chapters 4-7). Statistical analysis conducted as part of the research is also summarised, with more precise details presented in each of the subsequent chapters.

Chapter 4: Relationship between load and readiness to train in a Gaelic football pre-competition training camp
Published works by the author incorporated into this chapter:

This chapter presents an investigation into the monitoring of daily deviations of selected physiological and psychometric variables in elite Gaelic football players during a pre-competition training camp to minimize the risk of overtraining and injury. Data were collected during a 5-day warm-weather training camp. External training loads (TL) were measured via global positioning system (GPS) technology. Physiological response to external load was measured via countermovement jump (CMJ) using an Electronic Jump Mat. Internal TL (Session RPE X Session Duration) was recorded for each player post-session and psychometric data were recorded each morning upon rising using the Metrifit athlete monitoring system, calculating a readiness to train (RTT) score for each player.

Chapter 5: An investigation into the positional running demands of elite Gaelic football players: how competition data can inform training practice
Published works by the author incorporated into this chapter:

While Chapter 4 investigated the role of athlete monitoring (external and internal) in the preparation of elite athletes for competition (micro-cycle), this study explored the relationship in the positional running demands between training and match day
performance in elite Gaelic footballers across a season (macro-cycle). Training data was classified as (i) game-based (small sided game scenarios progressing to full game), (ii) skills-based (open and closed tasks to develop technique in passing, catching and shooting) or (iii) conditioning-based (high intensity running without the ball); dependent on the content of the respective sessions. Global positioning system (GPS) data were obtained from thirty elite Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) across a full season (13 competitive games and 78 training sessions).

Chapter 6: Match-play running demands and technical performance among elite Gaelic footballers: Does divisional status count?
Published works by the author incorporated into this chapter:

Chapter 5 presented an overview of the running demands associated with both training and match day performance in a cohort of elite Gaelic footballers. The purpose of this study was to provide a comparative analysis of such running demands, in addition to selected technical performance variables, between 2 different rank-ordered elite Gaelic football teams (Division 1 vs Division 3). Data were obtained from a Division 1 (26.7 ± 2.9 years, 179.2 ± 21.3 cm, 89.9 ± 21.2 kg) and a Division 3 (25.7 ± 3.5 years, 183.0 ± 4.7 cm, 84.4 ± 6.5 kg) team. Each variable was analysed across the 5 positional lines in the game (full-back, half-back, midfield, half-forward, full-forward). The same 25 competitive games were analysed using GPS and the Sports Code performance analysis system.

Chapter 7: Variation in training load and markers of wellness across a season in an elite Gaelic football team
Published works by the author incorporated into this chapter:
While previous studies in this thesis examined either a discrete micro-cycle (Chapter 4: Pre-Competition phase) or a full season macro-cycle (Ch.'s 5 & 6), this study serves to compare and contrast training load and markers of wellness across eight 4-week mesocycles investigating for patterns or trends in load that may exist across a season. Weekly external and internal load were obtained from thirty elite Gaelic football players (25.7 ± 3.5 years, 183.0 ± 4.7 cm, 84.4 ± 6.5 kg) across a full season (33 weeks, 8 seasonal blocks). External training loads (TL) were measured using 4-Hz GPS units. Internal TL, assessed via s-RPE, was recorded for each training activity and game. Psychometric data were recorded each morning upon rising, which calculated a readiness to train (RTT) score for each player.

Chapter 8: Thesis Conclusions and Recommendations for Future Research
This chapter consists of an overarching discussion and conclusion for this research process in its entirety. This presents findings from the series of investigations conducted. Practical implications based on the findings of the research are suggested and discussed. Additionally, it provides recommendations for future research within Gaelic football and the limitations of the current research undertaken.
### 1.5 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU</td>
<td>Arbitrary Units measurement of training load</td>
</tr>
<tr>
<td>CMJ</td>
<td>Counter Movement Jump</td>
</tr>
<tr>
<td>CV</td>
<td>Co-efficient of Variation</td>
</tr>
<tr>
<td>EF</td>
<td>Effect Size</td>
</tr>
<tr>
<td>FB</td>
<td>Full-Back one of the 5 positional lines in Gaelic Football</td>
</tr>
<tr>
<td>FF</td>
<td>Full-Forward one of the 5 positional lines in Gaelic Football</td>
</tr>
<tr>
<td>GAA</td>
<td>Gaelic Athletic Association</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HB</td>
<td>Half-Back one of the 5 positional lines in Gaelic Football</td>
</tr>
<tr>
<td>HF</td>
<td>Half-Forward one of the 5 positional lines in Gaelic Football</td>
</tr>
<tr>
<td>HSE</td>
<td>Number of High-Speed Efforts</td>
</tr>
<tr>
<td>HSR</td>
<td>High Speed Running</td>
</tr>
<tr>
<td>MF</td>
<td>Mid-Field one of the 5 positional lines in Gaelic Football</td>
</tr>
<tr>
<td>NFL</td>
<td>National Football League</td>
</tr>
<tr>
<td>RHSD</td>
<td>Relative High-Speed Distance</td>
</tr>
<tr>
<td>RTT</td>
<td>Readiness To Train</td>
</tr>
<tr>
<td>s-RPE</td>
<td>Session Rate of Perceived Exertion</td>
</tr>
<tr>
<td>TD</td>
<td>Total Distance</td>
</tr>
<tr>
<td>TL</td>
<td>Training Load</td>
</tr>
<tr>
<td>%HS</td>
<td>Percentage of Time at High Speed</td>
</tr>
</tbody>
</table>
1.6 Glossary of Terms

**Athlete monitoring**
A method to quantify and evaluate athletic preparation, to maximise performance and minimise injury risk. Measuring the training stress (internal & external) and the training response (Saw, 2016).

**External training load**
Any external stimulus applied to the athlete that is measured independently of their internal characteristics (Halson, 2014).

**Fatigue**
Tiredness resulting from mental or physical exertion or illness, in sport often manifested as failure to maintain the required or expected force (or power output) (Soligard et al., 2016).

**Internal training load**
Load measurable by assessing internal response factors within the biological system, which may be physiological, psychological, or other (Halson, 2014).

**Neuromuscular Fatigue**
An exercise-induced decrease in skill-based performance and/or capacity that originates within the neuromuscular system (Boyas, & Guevel, 2011).

**Training load**
Sport and non-sport burden (single or multiple physiological, psychological or mechanical stressors) as a stimulus that is applied to a human biological system (including subcellular elements, a single cell, tissues, one or multiple organ systems, or the individual) (Soligard et al., 2016, p.1031)

**Training response**
The term training response can be defined as a physical and psychosocial state that reflects whether an athlete is responding positively or negatively to training (Saw, 2016).

**Readiness to Train**
A physical and psychosocial wellbeing (wellness) state which enables an athlete to succeed as an athlete and in life, out-side of sport. (Saw, 2016).
Chapter 2: Literature Review – Applied Science of Gaelic Football
2.1 Introduction

This chapter provides a detailed review of relevant and pertinent scientific research conducted in the Gaelic football domain that has shaped a deeper understanding of the game. The purpose of this review is not only to document the research that has been completed in a variety of Gaelic football contexts, but also to highlight the gaps in the literature and provide direction for future research. To facilitate this comprehensive review of the literature, online searches of PubMed and Research Gate were conducted for all relevant and appropriate studies published. Keywords selected in the search were GPS, s-RPE, wellness markers, athlete monitoring, Gaelic football, training load, monitoring fatigue, over training, validity and reliability. This literature review is categorized into 3 main sections. Section 1 serves to provide an overview of the physical and physiological demands of Gaelic football and will provide a context for how related training modes can be evaluated. Section 2 examines the role of training load monitoring, with special reference to the influence of both external and internal load on the outcomes of training. Finally, Section 3 examines the current literature examining the relationship between training load and both performance and fatigue.

2.2 Gaelic Football – A Brief Background

Gaelic football is the largest participation sport in Ireland and is played by amateur sportsmen and women (Delaney & Fahey, 2005). It is governed by the Gaelic Athletic Association (GAA), which dates back to 1884 and was founded in Hayes Hotel in Thurles. Gaelic football is a field based sport played on a rectangular pitch, with a length of 130m to 145m and width of 80m to 90m. Played with teams of 15 players composed of a goalkeeper, six defenders, two midfielders, and six forwards, a score is recorded when the ball is kicked or fisted over the crossbar, which is worth one point, or when a goal is scored by kicking or punching into the net below the crossbar. This major score is worth three points (Bradley, 2007; Hassan, 2010; Reilly & Doran, 2001).

Inter-county football and hurling competitions began in 1887, the major contest being the All-Ireland Championships (Bradley, 2007; Hassan, 2010; Reilly & Doran, 2001). Successful club champions represented their county in the All-Ireland series with Commercials from Timerick defeating Young Irelands of Louth in the first ever final. It was only in 1892 when teams from various clubs in the county were selected onto county
panels. This resulted in the formation of the elite inter-county Gaelic football competitions. Players are still bound by the rules of the association which means they are strictly constrained by its amateur status.

Gaelic football is an intermittent high-intensity sport requiring high levels of strength, power, agility and speed as well as proficiency with game-related skills interspersed with periods of lower intensity aerobic activity (Collins, Solan, & Doran, 2013; King & O'Donoghue, 2003). As with many training and performance developments, GAA teams are continuously utilizing advances in sports science and coaching science from comparable professional sports, in particular the other football codes.

2.3 Physiological Profiles

Understanding of the physiological profiles of elite Gaelic footballers is of utmost importance for players. Players must adapt to the requirements of the modern game if they are to compete at the elite level. Furthermore, knowledge of these demands will assist strength and conditioning coaches to build a needs analysis of the game for future development of training programmes. The next part of this literature review will examine the fitness characteristics of players at the elite level in Gaelic football, making comparisons to other sports and to their sub elite counterparts (club players).

2.3.1 Maximal Aerobic Power

Maximal aerobic capacity (VO₂ max) defines the upper limit of the cardiopulmonary system, it is determined by the capacity to increase heart rate, augment stroke volume, and direct blood flow to the working muscle. Numerous studies have investigated the physiological characteristics of Gaelic footballers, with the respective fitness of players varying from club (sub-elite) to county (elite) articulated in table 2.1 (Brick & O’Donoghue, 2003; Keane, Reilly, & Borrie, 1995; Kirgan & Reilly, 1993; McIntyre, 2005; Watson, 1995). Elite inter-county players have been reported to train 4-6 times a week depending on the time of season and, as a result, their physiological characteristics are more advanced than their club counterparts (Keane et al., 1995). The maximal aerobic power (VO₂ max) of club players has been reported as being inadequately developed, with studies reporting estimated VO₂ max 20-30% lower than elite inter-county players (Keane et al., 1995; Watson, 1977). The relatively modest aerobic fitness of club players has been
attributed to a lower work rate in competition, matches of shorter duration (60 vs 70 mins) and inappropriate training programs (Keane et al., 1995; Watson, 1977).

Studies have reported the mean VO\(_2\) max levels of elite inter-county players in the range of 57.0±3.9 to 58.8±3.8 ml/kg/min (Brick & O’Donoghue, 2003; Doran, Donnelly, & Reilly, 2003; McIntyre, 2005; Watson, 1995). Interestingly, limited research has reported the mean estimated VO\(_2\) max of Gaelic football players throughout a competitive season. This may be due to the difficulty and time needed to schedule VO\(_2\) max testing, especially within an amateur sport like Gaelic football, coaches only have their players for limited periods during the week. As a result, VO\(_2\) max was not a key metric or component of fitness assessed throughout the year. However, Young and Murphy (1994) observed an increase from 54.1±4.6 to 57.1±4.6 between the off-season and end of pre-season, while a more recent study by Kelly and Collins (2015) also found comparable increase changes in VO\(_2\) max (8.8%, \(p < .05\)) from November (commencement of pre-season) to March (early in-season), with minor improvements observed in January (mid pre-season). The variance in VO\(_2\) max within the published literature, may be due to the timing of testing within the season and the different methods used to assess. At the time of writing, the author is unaware of any study conducted with associated aerobic capacity measurements obtained during an inter-county championship campaign in which teams are in their peak condition.
<table>
<thead>
<tr>
<th>Positional Status</th>
<th>Body Mass (kg)</th>
<th>Body Fat (%)</th>
<th>VO2max (ml/kg/min)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outfield players (n=26)</td>
<td>85.4 ± 10.4</td>
<td>12.4 ± 2.6</td>
<td>57.0 ± 3.9</td>
<td>Kelly and Collins (2015)</td>
</tr>
<tr>
<td>Outfield players (n=25)</td>
<td>86.5 ± 8.6</td>
<td>12.0 ± 4.3</td>
<td>58.0 ± 5.0</td>
<td>Inter-county players</td>
</tr>
<tr>
<td>Backs (n=12)</td>
<td>78.5 ± 7.7</td>
<td>15 ± 3.3</td>
<td>56.8 ± 5.0</td>
<td>Inter-county players</td>
</tr>
<tr>
<td>Forwards (n=12)</td>
<td>82.3 ± 4.2</td>
<td>14.5 ± 3.07</td>
<td>College players</td>
<td>McIntrye and Hall (2005)</td>
</tr>
<tr>
<td>Midfielders (n=4)</td>
<td>87.45 ± 1.1</td>
<td>14.2 ± 3.04</td>
<td>Inter-county players</td>
<td>McIntrye (2005)</td>
</tr>
<tr>
<td>Outfield players (n=29)</td>
<td>81.0 ± 9.0</td>
<td>13.4 ± 3.0</td>
<td>Inter-county players</td>
<td>Doran, Donnelly, and Reilly (2003)</td>
</tr>
<tr>
<td>Outfield players (n=33)</td>
<td>79.2 ± 8.2</td>
<td>12.3 ± 2.9</td>
<td>Inter-county players</td>
<td>Club players</td>
</tr>
<tr>
<td>Outfield players (n=11)</td>
<td>81.9 ± 6.9</td>
<td>15.0 ± 4.2</td>
<td>Inter-county players</td>
<td>Florida-James and Reilly (1995)</td>
</tr>
<tr>
<td>Outfield players (n=15)</td>
<td>70.7 ± 7.7</td>
<td>12.2 ± 2.1</td>
<td>Inter-county players</td>
<td>Club players</td>
</tr>
</tbody>
</table>

Table 2.1: Mean body mass, body fat, VO2max according to position.
2.3.2 Accelerative Speed

Accelerative speed has been shown to be an important performance requirement for players within field sports (Lockie, Murphy, Schultz, Knight, & Janse de Jonge, 2012). Gaelic footballers require high levels of accelerative speed, which is an important characteristic of the game in terms of winning possession, evading an opponent and transitioning quickly from defence to attack (Brown & Waller, 2014; McIntyre, 2005).

In a comparison study between League of Ireland soccer players and inter-county Gaelic footballers (and hurlers), McIntyre (2005) conducted a number of physiological tests. No significant difference was found between the three codes in a speed test over 15m. However, in another study that compared English Premier League soccer players and inter-county Gaelic footballers (Strudwick et al., 2002) using electronic timing gates placed at 10m and at 30m, it was found the Gaelic football players were significantly slower in 10m (1.89 ± 0.17sec vs 1.75 ± 0.08sec) and 30m (4.60 ± 0.30sec vs 4.28 ± 0.12sec) sprint tests than their professional soccer counterparts. However, these differences between studies can be explained due to the methods used to assess accelerative speed and may be due to the different surfaces, environments, conditions, time of year (pre-season vs in-season) during which these measurements were obtained. Interestingly, in a recent study that measured maximum velocity of elite Gaelic football players by playing position using GPS, no significant difference was found across the positional lines during match play, with speeds ranging from 29.2 – 32.1 km/h (Malone et al., 2015).

2.3.3 Repeated Sprint Ability

The ability to repeat sprint in high intensity intermittent passages of play is extremely important in the game of Gaelic football (Collins, Solan, et al., 2013; Malone, Solan, Hughes, & Collins, 2017). A player needs to move quickly into position to jump, catch a high ball, land without breaking stride and overcome a defending tackle while producing high levels of power, strength and speed. They must then recover quickly to produce additional high intensity sprint efforts to either get into position to support the player in
possession or be ready to defend the counterattack. To date, there is a dearth of research that has investigated the repeat sprint ability in elite Gaelic footballers (Collins, Doran, & Reilly, 2013; Strudwick et al., 2002). Strudwick et al. (2002) examined the running speed and repeated sprint ability of elite Gaelic footballers and Premier League soccer players using 7x30m sprints with a 15sec recovery. Players were instructed to complete each 30m rep as close to maximal effort as possible. Electronic timing gates were used to measure the performances and placed at 10m and 30m. The fatigue index was calculated as a percentage of decline in performance from the fastest and slowest times over both distances. The study found no significant difference between the professional soccer players and amateur (albeit elite) Gaelic footballers over both 10m and 30m distances expressed by the percentage fatigue index.

Additional research is needed to provide greater understanding of the higher intensity passages of play within Gaelic football match play. Additionally, the need to establish a specific Gaelic football repeated test that truly replicates the repeated efforts, distances, work-to-rest ratios, which are similar within elite Gaelic football competition.

2.3.4 Agility

Agility has been defined as the ability to change direction at speed in response to an external stimulus (Oliver & Meyers, 2009; Shephard & Young, 2006). The crucial words in the definition are "response to an external stimulus", thus true agility needs a reactive factor. Gaelic footballers are required to accelerate, decelerate, stop, start and change direction all at speed. Players rarely sprint in straight lines without having to stop or change direction. For example, a defending player reacting to the movement of an opponent must respond to a given stimulus to win the ball back or tackle their opponent. Consequently, a forward attacking must try to avoid being tackled or try to get into a position to score. To date, the performance measurement of agility has not appeared in any published Gaelic football literature. Various measurements (T-test, Illinois Test and the L-test) of agility have been used in other field sports such as Australian football (Sheppard & Young, 2006), soccer (Reilly, Williams, Nevill, & Franks, 2000) and rugby league (Gabbett & Domrow, 2007; Gabbett, Kelly, Ralph, & Driscoll, 2009). However,
it should be noted that these tests are in fact measures of change of direction speed and not actually a measurement of agility. Therefore, the absence of the reactive factor in the aforementioned tests do not incorporate the visual-processing, timing, reaction time, perception and anticipation required to interact with change of direction that are required in many team sports (Sheppard & Young, 2006).

Additionally, unlike true agility tests (testing a response to an external stimulus), elite athletes do not perform better on the agility tests already mentioned (T-test, Illinois Test and the L-test) in comparison to sub-elite rugby league athletes (Gabbett, 2002a). However, it has been found in other sports that elite athletes perform better on true agility tests (testing a response to an external stimulus) than their sub-elite counterparts, suggesting that the non-reactive change of direction may not be as important for athletes as true agility (Gabbett, Kelly, & Sheppard, 2008; Henry, Dawson, Lay, & Young, 2011; Serpell, Ford, & Young, 2010; Sheppard, Young, Doyle, Sheppard, & Newton, 2006; Young, Farrow, Pyne, McGregor, & Handke, 2011). This may imply that developing a Gaelic football player’s agility may have a major implication to their ability to compete at the elite-level within the sport. Additional research is recommended to provide a greater understanding of the movement patterns to a reactive stimulus of match play within Gaelic football. This knowledge could serve to establish a specific Gaelic football agility test that truly replicates the stimulus and related conditions evident within the game.

2.3.5 Muscular Strength

Gaelic football is a contact sport requiring high levels of muscular strength and power, which are key characteristics of an elite inter-county footballer (Strudwick et al., 2002). Players are required to have the ability to generate high levels of strength and power effectively in order to resist and instigate physical contact in tackling, shoulder to shoulder charging, winning or maintaining possession (Florida-James & Reilly, 1995; McIntyre, 2005; Reilly & Doran, 2001). McIntyre (2005) reported significant differences in IRM bench press between elite Gaelic footballers (73.7±12kg) and hurlers (63.2±15kg), and also reported that Gaelic footballers were superior to professional soccer players (68.1±13kg) in this regard, concluding that soccer has less physical
challenges and therefore upper body strength is not a priority. These findings are much lower than what was reported by Brick and O’Donoghue (2003) who also tested 1RM bench press with elite Gaelic footballers (93.6±12.3kg). This study also confirmed that Gaelic footballers had a superior upper body strength than hurlers and soccer players, but significantly lower than Rugby Union forwards.

A more recent study (Kelly & Collins, 2015) examined the variation of muscular strength across pre-season to mid-season with respect to the five playing positions. It was found that the upper body strength (1RM bench press) was at its greatest mid-season (range: full forwards 87.5 ± 8.3 to full backs 112 ± 15.2kg) and varied by position. To date, this research conducted by Kelly and Collins (2015) is the first to examine lower body strength within the Gaelic football literature. The 1RM deadlift was reported to be the method used to measure lower body strength within the study. Finding lower body strength was also at its greatest mid-season and varied by position with significant difference found between the half-backs and midfielders (range: midfielders 152.8 ± 18.2 to half-back 162.8 ± 17.7kg). However, the difference of ten years between studies (Brick and O’Donoghue, 2003 and Kelly and Collins, 2015) would suggest a greater emphasis on strength and conditioning in recent years has resulted in a significant increase in greater upper body strength in Gaelic footballers. A major limitation across studies examining strength in Gaelic football is that strength has not been calculated as a metric relative to body mass. Comparing absolute strength across playing position must be approached with caution as such variation may be due to body mass differences (i.e. heavier versus lighter players). Therefore, it is recommended that future research is needed, expressing strength relative to body mass within Gaelic football across multiple teams and positions.

2.3.6 Power

Most of the previous studies that investigated the physical profiles of Gaelic football used the vertical jump or counter movement jump test to measure muscular power (Brick & O’Donoghue, 2003; Cullen et al., 2013; Kelly & Collins, 2015; McIntyre & Hall, 2005; Shovlin, Roe, Malone, & Collins, 2017; Strudwick et al., 2002; Watson, 1995). Strudwick
et al. (2002) found inter-county players' vertical jump (58.3 ± 6.7) to be inferior to professional soccer players (63.4 ± 5.7), but much higher than that found by Watson (1995) in a similar cohort of inter-county players (50.3 ± 5.8). Such differences may be explained by the various methodological approaches used by the researchers between studies and the higher levels of conditioning that players were exposed to in the later study. The counter movement jump (CMJ) has been found to be a valid and reliable measurement of lower body muscular power (Davis, Briscoe, Markowski, Saville, & Taylor, 2003; Hoffman, Epstein, Einbinder, & Weinstein, 2000) and it is only in recent literature that CMJ scores appear for Gaelic footballers (Kelly & Collins, 2015; Shovlin et al., 2017), the mean CMJ for elite inter-county footballers was 38cm. More research is warranted, a more comprehensive study should examine differences of elite Gaelic footballers across multiple teams and positions.

2.3.7 Physiological Demands of Competition

The physiological demands of Gaelic football match-play have been examined in both club and inter-county players (Florida-James & Reilly, 1995; Reilly & Doran, 2001; Reilly & Keane, 2002). Reilly and Keane (2002) assessed 20 inter-county and 13 club players during competition. This study found the average heart rate of the inter-county players did not vary between halves and was 9 beats.min⁻¹ lower than their club counterparts (169 ± 9 vs 160 ± 6 beats.min⁻¹ respectively). Club players' heart rate tended to be more variable, increasing as the game neared the end. The peak heart rate for both sets of players were 201 ± 16 beats.min⁻¹ for inter-county players and 205 ± 10 beats.min⁻¹ for club players during competition. The increased values of the inter-county players compared to the club players, suggests this may be due to their ability to pace themselves throughout the game, being more economical and tactical in their running. What is most striking in this comparison is that inter-county games are 10 minutes longer than club games and thus placing greater demands on the energy systems of the elite cohort. These findings, similar to those of Florida-James and Reilly (1995), suggest high physiological strain in Gaelic football competition with average heart rate reaching 80% of maximum, independent of level of performance (i.e. elite or sub-elite). However, although these studies are the first to investigate and provide significant information into the
physiological demands of competition within Gaelic football, these studies are dated and may not reflect the modern game.

2.3.8 Objective Measure of the Movement Demands of Competition

Initial studies (Keane & Hughes, 1993; King & O’Donoghue, 2003; McErlean, Cassidy, & O’Donoghue, 2000; O’Donoghue, Donnelly, Hughes, & McManus, 2004) within Gaelic football examined differences in the movement demands of elite Gaelic football players using video and time-motion analysis. Research carried out by Keane and Hughes (1993) estimated that the overall distance covered by an elite Gaelic footballer was 8594 ± 1056m. The greatest distance was covered by mid-fielders 9131 ± 977m, a finding supported by similar research studies with Gaelic footballers (King & O’Donoghue, 2003; McErlean et al., 2000). However, although these studies are the first to investigate and provide significant information into the demands of the game of Gaelic football, major limitations with the classification of speed bands and the inter observer definition of movement must be considered when using video analysis.

In recent years, researchers have availed of new innovations in technology and used GPS athlete-tracking as a method to quantify the running demands in Gaelic football (Collins, Solan, et al., 2013; Malone et al., 2015; Malone, Solan, Collins, & Doran, 2016; Malone, Solan, et al., 2017; Reilly et al., 2014). In a study of 36 elite Gaelic footballers across 4 competitive national league games, it was reported that the average distance covered during the games, independent of position, was 8815 ± 1287 m, with a range of 6183 – 11104m (Collins, et al 2013). The average high-intensity distance covered was 1695 ± 503 m, revealing that midfielders covered greater high-intensity distance during match-play than defenders and attackers. It should be noted, that the study only investigated 4 competitive games and the associated profiles of the three main positions in Gaelic football (defender, midfielder, attacker) as opposed to the five positional lines (full back, half back, mid fielders, half forwards and full forwards).

The differences across the five positional lines of elite Gaelic footballers within a senior inter-county team has been examined during match-play by Malone et al. (2015). Key
findings from this research are presented in Table 2.2. This study, conducted using GPS technology, is the first within the sport to provide a description of match play running demands during competition across all five positions in an elite senior inter-county Gaelic football team. The research was carried out across two full seasons with 30 competitive games assessed. The middle eight positions (half-backs, midfielders and half-forwards) experienced greater activity profiles than the inside full back and full forward positions for all the GPS variables with the exception of maximum velocity (Table 2.2). Similar to Collins, et al. (2013), Malone et al. (2015) found that the midfielders covered more total distance and high speed running distance than any other position. These differences in running demands might be explained by the inter-changeable and roving tactical role typically assigned to the middle 8 players within Gaelic football (winning possession and transitioning from defence to attack). Also within the study, significant reductions were found in high speed running totals and sprint distance between the two halves with the midfielders experiencing the greatest (11%), followed by the half-backs (10.3%) and half-forwards (8.2%) due to their excessive workload.

Further work by Malone, et al. (2017) investigated duration-specific demands of 35 elite inter-county Gaelic football players during match play. Using a rolling average methodology of analysis (1-10min), the study was able to identify the ‘worst case scenario’ for Gaelic footballers across all the positional groups (Table 2.3). The rolling averages were analysed across 10 specific durations (1-10min) for each player with a maximum value for each specific duration recorded. The study analysed the relative distance covered (distance covered divided by time, expressed as \( \text{m} \cdot \text{min}^{-1} \)) in the following categories; total distance (\( \text{m} \cdot \text{min}^{-1} \)), high-speed distance (\( \text{m} \cdot \text{min}^{-1}, \geq 17 \text{ km} \cdot \text{h}^{-1} \)) and sprint distance (\( \text{m} \cdot \text{min}^{-1}; \geq 22 \text{ km} \cdot \text{h}^{-1} \)). The relative distance variable has been found within the GPS literature to be a more valid and accurate reflection of match intensity than total distance covered, as it takes into account the duration of the event (Cummins, Orr, O’Connor, & West, 2013). A major finding from the work of Malone, Solan, et al. (2017) was that the positional running performance of match-play is higher than previously reported in Gaelic football literature. Previous studies have been limited by only reporting the average running performance relative to the whole duration of the match (Malone et al., 2015), thus failing to quantify position specific ‘worse-case
scenario’ running demands required of players across specific durations across a match. These findings also suggested that half-back, midfield and half-forward positions must be exposed to higher levels of running within their training when compared to full-back and full-forward positions. In a recent systematic review, Whitehead, Till, Weaving and Jones (2018) identified moving averages to be the most appropriate method for identifying the peak match demands in a sport. Whitehead et al concluded that such studies need to incorporate multiple teams in order to give a more generalisable ‘worse-case scenario’ running demands for a sport, as well as the need for shorter duration-specific periods (<1min). This evokes limitations to Malone et al (2015) findings and suggests further research is required in the field of Gaelic football for the worst case scenario.

A related study conducted by Ryan, Malone, and Collins (2017) investigated the acceleration profile of elite Gaelic footballers across two seasons in 19 competitive matches. The number, distance and durations of accelerations were measured across 14 equal periods of 5-minute epochs (0-5, 5-10min, etc). The GPS variables analysed were total distance covered (m), high-speed distance (m; ≥17 km·h⁻¹); and very high speed distance (m; ≥22 km·h⁻¹). Findings revealed that, independent of position, players performed 166 ± 41 accelerations and that the mean acceleration distance was 267 ± 45 m distributed between 12 ± 5 accelerations per 5-minute period (Ryan et al., 2017). The study also revealed a reduction in accelerations in players as the match progressed, which substantiates the findings of Malone et al. (2015) and Malone, et al. (2017). The findings of these applied research studies provide invaluable information for coaches in devising sport-specific conditioning scenarios for their players to optimally replicate the positional requirements within conditioned-based running. The running performance profiles can also be used by medical teams for respective return to play protocols by ensuring that injured players are exposed to the positional-specific maximal running demands required to play the game. Until now, coaches and physios may have been prescribing training and rehab programs based on the mean of the whole squad and/or the whole match, resulting in under prescribing the most intense passages of play and players being underprepared. However, these studies only investigated the running demands of one team within one division of the National Football League (NFL). Furthermore, the style of play used by
the coach/team, match to match variation, and match outcome was not analysed within the studies. More research is warranted, a more comprehensive study should examine differences in the movement demands from multiple teams across divisions to gain a better overview and representation of performance measures.

2.4 Anthropometric Profiles

The body composition of Gaelic footballers has been reported to be in the range of 12.0-15% body fat, with a body mass of 70.7-86.5 kg (Table 2.1) (Brick & O’Donoghue, 2003; Brown & Waller, 2014; Florida-James & Reilly, 1995; Kelly & Collins, 2015; McIntyre, 2005; McIntyre & Hall, 2005; Strudwick, Reilly, & Doran, 2002; Watson, 1995, 1996). Gaelic footballers have been found to have higher body fat and body mass than professional soccer players, similar levels to hurling players and Rugby Union backs but lower than Rugby Union forwards (Brick & O’Donoghue, 2003). Similar to Rugby Union, body composition in Gaelic Football has been found to vary by position (Brick & O’Donoghue, 2003). Davies et al. (2015) found that midfielders were heavier and had higher body fat percentage when compared to backs and forwards (Davies, Toomey, McCormack, Hughes, Cremona & Jakeman, 2015). This study measured the body composition of 46 elite Gaelic footballers, obtained by dual energy X-ray absorptiometry (DXA). This is in contrast with the findings of Kelly & Collins (2015) who reported that full-forward line players were significantly heavier than the middle eight, and possessed the highest body mass and adiposity (Kelly & Collins, 2015). However a limitation to the methods used by Davies et al. was that players were categorised into three out-field positions, thus resulting in a smaller sample size for the midfield position. This is in contrast to the methodology of Kelly & Collins who conducted their analysis across all the five out-field positions, may reflect the lower running demands associated with playing in the full-forward position compared with midfielders who have been reported to having higher running demands and having lower body fat percentages (King & O’Donoghue, 2005; Malone et al., 2015; McIntyre, 2005).
Table 2.2: The running demands including total distance, high speed distance, sprint distance, accelerations, max velocity and relative distance (mean ± 95% CI) according to playing position in elite Gaelic footballers measured by GPS from Malone et al. (2015)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Full Backs (n = 43)</th>
<th>Half Backs (n = 43)</th>
<th>Mid Fielders (n = 43)</th>
<th>Half Forwards (n = 43)</th>
<th>Full Forwards (n = 43)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Distance (m)</td>
<td>6892 (6144 - 7344)</td>
<td>8700 (8200 - 9231)</td>
<td>9523 (9023 - 9744)</td>
<td>8952 (8552 - 9022)</td>
<td>7090 (6544-7290)</td>
</tr>
<tr>
<td>High Speed Distance (m)</td>
<td>1369 (981 - 1569)</td>
<td>1784 (1584 - 1991)</td>
<td>2228 (1755 - 2422)</td>
<td>1884 (1544 - 2044)</td>
<td>1366 (1066-1666)</td>
</tr>
<tr>
<td>Sprint Distance (m)</td>
<td>371 (351 - 391)</td>
<td>494 (474 - 503)</td>
<td>488 (458 - 512)</td>
<td>512 (498 - 552)</td>
<td>357 (245 - 377)</td>
</tr>
<tr>
<td>Accelerations (no)</td>
<td>152 (142 - 172)</td>
<td>204 (174 - 214)</td>
<td>219 (184 - 232)</td>
<td>195 (165-205)</td>
<td>152 (122 - 177)</td>
</tr>
<tr>
<td>Max Velocity (km·h)</td>
<td>30.2 (29.2 - 32.1)</td>
<td>31.2 (29.2 - 33.2)</td>
<td>32.1 (30.1 - 33.2)</td>
<td>29.8 (28.1-30.2)</td>
<td>29.2 (27.2 - 30.1)</td>
</tr>
</tbody>
</table>

Significantly different from a full-backs, b half-backs, c midfielders, d half-forwards, e full-forwards (all p < 0.001).
Table 2.3: The peak maximum relative distance, high speed distance and sprint distance (m min) according to playing position in elite Gaelic footballers measured by GPS from Malone, et al. (2017)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Full Backs</th>
<th>Half Backs</th>
<th>Mid Fielders</th>
<th>Half Forwards</th>
<th>Full Forwards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Relative Distance (m·min)</td>
<td>194 *</td>
<td>242 *</td>
<td>255 *</td>
<td>241 *</td>
<td>196 *</td>
</tr>
<tr>
<td>Maximum Relative High Speed Distance (m·min)</td>
<td>36.77 ± 3.1</td>
<td>47.14 ± 3.1</td>
<td>50.11 ± 4.2</td>
<td>45.71 ± 3.7</td>
<td>36.87 ± 3.8</td>
</tr>
<tr>
<td>Maximum Relative Sprint Distances (m·min)</td>
<td>7.79 ± 3.2</td>
<td>9.78 ± 3.1</td>
<td>11.77 ± 3.2</td>
<td>9.88 ± 3.2</td>
<td>8.99 ± 3.2</td>
</tr>
</tbody>
</table>

*standard deviation was not provided within the research
2.5 Monitoring Training Load

The International Olympic Committee’s consensus statement on load in sport and risk of injury defined load as,

"the sport and non-sport burden (single or multiple physiological, psychological or mechanical stressors) as a stimulus that is applied to a human biological system (including subcellular elements, a single cell, tissues, one or multiple organ systems, or the individual)"

(Soligard et al., 2016, p.1031).

Monitoring the training load that athletes are exposed to in both training and competition has become quite prevalent, with both sports scientists and coaches using multiple systems to monitor training loads on a sessional, daily, weekly and monthly basis. This has resulted in a significant increase in empirical and applied research in the sports domain in recent years (Bourdon et al., 2017). The precise control of training loads that are associated with individual response is critical for maximizing training adaptations and optimising recovery in preparation for competition (Borresen & Lambert, 2009). Therefore, it is recommended that training load and recovery be monitored within a team environment (Foster et al., 2001; Kellmann, 2010). Impellizzeri, Rampinini, Coutts, Sassi, & Marcara (2004) expressed the need to control and monitor the overall training load imposed on athletes with such load expressed by both distinct factors: the external training load, such as the distance covered and the internal training load, which is the psycho-physiological stress produced as a result of the external load (Figure 2.1).

There is a great difficulty in establishing a method to effectively quantify training using a single term without the monitoring of both training load factors. There are various different methods used to quantify each respective category of training load within athletes. Internal load can be measured using training impulse (TRIMP) based on heart rate, blood lactate, oxygen consumption, ratings of perceived exertion (RPE) and incorporating some form of psychological monitoring questionnaire (e.g. stress, mood state, fatigue) to assess the players’ training response to the activity in question. External load can be measured with accuracy using global positioning systems (GPS) and accelerometers (Borresen & Lambert, 2009), with the former particularly gaining popularity in field based sports as a means of collecting objective information regarding
the movement demands of athletes in training and competition (Petersen, Pyne, Dawson, Portus, & Kellett, 2010; Wisbey, Montgomery, Pyne, & Rattray, 2009).

It has been found that elite Gaelic football players have reported significantly higher levels of emotional and physical exhaustion in comparison to their non-elite counterparts (O’Neill et al., 2007). Monitoring the external and internal training loads of elite Gaelic football players and the associated differences in loads of the traditional training based activities used at the elite Gaelic football level have not been examined. An increased understanding of this relationship will assist coaches in planning optimum training loads between games and training sessions in addition to apply appropriate recovery strategies.

2.6 Measuring External Load

Endurance athletes have often used the training volume (kilometres per week) as an index of training with reasonable effectiveness. However, measurement of training volume ignores the critical importance of high intensity training bouts that has previously been found difficult to quantify in team sports due to their high-intensity intermittent nature (Bloomfield, Polman, O’Donoghue, & McNaughton, 2007). Therefore, monitoring the
external load within Gaelic football due to its high-intensity intermittent performance characteristics is particularly difficult.

2.6.1 Global Positioning System (GPS)

GPS is a satellite-based navigational technology that provides information on location and time for tracking devices. Originally developed for military purposes, it is now widely used by sports teams and athletes (Cummins et al., 2013; Malone, Lovell, Varley, & Coutts 2017). Satellites orbit the earth and send precise time information (from an atomic clock) that synchronises to the GPS inbuilt receiver (at the speed of light) to determine the duration of signal transit. A minimum of four satellites are required to determine the position of the GPS receiver trigonometrically by calculating the distance from the GPS receiver to the satellites (Malone, Lovell, et al., 2017). Advancements in GPS technology have resulted in extensive use of the devices to track athlete’s movements to monitor the external training load within team sports (Aughey, 2011). Key match-play performance characteristics associated with fatigue, such as high-intensity efforts and distance at high speed, can be recorded and analysed with these devices and have proven valuable when monitoring fatigue and performance in training and match play (Buchheit et al., 2013).

2.6.2 Validity and Reliability of GPS

Validity refers to the extent to which the measure corresponds with what is actually being measured, calculated from the relationship with another measure which is known or assumed to be valid; while reliability refers to the consistency or accuracy over repeated measurements (Saw, Kellmann, Main, & Gastin, 2017). With the advancements in recent GPS technology (higher sampling rate, data processing and software), both the validity and reliability have also improved (Scott, Scott, & Kelly, 2016). Scott et al. found 1-Hz and 5-Hz GPS units have limitations in their reporting of distance during high-intensity running, velocity measures, and short linear running. The authors also concluded that the 10-Hz GPS devices were the most valid and reliable instruments to date across linear and team sport simulated running, overcoming many limitations of earlier models, whereas the increase to 15-Hz devices had no additional benefit. Interestingly, Johnston et al. (2014) reported that 10-Hz units were superior to 15-Hz units; these findings provide support for further research with regard to sampling rates within GPS units. It warrants a mention that sampling rates are not the only factor impacting on GPS data accuracy; other
factors such as the chipset processor and the positioning of the device may also impact on the validity of the data output (Malone, Lovell, et al., 2017). The chipset within the unit is how the ‘raw’ data is exported and pre-filtered by the receivers’ firmware to reduce the noise within the GPS signal. This type of processing is dependent upon the model and the version of the firmware used by the manufacturer (Malone, 2017).

The majority of GPS validation studies have employed relatively simple field-based research designs using human subjects, which is problematic in itself, with validity assessed against a known distance using linear running without changes in direction (Nagahara et al., 2017; Varley, Fairweather, & Aughey, 2012). While these studies provided an in-depth assessment of velocity and distance, the limitations were that they did not use sport-specific movements involving changes of direction that replicate the demands of match play. However, Coutts and Duffield (2010) and McLeod, Morris, Nevill, and Sunderland (2009) employed sport-specific movement based circuits (Figure 2.2) and subsequently demonstrated that GPS devices have an acceptable level of validity lap and reliability retest to accurately monitor the demands of team sports. It warrants reporting that each individual device may have its own inherent variance between inter-unit reliability across different GPS models from the same manufacturer (Coutts & Duffield, 2010), which has serious implications within athlete monitoring across a longitudinal season if different units are worn by different athletes. Therefore it is recommended that a specific unit be assigned to each athlete for the entire season or period when monitoring (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010).

Figure 2.2: Circuit designed to simulate movement demands of team sport (Coutts & Duffield, 2010 pp134)
Specifically within Gaelic football, the VX Sport GPS 4-Hz unit has been examined by Malone et al. (2014) for accuracy and reliability during an intermittent sport-specific movement circuit. Within the study, a test-retest (7 days apart) reliability for total distance covered, high speed running, maximum speed and average speed was quantified (Malone, Collins, et al., 2014). Systematic differences were examined using a paired t-test on the test-retest data and revealed no significant differences for the total distance covered (300.5 ± 3.3 and 303.6 ± 5.6 m), high speed running (54.2 ± 14.9 and 55.7 ± 13.1 m), maximum speed (23.9 ± 1.9 and 24.1 ± 1.3 km·h⁻¹) and average speed (10.2 ± 1.0; 10.2 ± 0.9 km·h⁻¹) respectively. The typical error (TE ± 95% confidence interval [CI]) was 0.84 ± 0.3 for total distance covered, 0.75 ± 0.26 for maximum speed, 0.55 ± 0.19 for average speed, and 0.29±0.1 for high speed running, respectively. The coefficient of variation (CV% ± 95% CI) was 1.0 ± 0.4 for the total distance covered, 4.2 ± 1.5 for maximum speed, 4.4 ± 1.5 for average speed and for high speed running 8.0 ± 2.8, respectively. With the exception of high speed running, all of the measured variables demonstrated a CV (CV% ± 95% CI) of less than 5%, (Malone, Collins, et al., 2014). The study concluded that the devices were accurate and suitable for use in the measurement of intermittent physical activity during field games such as Gaelic football. However, as speed increased there appears to be an increased variation in the test retest data. This can be explained through the method used within the study. The determination of inter-unit reliability for velocity requires the specific velocities at which the participants move to be reproduced across trials (Malone, Lovell, et al., 2017). Human participants are unable to exactly replicate the same speeds on multiple trials, thus the study design utilizing a self-paced protocol is limited. Therefore, future research is needed to determine inter-unit reliability through the use of a mechanical device that will allow exact velocity and distance to be replicated (Malone, Lovell, et al., 2017). Additionally, it should be noted that the use of a t-test is not recommended in this context due to its inability to detect systematic differences. However, a Bland-Altman plot is more appropriate for such analyses. Buchheit et al. (2014) conducted a validity study in soccer using 4 different tracking systems during standardised drills with running distance and times collected using timing gates as the gold standard. Relative to the other 3 systems, a Bland-Altman plot (figure 3.1) revealed that the VX Sport GPS units produced smaller within-system differences at 7.2 km/h and 14.4 km/h. At the higher speed (19.8 km/h), this trend was not evident with both the Inmotio and Prozone systems demonstrating less bias. Overall, the VX units were found to have lower levels of bias relative to the other 3 systems.
Figure 2.3 Standardized bias (90% confidence intervals) in distance covered at 3 different set speeds for each tracking system. The number of * symbols indicate possible, likely, very likely and almost certain differences from the criterion measure, respectively. The grey area represents trivial difference (0.2 x pooled between-player SD). n = 14 for runs at 7.2 and 14.4 km.h<sup>-1</sup>, and n = 28 for run at 19.8 km.h<sup>-1</sup>. (Buchheit et al 2014 pp9)

2.6.3 **GPS and the Quantification of External Load**

GPS can be used to monitor the movement demands of individual athletes and can be used to objectively quantify levels of exertion and physical stress on the athlete. It can be used to examine different positional workloads within a sport, establish training intensities and monitor changes in player physiological demands (McLellan, Lovell, & Gass, 2011). The athletes’ movement demands and profiles (external loads) can be used in addition to the physiological responses (internal load) to characterize training or match play (McLellan et al., 2011). Within a survey of 82 professional soccer clubs, the most common variables reported in the athlete monitoring process were total distance, high speed distance, sprint distance and accelerations (Akenhead & Nassis, 2016). Injury prevention is a core objective in athlete monitoring and with injury-mechanism studies highlighting the role of high intensity activities contributing to injury, it seems logical that these variables are of importance to sports practitioners (Akenhead & Nassis, 2016).

A limitation within GPS research is the data is often separated into 5 or 6 speed zones (depending on the model) in an attempt to understand the ‘intensity-distribution’ of the athlete’s external load (Malone, Lovell, et al., 2017). The thresholds used for low speed,
moderate-speed, high-speed and very high-speed/sprinting differs across studies within the GPS literature (Cummins et al., 2013; Malone, Lovell, et al., 2017). Such variations make comparisons between individual studies, sports and competitions very difficult.

The rationale to which the various speed zones are set to regulate high speed can be determined either by an absolute or relative threshold. With absolute thresholds, a single speed is used for each zone; one approach is to use the team’s mean physical fitness score (i.e. anaerobic threshold) and apply it to the whole team (Clarke, Anson, & Pyne, 2015; Vigne, Gaudino, Rogowski, Alloati, & Hautier, 2010). This is very useful in allowing comparisons to be made between positions and individuals within the team. Within the Gaelic football literature, the speed zones and descriptors have been consistently applied across all the studies using absolute thresholds found to be relative to the sport (Malone et al., 2015; Mangan, Malone, Ryan, McGahan, O’Neill, et al., 2017; Mangan, Ryan, et al., 2017; Reilly et al., 2014). The speed zones have been set across five zones, standing and walking (0–6.9 km h⁻¹), jogging (7–11.9 km h⁻¹), cruising/striding (12–16.9 km h⁻¹), high speed running (17–21.9 km h⁻¹) and sprinting (>22 km h⁻¹) (Reilly et al., 2014).

The relative threshold approach is based on the individual performance characteristics such as maximal sprint speed (Gabbett, 2015) or physiological justification (e.g. speed at the second ventilator threshold [VT₂]) (Abt & Lovell, 2009) and is set to player-independent (arbitrary) speed thresholds. This method is very beneficial when measuring an individual’s external load during training or competition; when the monitoring of the training load is specific to that individual athlete. However, practitioners are advised to be cautious when only using one of these performance characteristics, for example maximum speed or physiological (e.g. speed at the second ventilator threshold [VT₂]) in isolation, as this approach has been found to result in flawed interpretation (Hunter et al., 2015). Hunter et al. (2015) found by setting the relative speed zones using maximal sprint speed in isolation resulted in player's % HSR and % VHSR, being incorrectly interpreted, when compared to the individualized method of measuring %HSR and %VHSR. Suggesting that this approach of measuring just maximal sprint alone did not take into account the physiological rationale of the player and may have major implication in monitoring the individual athlete.

Practitioners have many challenges in an applying individualized speed thresholds, namely the lack of consensus within the literature, the selection of performance
characteristics to be measured and how these are to be assessed. Furthermore, there are numerous practical difficulties in executing regular performance tests with large squads of athletes, all of which present considerable obstacles to this task implementation (Malone, Lovell, et al., 2017). Further research is warranted with regard to the investigation of the individualized versus arbitrary speed zones, which will ultimately aid the sports practitioner in making more informed decisions on training prescription and monitoring the external load. Interestingly, future developments in GPS software may include the capability to measure absolute and relative speed zones to facilitate practitioners in their comparison of data from both approaches.

2.7 Measuring the Internal Load

Bourdon and colleagues (2017) recently published a consensus statement on athlete monitoring, defining internal training loads as the relative biological (both physiological and psychological) stressors imposed on the athlete during training or competition. As previously stated, measures such as heart rate, blood lactate, oxygen consumption and ratings of perceived exertion (RPE) are all commonly used to assess internal load. Many of the overtraining and athlete monitoring studies have proven that psychological indicators are more sensitive and consistent than physiological indicators (Meeusen et al., 2013). Additionally, psychological measures can be employed and reported a lot quicker than physiological or blood markers, which can take days or weeks to assess (Bourdon et al., 2017). With the recent advances in sports technology, the development of online player monitoring tools that provide coaches with subjective information on player wellness can help manage training load for potential risk of overtraining (Killen, Gabbett, & Jenkins, 2010).

2.7.1 Session Rate of Perceived Exertion (s-RPE)

To assess internal training load, Foster (1998) proposed using the session rate of perceived exertion (s-RPE), combining both the intensity and duration of the activity. This provides an assessment score in arbitrary units (AU) for the athlete’s internal load by multiplying the athlete’s perceived effort from a scale of 1-10 for the entire session (adapted Borg scale illustrated in Table 2.6) and the duration of the session (Scale of effort 1-10 x time (mins) session duration). Due to its ease of use and low cost, s-RPE has become widely used by sports practitioners across many sports and has been found to
strongly correlate with objective load measures such as heart rate (Wallace, Slattery, & Coutts, 2009) and blood lactate (Gabbett, 2010b). Additionally, s-RPE has been used to measure the various training activities that are undertaken by team-sport athletes, such as weight training (Sweet, Foster, McGuigan, & Brice, 2004), pitch-based conditioning and skills-based sessions (Clarke, Farthing, Norris, Arnold, & Lanovaz, 2013; Williams, Trewartha, Cross, Kemp, & Stokes, 2017). Thus, the s-RPE method represents a highly practical tool for monitoring the internal training loads of athletes within Gaelic football.

Table 2.4. Modified Borg CR-10 Scale (Foster et al., 2001)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Rest</td>
</tr>
<tr>
<td>1</td>
<td>Very, Very Easy</td>
</tr>
<tr>
<td>2</td>
<td>Easy</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat Hard</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very Hard</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Maximal</td>
</tr>
</tbody>
</table>

2.7.2 Validity and Reliability of Session Rate of Perceived Exertion

An individual’s s-RPE is a psycho-physiological subjective perception of intensity of effort in response to the external load undertaken by the athlete and has been found to be a valid and reliable method of monitoring the internal load (Gabbett & Domrow, 2007; Herman, Foster, Maher, Mikat, & Porcari, 2006; Impellizzeri et al., 2004; Wallace et al., 2009).
Gabbett and Domrow (2007) assessed validity and reliability s-RPE, the relationship between heart rate and s-RPE, and between blood lactate concentration and s-RPE, within rugby league. A strong correlation was found between training heart rate and training s-RPE ($r = 0.89$), and training blood lactate concentration and training s-RPE ($r = 0.86$), respectively (Figure 2.3). Within the same investigation, a test-retest reliability study using a sub-set of eleven players was conducted to examine whether s-RPE had within-subject reproducibility to measure the training load (Gabbett & Domrow, 2007). The players completed two identical training sessions with one week between sessions. Within-subject relationships were strong (Intra class correlation (ICC) = 0.99, Coefficient of variation (CV) 4.0%) suggesting that the s-RPE method is reliable for assessing training load in contact-based sports (Gabbett & Domrow, 2007). The findings within the above studies present s-RPE as a valid, reliable measure for measuring the internal training load.

### 2.7.3 Applications of s-RPE to Quantify the Internal Load

In the application of s-RPE to quantify internal training load during exercise sessions, practitioners should follow standard instructions and anchoring procedures to familiarize athletes with the scale and its use (McGuigan, 2017). This will increase the reliability and validity of the s-RPE (Borg, 1998). An athlete’s s-RPE is advised not to be collected immediately following the training session and has been suggested to be taken verbally approximately 30 min after completion (Foster, 1998; Foster et al., 2001). This was to ensure that the perceived effort was reflective of the entire session rather than the exercise intensity of the most recent activity (Herman et al., 2006; Impellizzeri, 2004). However, research conducted by Singh, Foster, Tod, and McGuigan (2007) demonstrated that there was no significant difference from measures taken 30 min and 10 min post session. This study concluded that 10 min post session is sufficient time to obtain s-RPE measures (Singh et al., 2007). These findings have been supported in recent literature by other researchers in the field (Christen, Foster, Porcari, & Mikat, 2016; Uchida et al., 2014), providing practitioners with confidence waiting 10 min post session will give a valid measure of s-RPE.
A number of derivative measures of internal training load can be calculated from the daily s-RPE values and be used to prescribe training with respect to the training stimulus, overtraining and injury risk (Foster, 1998). Foster (1998) suggested the summing the daily session loads for the entire week that provides training monotony and strain measurements. Training monotony is the variation in daily session loads across the week. It can be calculated by taking the average load across the week and dividing it by the standard deviation of the daily load. For example, if athletes are constantly providing high s-RPE scores during a week of training, with little variation in the day to day training load, the monotony will be high, which may indicate the need to change the training program (Comyns & Flanagan, 2013). Training strain is a result of the weekly training
load and monotony and represents the overall stress that the athlete was exposed to throughout the training week (Comyns & Flanagan, 2013). It is calculated by multiplying the weekly training load by the training monotony score. Again, if the weekly training load is high, together with a high monotony score, this will produce excessive training strain. Athletes have been found to be at greater risk of injury and illness risk during periods of high strain and monotony (Blanch & Gabbett, 2015; Foster, 1998). Using s-RPE to monitor load, monotony and strain over a period of a time can aid sports scientists and coaches to determine individual athlete risk of overreaching and over training (McGuigan, 2017). Gallo, Cormack, Gabbett, Williams, and Lorenzen (2015) found that certain characteristics influence the relationship between external and s-RPE load such as an athlete's training age, fitness levels and playing position. This supports the advocacy of using a combination of both internal and external load measures to monitor training load within team sports (Gallo, Cormack, Gabbett, Williams, et al., 2015).

2.8 Measuring the Training Response

The term training response can be defined as a physical and psychosocial state that reflects whether an athlete is responding positively or negatively to training (Saw, 2016). As previously stated by Impellizzeri et al. (2004), to quantify the external (such as the distance covered) and internal load (self-perceived exertion) experienced by an athlete, it is necessary to quantify the athlete’s training response. For example, if an athlete experiences a greater than expected internal stress (RPE) in response to a given external stress, the athlete may be showing signs of a negative training response (Pyne & Martin, 2011). Therefore, measures of external and internal training load may adequately fail to consider the complex interaction of the various factors that can affect athletic preparation and performance (Saw, 2016). The training response is highly individual, a collective influence of factors such as: age, sex, training history, current training status, psychological factors, the presence of other stressors outside of training, and ability to tolerate stress are all influential on the athlete’s well-being (Borresen & Lambert, 2009). Furthermore, the monitoring an athlete’s training load along with markers of wellness (e.g. stress, fatigue) has been found to have the potential to reduce periods of overtraining among sports participants. Therefore, practitioners are encouraged to not only measure training load but also incorporate some form of psychological monitoring questionnaire (e.g. stress, fatigue) to assess the player’s training response to the previous day’s activity.
(McLean, Coutts, Kelly, McGuigan, & Cormack, 2010; Meeusen et al., 2013) or non-sport burden (Soligard et al., 2016).

Research studies within the field of athlete monitoring and overtraining have demonstrated that psychological indicators are more sensitive and consistent than physiological indicators (Meeusen et al., 2013). Similar to s-RPE, a major benefit with wellness markers is the ease of use and low cost, making this method very popular with sports scientists for athlete monitoring and to training quantification (Hopkins, 1991; Taylor, Chapman, Cronin, Newton, & Gill, 2012). Therefore, the use of a tool that measures markers of wellness is highly recommended to evaluate the training response when monitoring load and to aid in the determination of the wellbeing of elite Gaelic football players.

### 2.8.1 Measuring Wellness Markers

Research (Taylor, et al 2012) has found the measurement of an athlete’s self-reported wellness to be an essential method for monitoring the training response, and furthermore this process is a relatively simple, cheap and effective method of monitoring athlete wellbeing (Saw, 2016). Research studies within the field have found wellness questionnaires are sensitive to detecting changes in stress and fatigue in elite athletes (McLean et al., 2010; Saw, Main, & Gastin, 2015a). Various wellness questionnaires have been reported within the research literature across a range of sports and athletes (Saw et al., 2015a). Self-report measures based on an athlete’s perceived physical, psychological and/or social wellbeing are regularly completed on a daily and weekly basis. Taylor et al. (2012) revealed that more than 80% of sports practitioners use self-designed questionnaires in high performance sports environments. This is due to a number of reasons but a key reason is that the majority of published questionnaires contain too many items and thus take too much time to complete and analyse; in other cases, such instruments lack sport specificity (Taylor et al., 2012). To minimize unnecessary additional burden on athletes whilst obtaining high quality and meaningful data (McGuigan, 2017) over the long-term, the majority of these self-designed wellness questionnaires typically consist of 4 -12 items, measured using either 1-5 or 1-7 Likert scales, with higher scores indicating greater levels of wellness (McGuigan, 2017; Taylor et al., 2012). Consistent items identified within these questionnaires are muscle soreness, fatigue, wellness and sleep quality/sleep duration (McGuigan, 2017). Saw et al., (2015a)
expressed caution when using a single item like ‘fatigue’ as it introduces uncertainty around the exact meaning. For example, to rate fatigue, athletes may reflect on their physical or their psychological fatigue, their fatigue due to training, or in general wellbeing. However, despite their popularity and common practice within elite sport, there is a dearth of research on the effectiveness of self-designed questionnaires used over a full season (or several seasons) of competition and training.

2.8.2 Validity and Reliability of Wellness Measures

Gastin and colleagues (2013) claim validity with a self-designed wellness questionnaire within elite Australian footballers across a full competitive season. The study found the self-designed questionnaire was sensitive to daily and weekly fluctuations in recovery status, particularly with regard to the high load of games and subsequent offloading during bye weeks (Gastin et al., 2013).

Saw et al. (2017) advised the more error contributed by various sources (i.e., the individual and their environment), the less reliable and sensitive a measure is for assessing the athlete state. Gastin et al. (2013) assessed the reliability of the self-reported wellness questionnaire, by measuring test–retest reliability ($n = 809$) in data collated from 2 similar training weeks during a pre-season competition. Typical error, expressed as a percentage coefficient of variation, % CV = 24.1%; intra-class correlation coefficient, ICC = 0.58. With the variability greater the day after a game (31.9%) and smallest on the day of a game (12.4%), the author concluded that this variability reflected player responses from week to week, both in how they felt and how they reported within the questionnaire. However, it should be noted that the study design and assessment of such validity is complex, as each criterion (training week) also possesses a degree of error (i.e. the individual and their conditions leading into each week). Furthermore, the ICC (0.58) is considered to be moderate and the high variability the day after a game demonstrates the need for further research to support the claim that wellness markers are sensitive to detecting changes in fatigue. A more individualised approach to monitoring using wellness questionnaires is needed in future research.

Psychometric wellness questionnaires used in previous athlete monitoring studies (Gastin et al., 2013; Hooper & Mackinnon, 1995; Kellmann, 2010; McLean et al., 2010; Saw et
al., 2015a) have found wellness questionnaires to be sensitive to detecting changes in stress and fatigue in elite athletes (McLean et al., 2010). However, caution must be considered in terms of interpretation of data as the scores and inferences may be affected by how the questions are worded, the response options within the questionnaire and also the context of the questions (Schwarz, 1999).

2.8.3 Applications of Wellness Measures to Quantify the Training Response

Saw, Main, and Gastin (2015b) conducted a study examining the factors that influence the implementation of wellness measures to quantify the training response in sport and reported that the social environment (e.g. buy-in and reinforcement) was critical for athlete compliance and coordinating those involved in the monitoring. Also, the connection of the questionnaire to the athlete’s goals and its impact on their training were considered important motivating factors (Saw et al., 2015b). Thus, sports practitioners must consider the design of such wellness questionnaires, reflecting on factors that could influence the data and also how the data is to be collected. Additionally, sports scientists must educate the athlete and coaching staff on the importance of honesty with their answers within the questionnaire. This will assist any fears that the coaching staff might have with athletes reporting falsely and dishonestly in order to either avoid training or hide illness or injury. Interestingly, Saw et al. (2015b) found the use of technology as beneficial with the implementation of questionnaires and compliance with athletes. This suggests that the use of apps for athletes to complete their questionnaires on smartphone or tablet is to be recommended. This method of evaluation will also decrease completion time and the inbuilt program should contain capability to analyse the data and provide feedback automatically to the athletes and coaching staff.

The analysis and interpretation of the data from wellness questionnaires requires the assessment of whether or not a change is meaningful. All analysis of the data must take into account the individual’s reporting habits. Taylor et al. (2012) found the most frequently used method to measure wellness was to observe trends in an athlete’s profile over successive days and sessions. By calculating the deviation in an athlete’s score from their mean, practitioners may then set a threshold for what deviation from the mean reflects a meaningful change, and therefore is ‘red-flagged’ (e.g. ±1.5 standard deviation away from the mean) (McLean et al., 2010).
2.9 Injury Rates within Gaelic Football

Gaelic footballers generate high levels of strength and power effectively in order to resist and instigate physical contact in tackling, shoulder to shoulder charging in winning possession and/or maintaining possession of the ball (Florida-James & Reilly, 1995; McIntyre, 2005; Reilly & Doran, 2011). Due to the physical contact and high intensity nature of the game, it is inevitable that injuries will occur. A number of studies have examined the injury rate per year in elite Gaelic footballers (Cromwell, Walsh, & Gormley, 2000; Newell, Grant, Henry, & Newell, 2006; Wilson, Caffrey, King, Casey, & Gissane, 2007). Cromwell et al. (2000) reported 1.78 injuries per player per year, Newell et al. (2006) found an average of 1.46 injuries in their research for the same period of time. While a study by Wilson et al. (2007) revealed an average of 2.20 injuries per player per year. For the purpose of these studies, an injury was defined as one that caused a player to miss one training session or match or that required at least one treatment. More recently, Murphy, O’Malley, Gissane, and Blake (2012) reported a rate of 1.19 injuries per player per year, with the majority of injuries happening in match play (61.86 per 1000 hours and 4.05 per 1000 hours for training). Furthermore, this study found 59% of match play injuries occurred in the second half, suggesting a fatigue element may be contributing to injury incidence (Murphy et al., 2012). Although a high intensity contact sport like Gaelic football carries a high risk of contact injury, the primary source of injuries reported were non-contact, with over 70% of all injuries predominantly in the lower limb (Murphy et al., 2012; Newell et al., 2006; Wilson et al., 2007). This would reflect the principal mechanics and movement patterns of the game, notably sprinting, decelerating, turning and landing. Murphy et al. (2012) reported that the thigh region accounted for more than one third of all injuries with the hamstring being the most prevalent contributor in this regard at 24%. Through the identification of injury risk factors, the four-year prospective study, is the first step to an effective injury prevention protocol within Gaelic football (Murphy et al., 2012). However, more research is warranted in the athlete monitoring domain to fully explore and understand associated risk factors to injury in elite Gaelic footballers across a season.
2.9.1 Influence of Training Load on Injury Rates

Several studies have reported the influence of training load and injury risk within team sports (Cross, Williams, Trewartha, Kemp, & Stokes, 2016; Gabbett & Domrow, 2007; Gabbett & Jenkins, 2011; Gabbett, Jenkins, et al., 2012) with several suggesting the presence of higher training loads presenting a positive relationship with injury risk (Gabbett, 2004; Gabbett & Domrow, 2007). Furthermore, the same cohort of researchers also found greater high speed running scores positively associated with a higher prevalence of lower body soft tissue injury (Gabbett, Jenkins, et al., 2012).

More recent research has investigated the training load ratio, known as the Acute:Chronic-Workload Ratio (ACWR), which uses rolling averages to compare work-loads. This refers to the acute load of Week 1 presented as a ratio relative to the load of the previous 4 weeks (known as the ‘chronic load’). The ratio ultimately considers the load the athlete is prepared for in the coming week, with research demonstrating high chronic loads presenting as more resistant to injury and inverse spikes in acute load increasing the risk of injury (Blanch & Gabbett, 2015; Gabbett, 2016; Hulin et al., 2013; Hulin, Gabbett, Lawson, Caputi, & Sampson, 2015) (Figure 2.4). However, it must also be mentioned that although ‘spikes’ in training load may contribute to injuries, undertraining may cause a similar outcome with regard to unnecessary exposure to injury. This is reflected in a U-shaped effect presented in Figure 2.4, which illustrates that both overtraining and undertraining increase the risk of injury. This viewpoint is understated within current training-load injury literature.

Hulin et al. (2013), reported on the high chronic training loads within cricket bowlers, finding that the fast bowlers who completed a greater number of balls over the 4-week chronic period were adequately protected against injury risk than bowlers who bowled fewer balls (Hulin et al., 2013). This is in contrast to the earlier research mentioned (Gabbett, 2004; Gabbett & Domrow, 2007) higher training loads presenting a positive relationship with injury risk. It is now emerging from the research that higher chronic training loads can protect athletes from injury and this has been described as the ‘vehicle’ that drives athletes towards or away from injury (Windt, Gabbett, Ferris, & Khan, 2017). With the current perspective that athletes should train smarter and harder, it appears that training acts as a ‘vaccine’ against injuries (Gabbett, 2016). With specific regard to Gaelic football, Malone et al. (2017a) investigated the relationship between training load and...
injury risk within an elite population. Thirty-seven elite Gaelic footballers from one squad were involved in a single season study. This study found that high acute: chronic workload ratio (>2.0) increases the risk of injury, with moderate acute: chronic workload ratio (≥1.35 to ≤1.5) protect against injury (Malone, Roe, Doran, Gabbett, & Collins, 2017a).

Interestingly, Menaspa (2017) has questioned the validity of the ACWR, expressing concern regarding the use of rolling averages. Such concern lies in the belief that rolling averages fail to account for the decreasing nature of fitness, implications of unloading weeks and fatigue effects over time. Therefore, ACWR may not accurately represent variations in load accumulation. Williams et al. (2017) have proposed the use of ‘exponentially-weighted moving averages (EWMA)’ for the calculation of acute and chronic loads, which assign a decreasing weighting for each older load value. However the authors concluded that further research is required to determine if this model provides a superior approach than the ACWR for predicting injury. The most important point is to continue to investigate and establish the most relevant method of analysis across different environments and sports, using exponentially weighted moving averages, different timeframes, metrics and thresholds (Williams et al. 2017). Specifically within Gaelic football, applying the ACWR presents challenges, such as defining locomotor profiles of individual players, integrating data from different GPS systems, data collection during the off-season and club/university duty phases.

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**Figure 2.5:** The relationship between the acute: chronic-workload ratio and injury risk. (Blanch & Gabbett 2016 pp473).
2.9.2 Relationship between Training Load, Injury, and Fitness

Malone, Roe, Doran, Gabbett, and Collins (2017b) reported that high acute: chronic workload ratio (>2.0) increases the risk of injury, with moderate acute: chronic workload ratio (≥1.35 to <1.5) protecting against injury. The study also found that high aerobic capacity and playing experience offers injury protection against rapid changes in workload and high workload ratios. It follows that protection against injury is related to the athlete’s ability to tolerate load (high chronic load) and in addition, exposure to training helps develop the physical qualities i.e. aerobic fitness. This emphasizes the importance of identifying players with poor aerobic fitness and low playing experience who are at higher risk of injury.

Within another study Malone, Roe, et al. (2017a) investigated the interaction of chronic training loads, exposure of maximal velocity and risk of injury within elite Gaelic footballers. The study found that players who were exposed to ≥ 95% 6 to 10 times per week of their maximum velocity were at less risk of injury, compared to players who completed lower maximal velocities. Furthermore, the study found that players who had higher chronic training loads (≥ 4750 AU) were at less risk of injury compared to players with lower chronic training loads. These findings provide valuable information for coaches in devising sport-specific conditioning tasks that expose players to maximum velocity and help build towards higher chronic training loads more intelligently. It warrants a mention that the investigation for both studies by Malone was conducted with one team over one season, therefore the findings can only be inferred relative to the population that they were derived from. Additionally, the method of using a 1km trial to assess aerobic fitness has its limitations, time trials under 2km have been found to overestimate maximal aerobic speed (Bellenger, Fuller, J. Nelson, M. Hartland, M. Buckley, J. Debenefictis, T. 2015). Further studies across several Gaelic football teams are needed to provide a comprehensive understanding of the training load-injury risk relationship within the sport. Monitoring of players’ training load, along with markers of wellness (e.g. stress, mood state, and fatigue) have also been found to reduce periods of overtraining among athletes. However, these measures of wellness have not been investigated within the Gaelic football literature to date. Therefore, further research is recommended to not only measure training load, but also to incorporate some form of psychological monitoring questionnaire (e.g. stress, mood state, fatigue) to assess the
players’ training response to the previous day’s activity (McLean et al., 2010; Meeusen et al., 2013).

2.10 Summary

The key findings from the current research literature review are outlined below.

- Average heart rate of Gaelic football players reaches 80% of maximum during match play, independent of level of performance (i.e. elite or sub-elite).
- The work: rest ratio has been reported to be 1:6.6 + 2.2, however the average duration and recovery was found to vary across positions with the central players.
- Gaelic football players cover on average 6892 to 9523 m during a 70-minute match, which is dependent on both the standard of competition, age and playing position.
- Of this distance, on average 1366 to 2228 m is covered at high-speed, with speed thresholds used to demarcate high-speed running set at ≥17 km·h⁻¹.
- On average, Gaelic football players perform 166 ± 41 accelerations, the mean acceleration distance was 267 ± 45 m distributed between 12 ± 5 accelerations per 5-minute period.
- Game-related spatial confinements substantially limit the frequency of sprints greater than 20 m, which is dependent on player position.
- Significant reductions were found with high speed running and sprint distance between the two halves of match-day performance. This reduction was greater in the second half of play for the middle 8 positions with the midfielders experiencing the greatest (11%), followed by the half-backs (10.3%) and half-forwards (8.2%).
- The main injuries reported were non-contact, with over 70% of all injuries predominantly in the lower limb.
- The demands of competition summarised above impose a high metabolic stress on players, which coupled with the volume of acceleration, deceleration and contact incidents provoke fatiguing effects. A variety of fatigue effects occur that reduce a player’s running capacity following competition. These fatiguing effects must be considered in the subsequent planning of training.
- Sample rate, speed, sprint effort, effort duration and the type of the exercise undertaking appear to influence the validity and reliability of GPS.
• The 10-Hz GPS devices seem the most valid and reliable to date across linear and team sport simulated running, overcoming many limitations of earlier models, whereas the increase to 15-Hz GPS devices have had no additional benefit. The sampling rate alone will not improve the GPS data, other factors such as the chipset processor used by the unit and the positioning of the unit on the body can all impact on the data output.

• The VX Sport GPS unit has been examined within the sport of Gaelic football and has been found to be valid and reliable during an intermittent sport-specific movement circuit.

• Despite being a measure of external load, GPS variables appear to have evidence of dose-response relationships with the variability in physiological responses to match-play and with other training outcomes such as injury risk.

• A review of the methods used to represent internal training load reveals that currently numerous methods exist and are very comparable to external training load methods previously reviewed.

• Due to the lack of a gold-standard criterion measure of internal training load, previous research has investigated training load validity against other measures of internal training load.

• The relationships between s-RPE and external training load methods have yet to be examined in elite Gaelic football competition and training.

• The widespread implementation of s-RPE has been based on the assumption of validity due to strong relationships with other internal training load measures. However, these other measures of internal training load have been used despite themselves lacking evidence of their validity.

• High acute: chronic workload ratio (>2.0) increases the risk of injury, with moderate acute: chronic workload ratio (≥1.35 to ≤1.5) protecting against injury within an elite Gaelic football sample cohort.

• Protection against injury is related to the athlete’s ability to tolerate load (high chronic load) and in addition, exposure to training helps develop the physical qualities of fitness. Therefore, identifying players with poor 1km time trial and develop their ability to tolerate load will reduce their risk of injury.

• The ACWR presents challenges within Gaelic football such as defining locomotor profiles of individual players, integrating data from different GPS systems, data collection during the offseason and club/college duty phases.
Chapter 3: Research Methods
3.1 Introduction

With regard to series of studies presented in Chapters 4-7, data were collected across the 2015-2017 GAA seasons (Dec-Sept) with two elite Gaelic Football teams. Match data comprised of the All-Ireland Championship competition, the most prestigious competition in Gaelic football and the National Football League competition, the second most prestigious competition, where each team plays the other 7 teams in their division only once. External training load (TL) was evaluated via selected GPS measures during all field based training and match-play. Internal TL (RPE x session duration) was recorded for each training activity and match post-session. Psychometric data (wellness markers) were recorded each morning upon rising using the Metrifit athlete monitoring system (Health and Sport Technologies Ltd, Dundalk, Ireland). Subjects were familiar with the rating system having completed an educational workshop during Pre-Season. Players were categorized as being from one of the five positional lines in Gaelic football i.e. full back (FB), half back (HB), midfield (MF), half forward (HF) or full forward (FF).

3.2 Participants

A total of 60 elite Gaelic football players from two elite inter-county teams (Division 1 and Division 3), participated in the studies contributing to the research program (Table 3.1). Ethical approval was sought and granted from the Cork Institute of Technology (CIT) Human Research Ethics Committee. Participants were provided with a detailed explanation of the study design and associated expectations and completed a consent form prior to commencement of data collection.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Number (N)</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Body Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elite Divisional 1 Gaelic footballer team</td>
<td>30</td>
<td>26.9 ± 3.5</td>
<td>182.8 ± 6.1</td>
<td>84.6 ± 8.1</td>
</tr>
<tr>
<td>Elite Divisional 3 Gaelic footballer team</td>
<td>30</td>
<td>25.7 ± 3.5</td>
<td>183.0 ± 4.7</td>
<td>84.4 ± 6.5</td>
</tr>
</tbody>
</table>
3.3 External Training Load

External training load (TL) was evaluated via selected GPS measures for all field based training and games. Training data was collected during pre-season and in-season and was classified as (i) game-based (small sided game scenario’s progressing to full game), (ii) skills-based (open and closed tasks to develop technique in passing, catching and shooting) or (iii) conditioning-based (high intensity running without the ball), dependent on the content of the sessions.

3.3.1 VX Sport GPS

External training load (TL) was assessed objectively using VX Sport 4 Hz GPS unit (VX Sport; Visuallex Sport, Lower Hutt, New Zealand, Firmware: V1.60 28). Upon commencement of each season, participants were allocated their own individual device, which was numbered and used only by them for the entire season. The unit was worn with a small vest on the upper back between the shoulder blades (Sample picture provided in the appendices). All devices were activated by the side of the pitch, satellite-locked for a minimum of 30 minutes before the commencement of each match and training session (Maddison & Ni Mhurchu, 2009; Malone et al., 2005). Following each match and training session, GPS data were downloaded using the VX software (VXSport View, New Zealand). Each file was trimmed to remove warm up, half time and cool down periods. All analyses was conducted across the 5 out-field positional groups (FB, HB, MF, HF, FF).

3.3.2 Validity and Reliability of VX Sport GPS

The VX Sport GPS (VX Sport; New Zealand) sampling rate within this micro-technology unit has demonstrated an acceptable level of validity and reliability for measuring movement demands within field sports (Coutts & Duffield, 2010, Buchheit, et al 2014, Malone, Collins, et al., 2014). Specifically within Gaelic football, the VX Sport GPS unit has been examined by Malone, Collins, et al. (2014) for accuracy and reliability during an intermittent sport-specific movement circuit.
3.3.3 Arbitrary Velocity Thresholds

Selected thresholds and metrics used in the current series of studies have been used previously in the GAA literature (Collins, Solan, et al., 2013; Malone et al., 2015; Malone et al., 2016). The speed zones and descriptors were consistently applied across all the studies using absolute thresholds found to be relative to the sport (Malone et al., 2015; Mangan, Malone, Ryan, McGahan, O’Neill, et al., 2017; Mangan, Ryan, et al., 2017, Reilly et al., 2014), standing and walking (0–6.9 km·h⁻¹), jogging (7–11.9 km·h⁻¹), cruising/striding (12–16.9 km·h⁻¹), high-intensity running (17–21.9 km·h⁻¹) and sprinting (>22 km·h⁻¹) (Reilly et al., 2014).

Sport-specific running variables assessed in the current research were total distance (TD) (m), high speed running distance (HSR) (>17 km/h), maximum velocity (MV) (km/h), percentage of time spent at high intensity (PHI) (%) and number of high intensity sprint efforts (HSE) (>17 km/h). Additionally, relative distance (RD) per minute (m/min) and relative high intensity distance (RHID) per min (m/min) were examined where appropriate. The latter is a more accurate reflection of match intensity than total distance covered, as it takes into account the event time (Cummins et al., 2013). High sprint efforts were calculated once a player changed speed by 2 km·h⁻¹ within 1 second. The change was triggered over a minimum time of 2 seconds, (to distinguish a lunge from a sprint). The sprint effort stopped when the player decelerated to <75% of maximum speed reached in the forgoing sprint effort (Malone et al., 2015). Metrics used in the current research have experimental support for monitoring training load in preparation for elite team sport competition (Gabbett & Ullah, 2012; Malone et al., 2012; Reilly et al., 2014).

3.4 Internal Training Load

Internal training load (TL) was measured via selected s-RPE for all training and games. Training data was collected during preseason and in-season and was classified as (i) game-based, (ii) skill-based, (iii) conditioning-based and (iv) strength and conditioning sessions dependent on the content of the sessions.
3.4.1 Session Rating of Perceived Exertion (s-RPE)

Internal training load was measured using the method of Foster et al. (2001), with session rating of perceived exertion (s-RPE) and exercise intensity using Borg’s CR-10 scale 1-10 scale (Borg, 1998) selected. All s-RPE values were obtained post-training and matches (Scale of effort 1-10 x time (mins) session duration). Each player’s s-RPE was collected verbally approximately 30 minutes after completion of every pitch session (after cool down and debriefing by the coach). This timing ensured that the perceived effort was reflective of the entire session rather than the most recent exercise intensity (Herman et al., 2006; Impellizzeri et al., 2004). Each individual s-RPE was then entered into the Metrifit athlete monitoring smartphone application and expressed as Arbitrary Units (AU) as a measure of internal Training Load. An Educational Workshop was provided to all participants in the preseason period to enhance their understanding of the process, familiarise them with the verbal anchors embedded in the scale and ensure clarity in the rating system itself. Furthermore, a specifically designed s-RPE Poster was present at each session to assist participants in their subjective rating of same.

3.4.2 Wellness Markers

Upon rising each morning, players completed a psychometric questionnaire to assess general wellness reflective of the previous day’s exertions. This task was recommended to be completed in private and at the same time each morning. All wellness data were collected using an athlete monitoring application (app) called Metrifit (Metrifit, Health and Sport Technologies Ltd, Ireland) trade mark term ‘Readiness To Train’ (RTT). Sample outputs of the Metrifit interface for both athlete and coach screens are provided in the appendices A126 and A127. Psychometric wellness questionnaires, used within previous sports science athlete monitoring studies (Gastin et al., 2013; Hooper & Mackinnon, 1995; Kellmann, 2010; McLean et al., 2010; Saw et al., 2015a), have found such questionnaires to be a valid and reliable tool to assess general indicators of player wellness (McLean et al., 2010). The stated questions were designed based on previous recommendations from numerous athlete monitoring training literature (Gastin et al., 2013; Hooper & Mackinnon, 1995; Kellmann, 2010; McLean et al., 2010) and were used to assess general indicators of player readiness to train (RTT). The questionnaire comprised of 6 questions relating to (i) perceived energy levels, (ii) sleep quality, (iii) muscle readiness, (iv) stress levels, (v) diet and (vi) mood state. Each question was scored
on a five-point scale with 1 and 5 representing poor and very good wellness ratings respectively (Table 3.2). Each question contributed a percentage weighting based on perceived importance as reported in previous literature (McGuigan, 2017; Taylor et al., 2012, Hooper & Mackinnon, 1995; McLean et al., 2010), which accumulated to an overall RTT percentage score for each individual player (Energy levels 20%, Sleep quality 19%, Muscle soreness 19%, Mood 14%, Stress 14% and Diet 14%). Based on the findings of Beasley (2015), who reported that GAA players were not getting adequate dietary intake, the diet-based variable was included in RTT algorithm. All the players were familiar with the rating system having completed an educational workshop in pre-season and instructed on its use by the primary researcher.

3.5 Counter Movement Jump

Counter Movement Jump (CMJ) testing was conducted each morning (09.00-10.00am) and evening (5.00-6.00pm) before each field session during the 5-day training camp using an electronic jump mat (FSL Electronics, Northern Ireland) by the same administrator to insure test-retest reliability. Kennedy (2010) investigated the reliability of the FSL jump mat and reported the tool to be a relatively precise testing device with resulting error calculated to be 1.92 ± 2.09 cm. The study recommended the use of the FSL jump mat due to its high levels of precision, its lightweight portability and its sports-specific applicability within field based testing environments. However, the study suggested that the results from the FSL jump mat cannot be compared directly with other similar devices or used interchangeably with force plate measurements due to the significant bias evident.

The CMJ test has been found to be a practical athlete monitoring tool used to examine neuromuscular performance and appears a suitable test to detect fatigue-induced changes in neuromuscular function (Gathercole, Sporer, Stellingwerff, Sleivert, 2015, Austruy 2016). Furthermore, a single CMJ has proved to be a useful tool for assessing neuromuscular fatigue in Australian football to detect delayed neuromuscular recovery (Cormack, Newton, & McGuigan, 2008). Many definitions of fatigue exist (Enoka, 1995), neuromuscular fatigue can be defined as an exercise-induced decrease in skill-based performance and/or capacity that originates within the neuromuscular system (Boyas, & Guével, 2011).
Prior to each testing session, participants performed a structured 2-minute dynamic warm up followed by 3 practice CMJs with 60 seconds rest between each rep before the single CMJ test measurement was recorded (Beattie & Flanagan, 2014; Cormack et al., 2008). Any participants suffering from a lower extremity injury were excluded from the testing protocol.

3.6 Statistical Analysis

Following each training session and match, GPS data were downloaded using the VX software. Each file was trimmed to ensure that only data recorded when the player was on the field at the start and end of each session (excluding match warm-up and cool-down) was included for analysis. Only full match and training data sets were included in the analysis. GPS scores, wellness markers and s-RPE values were downloaded from the athlete monitoring tool Metrifit and exported into a customized Microsoft Excel spreadsheet (Microsoft, Redmond, USA). All data were then inputted, stored and analysed using IBM SPSS Version 22. Missing data were accounted for by creating missing categories. A detailed description of the analysis used for each study is documented within each respective chapter.
Table 3.2: Daily wellness questionnaire.

<table>
<thead>
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<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mood State</strong></td>
<td>Highly annoyed/irritable/down</td>
<td>Snappiness at team mates, family and co-workers</td>
<td>Less interested in others/activities than usual</td>
<td>Good mood</td>
<td>Very positive mood</td>
</tr>
<tr>
<td><strong>Sleep Quality</strong></td>
<td>Hardly slept at all</td>
<td>Tossed and turned</td>
<td>Reasonable/Just OK</td>
<td>Good night’s sleep; Feeling refreshed</td>
<td>Had a great sleep. Feeling very refreshed</td>
</tr>
<tr>
<td><strong>Energy Levels</strong></td>
<td>Very lethargic – no energy at all</td>
<td>Very low energy levels</td>
<td>Reasonable energy levels</td>
<td>Good energy levels</td>
<td>Full of energy</td>
</tr>
<tr>
<td><strong>Muscle Soreness</strong></td>
<td>Extremely sore</td>
<td>Very sore</td>
<td>Quite sore</td>
<td>Mild soreness</td>
<td>Not sore at all</td>
</tr>
<tr>
<td><strong>Diet yesterday</strong></td>
<td>All meals high sugar/processed food, no fruit/veg</td>
<td>Some meals high sugar/processed food, no fruit &amp; veg</td>
<td>Ate reasonably, some sugar/processed food intake, at least 1 serving of veg</td>
<td>Ate well, low sugar/processed food intake, 2 or more servings veg &amp; fruit</td>
<td>Ate really well, no added sugar/processed foods and lots of veg and some fruit</td>
</tr>
<tr>
<td><strong>Stress</strong></td>
<td>Highly stressed</td>
<td>Feeling stressed</td>
<td>Reasonable / Just OK</td>
<td>Relaxed</td>
<td>Very relaxed</td>
</tr>
</tbody>
</table>
Chapter 4: Relationship between load and readiness to train in a Gaelic football pre-competition training camp

This study has been accepted for publication following peer-review. Full reference details are:

4.1 Abstract

Purpose: To investigate daily deviations of selected physiological and psychometric variables in elite Gaelic football players during a pre-competition training camp to minimize the risk of overtraining and injury. Methods: Thirty elite Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) participated in this study. Data were collected during a 5-day warm-weather training camp. External training loads (TL) of total distance (TD) and high speed running distance (HSR) were measured via global positioning system (GPS) technology. Physiological response to external load was measured via countermovement jump (CMJ) using an Electronic Jump Mat. Internal TL (Session RPE X Session Duration) was recorded for each player post-session and psychometric data were recorded each morning upon rising using the Metrifit athlete monitoring system, calculating a readiness to train (RTT) score for each player. Results: There were no statistically significant day to day variations in countermovement jump (CMJ) scores and RTT (Coefficient of Variation: 7.98% & 13.87%, small to moderate effect size respectively). Data were stratified based on the volume of HSR performed, with no statistically significant differences in RTT on the following day between selected high or low ‘loaders’. While TD, HSR and internal TL varied significantly from day to day, there were no adverse effects on individual CMJ or RTT scores on the following day. Conclusion: The findings of the current study demonstrate that an appropriately planned pre-competition training camp can provide a dedicated and prolonged period of time to develop tactical and team play elements while not adversely impacting levels of neuromuscular fatigue or perceptual ratings of wellness.

Key words: Psychometric variables, training load, RPE, GPS
4.2 Introduction

The amateur status of elite Gaelic footballers, means coaches only have their players for limited periods during the week. As a result, performance improvement in such a limited training environment is the greatest challenge. The importance of technical ability and tactical development, in addition to the application of the requisite fitness levels in an amateur team sport, must be specifically planned and incorporated into these sessions. With most players in full time employment or university, the frequency of training and matches, and the requisite travel involved between both, means that players rarely have adequate time to fully recover (O’Neill et al., 2007).

The primary objective of a ‘pre-competition’ training camp is to consolidate all of the cumulative facets of training undertaken to that point and to ensure a coherent and effective focus to facilitate optimal performance in competition. This contrasts with the more orthodox ‘pre-season’ training camp where the focus is primarily dedicated to the development of a broader fitness base for the impending season and where training loads (TL) may be up to 2-4 times greater than at pre-competition (Jeong, Reilly, Morton, Bae, & Drust, 2011). The burden of congested competition schedules creates challenges for Gaelic football coaches in terms of balancing the requirements of developing and maintaining physical fitness, optimizing recovery, technical and tactical development, as well as adjusting the TL before and between games and competitions (Gastin et al., 2013). The precise control of TLs that are associated with individual response is critical for maximizing training adaptations and optimizing recovery in preparation for competition (Borresen & Lambert, 2009). Therefore, the monitoring of TL and recovery is strongly recommended within a team environment, particularly during an intense training period (Foster et al., 2001; Kellmann, 2010). It has been reported that overall wellness is sensitive to subtle changes in the previous day’s training load during an intensive training camp in elite Australian footballers (Buchheit et al., 2013).

Recent advances in sports technology have resulted in the development of player monitoring tools which provide coaches with subjective information regarding player wellness and help to manage the potential risk of overtraining and injury (Killen et al., 2010). Monitoring tools have been used to assess internal TL using rate of perceived exertion (RPE) (Scale of effort 1-10 x time (mins) session duration) and the scores have been found to strongly correlate with heart rate variability ($r = 0.55-0.94; p < 0.05$)
(Wallace et al., 2009). Although heart rate analysis is well accepted in endurance sports, its validity is often questioned in team sports due to the intermittent nature, which often involves physical contact (Borresen & Lambert, 2009). An individual’s psycho-physiological subjective perception of intensity of effort, for which the RPE scale has been found to be valid and reliable, is a means of measuring an athlete’s internal (Herman et al., 2006; Impellizzeri et al., 2004; Wallace et al., 2009). Monitoring of players’ TL, in addition to markers of wellness (e.g. stress, mood state, fatigue), has the potential to reduce periods of overtraining among athletes. Therefore, practitioners are encouraged to not only measure TL but also incorporate some form of psychological monitoring questionnaire (e.g. stress, mood state, fatigue) to assess the players’ training response to the previous day’s activity (McLean et al., 2010; Meeusen et al., 2013). Psychological questionnaires, used within previous applied research (Gastin et al., 2013; Hooper & Mackinnon, 1995; Kellmann, 2010; McLean et al., 2010), have been found to be a valid tool to assess general indicators of player wellness (McLean et al., 2010).

The use of global positioning systems (GPS) are gaining popularity in field based sports as a means of collecting objective information regarding the movement demands of athletes in training and competition (Petersen et al., 2010; Wisbey et al., 2009). Greater levels of high speed running have been associated with an increased risk of lower body soft-tissue injury, whereas distances covered at low and moderate speeds offer a protective effect against soft-tissue injury (Gabbett & Ullah, 2012). Within a cohort of professional soccer players, perceived ratings of fatigue ($r = -0.51$; large; $p < 0.001$) were sensitive to daily fluctuations in high speed running during the competition phase (Thorpe et al., 2015). Key match-play performance characteristics associated with fatigue, such as high-intensity efforts and distance ran at high speed ($\geq 17 \text{ km h}^{-1}$), which can be recorded and analysed with these devices, have proven valuable when monitoring fatigue and performance in training and match play during a training camp environment (Buchheit et al., 2013). In addition, a single countermovement jump (CMJ) has proven to be a valid test for assessing neuromuscular fatigue in studies conducted in an applied training environment, providing coaches with the capacity to detect delayed neuromuscular recovery/fatigue (Cormack et al., 2008; McLean et al., 2010). CMJs are often used in combination with a psychometric questionnaire to provide coaches with a more informed decision to adjust TLs so performance can be optimised (McLean et al., 2010).
There is a dearth of research within the Gaelic football literature that has examined the relationship between internal and external TLs. An increased understanding of this relationship will assist coaches in (a) planning optimum TLs between games and training sessions and (b) developing appropriate recovery strategies. The purpose of this study was to: (i) document the daily variations of selected physical (GPS, CMJ) and psychometric (TL, wellness markers) variables during a pre-competition training camp in elite Gaelic football players and (ii) investigate the relationship between TL and readiness to train on the following day.

4.3 Methods

4.3.1 Experimental Approach to the Problem

This study used a repeated measures design to investigate daily variations of selected physiological and psychometric variables in elite Gaelic football players during a pre-competition training camp. External training loads (TL) were measured via selected GPS metrics of total distance (TD) and high speed running distance (HSR). The physiological response to the external load was measured via countermovement jump (CMJ) using an Electronic Jump Mat. Internal TL (Session RPE X Session Duration) was recorded for each player post-session and psychometric data (wellness markers) were recorded each morning upon rising using the Metrifit (Metrifit, Health and Sport Technologies Ltd, Ireland) athlete monitoring tool trade mark term 'Readiness To Train' (RTT) (Table 4.1). Data were collected during a 5-day warm weather (28 ± 3°C) pre-competition training camp in the month of June. In the weeks preceding the camp, subjects had been exposed to a chronic load (rolling average of the previous 4 weeks) of TD (14638m), HSR (2631m) and internal TL (1477AU), which included a taper week of 60%, prior to the 5 day training camp. Seven pitch sessions were completed across the 5-day training camp, with a primary emphasis on developing tactical play, refining technical skills and improving decision making. Two strength and conditioning sessions were also completed. Players were provided with pre- and post-training with nutrition plans devised by a qualified performance nutritionist to ensure adequate dietary intake between and during the sessions based on the findings of Beasley (2015). Additional post-recovery sessions were completed after each pitch session incorporating active pool recovery and stretching. The monitoring cycle started following each training session. Participants were divided into two training load groups (high or low) across each positional line (full-back, half-
back, midfield, half-forward, full-forward), based on the respective volume of HSR completed within the session. Training response (wellness scores) was monitored based on training load group. This served to identify individuals at an increased risk of fatigue. If wellness scores were low (i.e. athlete scoring a 1 or 2 in any wellness question), CMJ was closely monitored. If CMJ score fell significantly below the previous days score, the athlete was assessed by the physiotherapist and the session was subsequently modified or the player was rested.

Table 4.1: Variables used to monitor training load and subsequent fatigue

<table>
<thead>
<tr>
<th>Tool</th>
<th>Measures</th>
<th>Internal/External Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metrifit – RTT psychometric questionnaire</td>
<td>Stress</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Muscle soreness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diet</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Energy levels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sleep Quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mood</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sleep Duration</td>
<td></td>
</tr>
<tr>
<td>RPE</td>
<td>Perception of effort</td>
<td>Internal</td>
</tr>
<tr>
<td>CMJ - Neuromuscular Performance &amp; fatigue</td>
<td>Flight time/Height</td>
<td>External</td>
</tr>
<tr>
<td>GPS</td>
<td>High Speed Running</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>Total Distance</td>
<td></td>
</tr>
</tbody>
</table>

RTT (Readiness to train), RPE (Rate of Perceived Exertion), CMJ (Counter Movement Jump) and GPS (Global Positioning System)

4.3.2 Subjects

Thirty injury free elite Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) from the top ranked team in Ireland volunteered to participate in this study. Subjects were exposed to all experimental protocols during the first half of the competitive season for a minimum of 5 months leading into the training camp. The Research Ethics Committee of the host institution provided ethical approval for the study, with all players consenting to participate.

4.3.3 Procedures

_Neuromuscular Fatigue_

The CMJ test has been found to be a practical athlete monitoring tool used to examine neuromuscular performance and appears a suitable test to detect fatigue-induced changes
in neuromuscular function (Gathercole, Sporer, Stellingwerff, Sleivert, 2015, Austruy 2016). Furthermore, a single CMJ has proved to be a useful tool for assessing neuromuscular fatigue in Australian football to detect delayed neuromuscular recovery (Cormack, Newton, & McGuigan, 2008). Therefore, players performed a CMJ twice daily using an electronic jump mat (FSL Electronics, Northern Ireland) to detect delayed neuromuscular recovery (Cormack, Newton, & McGuigan, 2008). CMJ testing was conducted each morning (09.00-10.00am) and evening (5.00-6.00pm) before each field session by the same administrator to insure test-retest reliability. Prior to CMJ evaluation, participants followed a structured 2-minute dynamic warm up followed by 3 practice CMJs, with 60 seconds rest between each repetition before the single CMJ test measurement was taken (Beattie & Flanagan, 2015; Cormack et al., 2008). CMJ was performed with hands placed on the hips and subjects were instructed to jump as high as possible. All jumps were performed at a self-selected countermovement depth and no instruction was given on what countermovement depth to use (Kennedy 2010). The subjects were required to land on the same point as take-off and rebound with straight legs when landing in order to avoid knee bending and subsequent alterations in measurements. The best performance from each jump was recorded (Al Haddad, Simpson, & Buchheit, 2015). Any participants suffering from a lower extremity injury (30 x 9 session = 270 evaluations with 6 missed tests = 2.2%) were excluded from the testing protocol.

**External Training Load**

External training load was objectively measured using VX Sport 4 Hz GPS units (VX Sport; New Zealand). VX Sport GPS units have been shown to be valid (Coutts & Duffield, 2010), accurate, and reliable (Malone, 2014) during intermittent activity. Each athlete was allocated their own individual device which was numbered and used only by them for the entire training camp. The unit was worn with a custom designed VX Sport vest on the upper back between the shoulder blades. All devices were activated by the side of the pitch, satellite locked and established for a minimum of 30 minutes prior to the commencement of each training session (Malone, 2014). Following each session, GPS data were downloaded using the VX software. Each file was trimmed to ensure that only data recorded when the player was on the field at the start of each session was included for analysis. Metrics used in the current study included total distance (TD) covered and high speed running (HSR) distance (≥17 km·h⁻¹), which have experimental support for monitoring training load in preparation for elite team sport competition (Gabbett & Ullah,
2012; Malone et al., 2015; Reilly et al., 2014). Following each training session, participants were divided into two training load groups (high or low) across each positional line (full-back, half-back, midfield, half-forward, full-forward), based on the volume of HSR each participant completed within the session. Training response (wellness scores) was then closely monitored based on respective training load group. This served to identify any individuals who may be at an increased risk of fatigue.

**Internal Training Load**

Internal training load was measured using a 1-10 rating of perceived exertion (RPE) scale. Subjective markers were obtained using session-RPE values recorded post-training (Scale of effort 1-10 x time (mins) session duration). Each player’s RPE was attained verbally approximately 30 minutes after completion of every pitch session (post cool down and coaching team debrief). This timing ensured that the perceived effort was reflective of the entire session rather than the most recent exercise intensity (Herman et al., 2006; Impellizzeri et al., 2004). Each player’s RPE was then entered into the Metrifit athlete monitoring smartphone application and expressed as Arbitrary Units (AU) to provide the TL for the session.

**Readiness to Train**

Upon rising each morning, players completed a psychometric questionnaire to assess general wellness reflective of the previous day’s exertions. This task was recommended to be completed in private and at a constant time each morning. All wellness data were collected using an athlete monitoring web-based platform. The stated questions were designed based on previous recommendations from numerous athlete monitoring training literature (Gastin et al., 2013; Hooper & Mackinnon, 1995; Kellmann, 2010; McLean et al., 2010) and were used to assess general indicators of player readiness to train (RTT). The questionnaire comprised 6 questions relating to perceived energy levels, sleep quality, muscle soreness, stress levels, diet and mood state. Each question was scored on a five-point scale with 1 and 5 representing poor and very good wellness ratings respectively (Table 4.2). Each question contributed a percentage weighting based on perceived importance as reported in previous literature (McGuigan, 2017; Taylor et al., 2012, Hooper & Mackinnon, 1995; McLean et al., 2010), which accumulated to an overall RTT percentage score for each individual player (Energy levels 20%, Sleep quality 19%, Muscle soreness 19%, Mood 14%, Stress 14% and Diet 14%). Subjects were familiar
with the rating system having completed the process over the pre-season period and had been instructed on its use by the researcher with the team.

4.3.4 Statistical Analysis

All data were stored and analysed using IBM SPSS Version 22. Missing data were accounted for by creating missing categories. Mean and standard deviations were used to summarize the data. Prior to analysis, data were checked for normality (Shapiro Wilk test), while Levene’s test was used to test the homogeneity of variances. A 5% level of significance was used in all tests. Statistically significant results were complemented by the corresponding measure of strength of the result (Small effect: $0.01 < \eta^2 < 0.06$; Medium effect: $0.06 \leq \eta^2 < 0.14$; Large effect: $\eta^2 \geq 0.14$) (Cohen, 1988).

If the assumptions of normality, sphericity and homogeneity of variances were met, repeated measures ANOVA’s were used to investigate changes in TL, wellness and fatigue across each of the days. Five response variables were used: (i) TD; (ii) HSR; (iii) Internal TL; (iv) RTT and (v) CMJ. The within-subject effect was the training camp day (i.e. Day 1–5). When significance was found, the Bonferroni statistic was used to identify the nature of these differences.

The relationship between both external/internal TL and RTT on the following day was investigated using the Pearson correlation coefficient for normally distributed measures and Spearman rho for those deemed to be non-normally distributed. For the correlation analysis, only players who had full data set of each measurement (CMJ, RTT, GPS and RPE) for each day were included ($n=16$). Coefficient of variation was calculated ($\text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$) to compare the changes in RTT and CMJ across the 5-day period.

Independent $t$ tests were performed on RTT on the following day for each training load group based on the HSR distance performed on the previous day. Each positional line (full-back, half-back, midfield, half-forward, full-forward) was equally divided into two groups ($n = 3$ High and $n = 3$ Low loaders) and assigned to a high or low training load group based on the amount of HSR completed by each player on the previous day’s training session.
<table>
<thead>
<tr>
<th>Mood State</th>
<th>Sleep Quality</th>
<th>Energy Levels</th>
<th>Muscle Soreness</th>
<th>Diet yesterday</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly annoyed/irritable</td>
<td>Hardly slept at all</td>
<td>Very lethargic—no</td>
<td>Extremely sore</td>
<td>All meals high sugar</td>
<td>Highly stressed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>energy at all</td>
<td></td>
<td>processed food, no fruit &amp;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>veg</td>
<td></td>
</tr>
<tr>
<td>Highly stressed</td>
<td>Tossed and turned</td>
<td>Reasonable energy</td>
<td>Quite sore</td>
<td>Ate reasonably, some</td>
<td>Feeling stressed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>levels</td>
<td></td>
<td>sugar processed food intake,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>at least 1 serving of veg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good mood</td>
<td>Reasonable/Just OK</td>
<td>Reasonable energy</td>
<td>Mild soreness</td>
<td>Ate well, low sugar</td>
<td>Relaxed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>levels</td>
<td></td>
<td>processed food intake, 2 or</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>more servings veg &amp; fruit</td>
<td></td>
</tr>
<tr>
<td>Snappish in team mates,</td>
<td>Less interested in others/activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>than usual</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.2: Daily wellness questionnaire.
4.4 Results

Daily variation in measured variables are presented in Table 4.3. When the results for the measured variables were considered separately using repeated measures ANOVA, three variables, TD ($F = 254.918, p < 0.0005$, large effect size), HSR ($F = 64.138, p < 0.0005$, large effect size) and internal TL ($F = 271.101, p < 0.0005$, large effect size) were found to be statistically different across the 5 days (Table 2). Internal TL was found to be non-normally distributed; the Friedman Test also revealed a statistically significant difference in scores across the 5 days ($\chi^2 = 74.2, p < 0.0005$) and the Wilcoxon tests, which controlled for multiple comparisons, were used to identify the daily differences. Despite the variations in internal and external training loads, there was no statistically significant differences in RTT and CMJ scores across the 5 days ($p = .238$ & $.171$).

Non-significant correlations were found between internal TL, TD and HSR and markers of wellness and neuromuscular fatigue scores on the following day (Table 4.4). The coefficient of variation for the markers of wellness and neuromuscular fatigue across the entire week ($CV: 13.87\% & 7.98\%$) demonstrated no significant day-to-day variation ($p = .369$).

A series of independent sample $t$-tests were conducted between the high and low HSR group for RTT, CMJ and TL on the following day. No significant differences were found between high and low HSR groups for RTT ($p = .237$) and CMJ ($p = .914$) scores on the following day. For RTT the effect sizes were found to be small with the exception of Day 2 which was found to have a medium effect (Figure 4.1). Although not statistically significant, high ‘loaders’ tended to have a lower RTT score than low ‘loaders’, demonstrating a negative relationship between HSR and RTT (greater HSR results in lower RTT).
Table 4.3: Daily variation in total distance, high speed running, training load, readiness to train and counter movement jump scores

<table>
<thead>
<tr>
<th></th>
<th>Day 1 (Mean ± S.D.)</th>
<th>Day 2 (Mean ± S.D.)</th>
<th>Day 3 (Mean ± S.D.)</th>
<th>Day 4 (Mean ± S.D.)</th>
<th>Day 5 (Mean ± S.D.)</th>
<th>F</th>
<th>P</th>
<th>Partial Eta Squared</th>
<th>Pairwise Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS TD (m)*</td>
<td>5846 ± 942</td>
<td>2419 ± 561</td>
<td>4248 ± 376</td>
<td>2938 ± 496</td>
<td>7105 ± 690</td>
<td>254.918</td>
<td>&lt;0.0005</td>
<td>Large (0.937)</td>
<td>D1 &gt; D2, D3, D4, D2 &lt; D3, D4, D5, D3 &gt; D4, D4 &lt; D5</td>
</tr>
<tr>
<td>GPS HSR (m)</td>
<td>952 ± 26</td>
<td>415 ± 198</td>
<td>640 ± 118</td>
<td>468 ± 184</td>
<td>988 ± 261</td>
<td>64.138</td>
<td>&lt;0.0005</td>
<td>Large (0.790)</td>
<td>D1 &gt; D2, D3, D4, D2 &lt; D3, D4, D5, D3 &gt; D4, D4 &lt; D5</td>
</tr>
<tr>
<td>TL (AU)*</td>
<td>482 ± 89</td>
<td>187 ± 13</td>
<td>570 ± 56</td>
<td>387 ± 27</td>
<td>684 ± 48</td>
<td>271.101</td>
<td>&lt;0.0005</td>
<td>Large (0.935)</td>
<td>D1 &gt; D2, D4, D2 &lt; D3, D4, D5, D3 &gt; D4, D4 &lt; D5</td>
</tr>
<tr>
<td>RTT (%)</td>
<td>72.1 ± 11.2</td>
<td>68.4 ± 10.0</td>
<td>70.6 ± 8.0</td>
<td>73.1 ± 8.9</td>
<td>67.7 ± 13.5</td>
<td>1.412</td>
<td>.238</td>
<td>.066</td>
<td></td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>37.17 ± 3.21</td>
<td>37.48 ± 3.02</td>
<td>37.28 ± 3.25</td>
<td>37.97 ± 2.94</td>
<td>38.38 ± 3.46</td>
<td>1.649</td>
<td>.171</td>
<td>.084</td>
<td></td>
</tr>
</tbody>
</table>

* Greenhouse-Geisser was used to test within subject effects as sphericity was not assumed for the test. RTT (Readiness to train), TL (Internal Training Load), CMJ (Counter Movement Jump) and GPS (Global Positioning System) HSR (High Speed Running) TD (Total Distance)
Figure 4.1: Changes in readiness to train (RTT), countermovement jump (CMJ), and internal training load (TL) between players with high and low high speed running and total distance during the 5 day training camp. Data are mean ±SD
Table 4.4: Correlations between markers of fatigue, external and internal training load on the previous day

<table>
<thead>
<tr>
<th>Variable</th>
<th>GPS TD</th>
<th>GPS HSR</th>
<th>TL *</th>
<th>CMJ (PM)</th>
<th>RTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS TD</td>
<td>-</td>
<td>.839</td>
<td>.846</td>
<td>-.055</td>
<td>-.110</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>.352</td>
<td></td>
</tr>
<tr>
<td>GPS HSR</td>
<td>-</td>
<td>-</td>
<td>.677</td>
<td>-.070</td>
<td>-.168</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>.152</td>
<td></td>
</tr>
<tr>
<td>TL *</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.102</td>
<td>-.074</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>.530</td>
<td></td>
</tr>
<tr>
<td>CMJ</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-.106</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>.369</td>
<td></td>
</tr>
<tr>
<td>RTT</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

* Spearman rho. RTT (Readiness to train), TL (Internal Training Load), CMJ (Counter Movement Jump) and GPS (Global Positioning System) HSR (High Speed Running) TD (Total Distance)

4.5 Discussion

This is the first report of its kind exploring selected physiological and psychometric measures for monitoring health, fatigue, wellness and GPS performance during a pre-competition training camp in elite Gaelic football players. There were 3 key findings from this study: (i) there was no significant day to day variation in RTT and CMJ scores; (ii) TD, HSR distance and internal TL varied significantly from day to day, and (iii) neither external or internal TL were found to adversely affect RTT or CMJ scores on the following day, even within the HSR high ‘loaders’ group.

Total internal TL for the week was 2310 AU, which was considerably greater than the average in-season Gaelic Football training week of 1000 – 1200 AU, observed prior to the pre-competition training camp. However, these internal TLs were similar to an in-season training week in other professional team sports, i.e. 2000–4000 AU (Gabbett & Jenkins, 2011; Impellizzeri et al., 2004). Despite the high TL, it was not found to adversely affect markers of wellness and neuromuscular fatigue. This was supported by the stable performance in CMJ and RTT wellness scores throughout the camp. It warrants a mention that each session, pitch- and gym-based, were immediately followed by an aqua-recovery session, something that is not always feasible during a standard home-based training week.
Interestingly, mean CMJ scores were at the highest on Day 5 rather than at the start of camp on Day 1, thus supporting the camp’s design, structure and implementation. This was also evident when data was stratified based on volume of HSR, with no difference in RTT and CMJ between high or low ‘loaders’. RTT was sensitive to subtle changes relative to the previous day’s HSR training load (figure 4.1 RTT), with high ‘loaders’ demonstrating lower RTT score than low ‘loaders’. In a recent study of professional Australian rules footballers, pre-training perceived wellness impacted on external training output during skills-based training sessions (Gallo, Cormack, Gabbett, & Lorenzen, 2015), with a lower pre-training RTT score resulting in players modifying their external load. Similar findings were reported in another study in Australian rules football (Cormack, Mooney, Morgan, & McGuigan, 2012) where fatigued players maintained HSR but had a lower contribution in physical performance (i.e. impact collisions and tackles). Whether or not this limitation in physical performance occurred in the athletes within the current study is unknown.

There are a number of likely explanations for the high level of training tolerance demonstrated by the players throughout the training camp. The vigilant pre-planning and implementation of each training session throughout the week was a major factor, with low volume/intensity skills and tactical sessions placed between competitive game-based sessions; and each carefully monitored with regard to session duration. Another reason that may explain the players’ tolerance might be the fact that all of the sessions were performed in warm environmental conditions which have been associated with an increase in average running intensity and distance (Mohr et al., 2010; Mohr, Nybo, Grantham, & Racinais, 2012). This was also found by Buchheit, Voss, Nybo, Mohr, and Racinais (2011) in a study conducted on soccer players performing in the heat where reduced muscle damage was recorded than in a game played in normal temperate conditions. Although this could be a valid reason for the player’s tolerance, it cannot be fully supported within the present study design. Additional research is needed to fully understand and explain the impact of heat exposure from the training camp on both external and internal training loads with respect to monitoring training adaptations, health and fatigue.

The findings from the current study must be taken into context with the limitations within the investigation. The current study only provides data relating to the 5 days of the training camp. The results need to be contextualized with what happened in the weeks
(4+ weeks) prior to camp. Future research could include data collection of longitudinal measures over a longer time frame (4+ weeks) pre and post camp, thus providing a more meaningful contextual understanding of the findings from this shorter intervention relating to health, fatigue, injury or illness of the athletes. This will provide further information of the impact on intensified periods of training on athletic performance.

4.6 Practical Applications

The findings of this study demonstrated a strong relationship between internal TL and the TD ($r = .846$) covered during the training sessions. There was also a positive relationship between the volume of HSR performed during the training sessions and internal TL ($r = .677$). These data improve the understanding of the relationship between internal and external training load and suggest that a combination of RPE, wellness markers, CMJ and GPS provide useful information to monitor the training response in a pre-competition training camp.

In an amateur team sport such as Gaelic football, coaches are constantly examining how best to utilise the limited time they have with their team so as to optimise performance. This study highlights that a 5 day pre-competition training camp incorporating 7 pitch sessions and 2 strength and conditioning sessions (speed mechanics and gym session) can be performed without inducing excessive neuromuscular fatigue or adversely affecting RTT. Results presented provide encouraging findings related to the use of pre-competition training camps in team sports such as Gaelic football as an effective strategy to develop tactical awareness, technical development and team-play without negatively impacting psycho-physiological subjective perception. Interestingly, following a three day recovery period post-camp (from the last day of camp), the teams mean RTT score increased by 6% (74 to 80%), followed by a further 7% in the 5 days leading up to game day (87%).
Chapter 5: An investigation into the positional running demands of elite Gaelic football players: how competition data can inform training practice

This study has been accepted for publication following peer-review. Full reference details are:
Purpose: This study investigated the positional running demands of elite Gaelic football players during match-play and compared these demands with typical training activities used to prepare players for competition. Methods: Global positioning system (GPS) data was obtained from thirty elite Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) across a full season (13 competitive games and 78 training sessions). Only players who completed the full match and respective training sessions were included (n = 107 match files and n = 1,603 training files). Data was collected using 4-Hz GPS units (VX Sport, New Zealand). Mean high speed (≥17 km·h; m/min), mean speed (m/min), percentage at high speed (%) and mean sprint efforts (≥17 km·h; no/min) were recorded. Running variables were analysed across the 5 outfield positional lines in Gaelic football (full back [FB], half back [HB], midfield [MF], half forward [HF], full forward [FF]). Results: For mean high speed running and mean speed, significant relationships (range $r = .811 - .964$ & $r = .792 - .998$ respectively) were found between competition and game-based training for players in the FB, HB, MF and FF lines ($p < .05$). Analyses of mean sprint efforts and percentage at high speed found positive correlations between competition and training activities across each of the positional lines. Conclusion: Appropriately designed training activities can ensure that the position-specific demands of elite Gaelic football competition are met using a game-based training approach. Collectively, these findings demonstrate the value of, and provide support for, the use of a game-based training approach as a method of preparing players for the physical demands of competition in elite Gaelic football.

**Key words:** GPS, Game based, Skills based, Conditioning based, Competition
5.2 Introduction

In the high performance elite Gaelic football environment, considerable time is devoted to the development of physical qualities amongst other performance-related variables. While specificity is considered a fundamental principle of training, it is difficult to replicate the demands of competition if those demands are poorly understood. Global Positioning Systems (GPS) are gaining popularity in field-based sports as a means for coaches to assess the activity profiles of their athletes in training and competition (Gabbett, Jenkins, et al., 2012; Petersen et al., 2010).

In more recent years, researchers have used GPS to study the physical demands of Gaelic football (Collins, 2013; Malone et al., 2015; Reilly et al., 2014). Collins, et al. (2013) found that midfielders covered greater high-intensity distance during match-play compared to backs and forwards. However, care must be taken when interpreting this data as the researchers only investigated the profiles of the three main positional categories in Gaelic football (defender, midfielder, forward) and not the five positional lines (full back, half back, midfielders, half forwards and full forwards). Reilly et al. (2014) investigated the differences across the five positional lines during match play via GPS and found the FB line covered significantly lower total distance ($5089 \pm 524$ m) and high-speed running distance ($690 \pm 188$ m) than the HB, MF and HF lines (middle eight positions) with a magnitude of moderate to large effect. There was no significant difference found with the FB and the FF line. However, the results of this study need to be interpreted carefully as only six competitive games were analysed across an inter-county youth team competition in which the game duration is 10 minutes less than senior competition (i.e. 60 vs 70 mins). Positional differences of elite Gaelic footballers have been examined during match-play across two full seasons (30 matches) (Malone et al., 2015). The middle eight positions, consisting of the HF, MF and HF lines, experienced greater running demands ($8700 - 9523$ m) than the inside line players (FB $6892$ m and FF $7090$ m) with medium to large effect size. The study by Malone et al. (2015) is the first to provide a description of match running performance during competition in elite Gaelic football using GPS and provides coaches with an informative introduction into the positional running demands of the game.

Currently, no published research has examined the individual running demands of training activities and their relationship with competition demands within Gaelic football.
The primary purpose of training is to prepare athletes for competition and ensure that they receive a training stimulus that reflects the demands of the game. Gaelic football players tend to use a combination of traditional conditioned-based training (high intensity running without the ball), game-based training (small-sided game activities progressing to full-game scenarios) and skills-based training (open and closed skill activities to develop technical competence). The physical running demands of each of these activities is unclear, with limited research detailing whether game-based training is superior to other methods of training as a method of preparing players for the movement demands of competition. Within other sports, research has been conducted (Gabbett, 2010a; Gabbett, Jenkins, et al., 2012; Gabbett & Mulvey, 2008) suggesting that game-based training activities can elicit similar running demands to those of competition (Gabbett & Mulvey, 2008). However, it has also been found that without thorough game-based design, such activities may not effectively prepare athletes for the more high intensity passages of play, with fewer sprint efforts found in comparison to competition (Gabbett, 2010a). Similarly, traditional condition-based training programs have reported fewer sprint efforts (Austin et al., 2010) and greater running-based demands (total distance) than have been found in competition (Gabbett, Jenkins, et al., 2012).

The purposes of this study were (i) to assess the position-specific running demands of both competition and training of an elite Gaelic football team across a full season, and (ii) to assess the relationship between the running demands in competition and training.

5.3 Methods

5.3.1. Experimental Approach to the Problem

This study was designed to investigate the position specific running demands of competition and traditional training methods used in elite Gaelic football. Data were collected across the 2015 GAA season (9 months, Jan-Sept) which consisted of 13 competitive games (practice game data was not included in the study) and 78 training sessions. Match data included the All-Ireland Championship competition \( (n = 6) \), the most prestigious competition in Gaelic football and the National Football League (NFL) competition \( (n = 7) \), the second most prestigious competition, where each team played the other teams in their division only once (Table 1). Training data was collected during pre-season and in-season and was classified as (i) game-based (small sided game scenario’s progressing to full game), (ii) skills-based (open and closed drills to develop
technique in passing, catching and shooting) or (iii) condition-based (high intensity running without the ball), dependent on the content of the sessions (Table 1). For each match and training session, only players who completed the full activity were included \( n = 104 \) match; \( n = 1,603 \) training data sets). Players were categorized relative to their positional line on the pitch, i.e. full-back (FB), half-back (HB), midfield (MF), half-forward (HF) or full-forward (FF). A description of the number of complete data sets for games and training based on positional lines is provided in Table 1.

5.3.2. Subjects

Thirty elite Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) from the same team in Ireland participated in this study. Ethical approval was attained from the Host Institution’s Human Research Ethics Committee. Players were provided with a detailed explanation prior to commencement of data collection and informed consent was obtained prior to participation.

### Table 5.1: Training mode, number of activities, number of players and number of GPS samples obtained across a full season in an Elite Gaelic football team

<table>
<thead>
<tr>
<th>Training/Competition</th>
<th>Duration of Activities (mins)</th>
<th>Number of Activities</th>
<th>Number of Players by Position</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Football League &amp; Championship Matches</td>
<td>76 ± 2.4</td>
<td>13</td>
<td>27 32 14 12 22</td>
<td>107</td>
</tr>
<tr>
<td>Game Based Training</td>
<td>89 ± 11.3</td>
<td>44</td>
<td>180 184 155 166 172</td>
<td>857</td>
</tr>
<tr>
<td>Skills Based Training</td>
<td>61 ± 19.3</td>
<td>26</td>
<td>124 141 109 116 118</td>
<td>608</td>
</tr>
<tr>
<td>Condition Based Training</td>
<td>88 ± 4.5</td>
<td>8</td>
<td>33 28 17 33 27</td>
<td>138</td>
</tr>
</tbody>
</table>

5.3.3 Procedure

Specific running demands were assessed objectively using VX Sport 4 Hz GPS units (VX Sport; Visuallex Sport, Lower Hutt, New Zealand, Firmware: V1.60 28). The GPS unit determines a player’s position (latitude and longitude) by using the distance of each satellite to the device and then mapping the devices location (Malone, 2017). Once the player’s position is sourced, by taking a second set of measurements, positional differentiation (change in location) can be achieved and velocity can be calculated (distance over time) (Malone, 2017). On commencement of the season, each athlete was allocated their own individual device which was numbered and used only by them for the
entire season. The unit was worn on the upper back between the shoulder blades. All devices were fully charged and activated by the side of the pitch, and subsequently satellite-locked for a minimum of 30 minutes prior to the commencement of each match and training session (Maddison & Ni Mhurchu, 2009; Malone et al., 2015). Following each match and training session, GPS data were downloaded using the VX software (VX Sport; Visuallex Sport, Lower Hutt, New Zealand, Firmware: VI.60 28). Each file was trimmed to remove warm up, half time and cool down periods. Sport-specific running variables assessed were mean high-speed (≥17 km/h), mean speed (m/min), percentage time spent at high-speed (%) and mean sprint efforts (≥17 km/h). The thresholds and metrics selected have been supported for monitoring elite Gaelic football in recent literature (Collins, et al., 2013; Malone et al., 2015; Malone et al., 2016). Sprint efforts were categorised once a player changed speed by 2 km·h⁻¹ within 1 second. The change was triggered over a minimum time of 2 seconds. The sprint effort stopped when the player decelerated to <75% of maximum speed reached in the forgoing sprint effort (Malone et al., 2015). All analyses were conducted across the 5 positional lines (FB, HB, MF, HF, FF).

5.3.4. Statistical Analysis

All data were analysed using IBM SPSS (Statistical Package for Social Studies), Version 22. Missing data were accounted for by creating missing data categories. Mean and standard deviations were used to summarize the data. Appropriate use of Analysis of Variance (ANOVA) presupposes that certain distributional characteristics of the variables involved are at least approximately achieved. Therefore preliminary assumption testing was conducted to check for normality (Shapiro Wilk test), while Levene’s test was used to test the homogeneity of variances. ANOVA was used to assess positional differences in each of the running-based scores in both competition and training. Where significance was found (95% CI) involving multiple variables, a Bonferroni post hoc test was used to identify these differences. Any statistically significant result was complemented by the corresponding measure of strength using partial eta (η²) effect size) (Small effect: 0.01 ≤ η² < 0.06; Medium effect: 0.06 ≤ η² < 0.14; Large effect: η² ≥ 0.14) (Cohen, 1980).

While this study examined game-based, skill-based and conditioning-based training, specific comparisons were conducted between competition and game-based training (as these sessions are devised with the aim of including movement patterns which were
similar to competition). The Pearson product moment correlation coefficient was used to examine this relationship. As the number of game-based training sessions exceeded the number of games (857 vs 107), the mean training scores and the mean competition scores for each variable for each player were used in this analysis. The strength of the relationship between significant variables was interpreted using guidelines developed by Cohen (1988), $r$ effect size (ES) (Weak: $.1 < r < .3$; Moderate: $.3 < r < .5$; Strong: $r \geq .5$).

5.4 Results

Significant differences were found among competition, game-, skill- and conditioning-based training in each of the running variables ($p < .05$) (Figure 1). Mean high-speed and percentage at high speed scores in the conditioning-based sessions exceeded the demands of competition, game- and skills-based training across all five positional lines ($p < .05$ for all, ES = large for all respectively). Mean speed was found to be significantly lower in all training-based activities compared to competition ($p < .05$, $ES = $ large) across all the positional lines. Mean sprint efforts ($p < .05$, range $0.42 \pm 0.18 - 0.57 \pm 0.26$) in the skills-based sessions were significantly lower than competition, game- and condition-based activities across all the positional lines. The percentage at high speed of game-based training (range $12.0\pm4.3 - 16.3\pm5.2\%$) was similar to competition ($p < .05$, range $11.8\pm2.2 - 17.6\pm4.7\%$) across the five lines.

One way between groups analysis of variance was conducted to explore position-specific running based demands in competition. There were significant differences in running demands across the five positional lines ($p < .05$) (Table 2). The effect sizes calculated using eta squared were found to be large for all the running variables. Post hoc analysis revealed that for mean speed (range $108.4\pm11.9 - 119.5\pm13.9\text{m/min}$) and mean sprint efforts (range $0.98\pm0.29 - 1.07\pm0.27\text{no./min}$), the middle eight players (HB, MF, HF) covered significantly greater distances and efforts ($p < .05$) than players in the FB and FF lines (mean speed $83.4\pm11.4\text{m/min} - 92.3\pm6.9\text{m/min}$; mean sprint efforts $0.59\pm0.16 - 0.74\pm0.17\text{no./min}$) (Table 2). For mean high speed (range $13.9\pm3.2\text{m} - 21.5\pm8.0\text{m}$) the HB, MF, HF and FF lines covered significantly more distance compared to the FB line (10.0±2.8m). Analysis of percentage of high speed showed that HB, HF and FF line players (range $15.0\pm2.8\% - 17.6\pm4.7\%$) spent a greater percentage of game time at high speed compared to the players in the FB (11.8±2.2%) line.

80
Table 5.2: Running demands of different positional groups across an elite Gaelic football competition

<table>
<thead>
<tr>
<th>Variable</th>
<th>Full back</th>
<th>Half Back</th>
<th>Midfield</th>
<th>Half Forward</th>
<th>Full forward</th>
<th>F</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean High Speed (m/min)</td>
<td>10.0 ± 2.8</td>
<td>17.4 ± 5.5†</td>
<td>16.3 ± 2.4</td>
<td>21.5 ± 8.0 † †</td>
<td>13.9 ± 3.2 †</td>
<td>16.997</td>
<td>Large</td>
</tr>
<tr>
<td>Mean Sprint Efforts (no./min)</td>
<td>0.59 ± 0.16</td>
<td>0.98 ± 0.29 † †</td>
<td>0.98 ± 0.12 † †</td>
<td>1.07 ± 0.27 † †</td>
<td>0.74 ± 0.17</td>
<td>17.925</td>
<td>Large</td>
</tr>
<tr>
<td>Mean Speed (m/min)</td>
<td>83.4 ± 11.4</td>
<td>108.4 ± 11.9 † †</td>
<td>112.9 ± 9.4 † †</td>
<td>119.5 ± 13.9 † †</td>
<td>92.3 ± 6.9</td>
<td>37.976</td>
<td>Large</td>
</tr>
<tr>
<td>Percentage at High Speed (%)</td>
<td>11.8 ± 2.2</td>
<td>15.7 ± 3.9 †</td>
<td>14.5 ± 1.8</td>
<td>17.6 ± 4.7 † †</td>
<td>15.0 ± 2.8 †</td>
<td>8.754</td>
<td>Large</td>
</tr>
</tbody>
</table>

GPS analysis was completed during 13 competitive matches (n = 23 players, totalling 107 full match data sets, mean duration 76±2.4min). Data are means (95% confidence intervals)
† Significantly different (p<0.05) from full backs
‡ Significantly different (p<0.05) from full forwards
<table>
<thead>
<tr>
<th>Variable</th>
<th>Full back</th>
<th>Half Back</th>
<th>Midfield</th>
<th>Half Forward</th>
<th>Full forward</th>
<th>F</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean High Speed (m/min)</td>
<td>9.0 ± 3.6</td>
<td>13.1 ± 4.0*</td>
<td>11 ± 3.8</td>
<td>15.3 ± 6.1*</td>
<td>11.1 ± 3.7*</td>
<td>46.187</td>
<td>Large</td>
</tr>
<tr>
<td>Mean Sprint Efforts (no./min)</td>
<td>0.56 ± 0.18</td>
<td>0.73 ± 0.21*</td>
<td>0.61 ± 0.20*</td>
<td>0.78 ± 0.26*</td>
<td>0.66 ± 0.19*</td>
<td>32.735</td>
<td>Medium</td>
</tr>
<tr>
<td>Mean Speed (m/min)</td>
<td>69 ± 13.1</td>
<td>77 ± 15*</td>
<td>76 ± 15.7*</td>
<td>83 ± 19.2*#</td>
<td>72 ± 10.8</td>
<td>21.559</td>
<td>Medium</td>
</tr>
<tr>
<td>Percentage at High Speed (%)</td>
<td>12.0 ± 4.3</td>
<td>15.1 ± 5.1*</td>
<td>12.8 ± 4.7</td>
<td>16.3 ± 5.2*</td>
<td>13.6 ± 4.1*</td>
<td>23.595</td>
<td>Medium</td>
</tr>
</tbody>
</table>

GPS analysis was completed during 44 game based training sessions (n = 30 players, totalling 857 full data sets, mean duration 89±11.3min). Data are means (95% confidence intervals). Kruskal- Wallis Test for non-parametric and Mann-Whitney U test was used to compare medians between the positional groups for relative sprint efforts and mean speed
*Significantly different (p <0.05) from full backs
†Significantly different (p <0.05) from full forwards
‡Significantly different (p <0.05) from mid fielders
#Significantly different (p <0.05) from half backs
A one way between groups analysis of variance was conducted to explore position specific running demands in game-based training. Significance was found in the running demands across all the lines \((p < .05)\) with effect sizes found to be moderate too large for all the running variables (Table 3). In game-based training, players in the middle eight covered significantly greater distances than the FB and FF lines. Players in the HF line were found to have the highest running-based scores; for mean speed \((82.5\pm19.2\text{m})\) and mean high speed \((15.3\pm6.1\text{m})\), they were found to cover significantly more distance than players in any other line \((p < .05)\). The FB line players were found to have the lowest running-based distance scores when compared to players on all other lines. Analysis of the percentage at high speed variable found that HB \((15.1\pm5.1)\), HF \((16.3\pm5.2)\) and FF \((13.6\pm4.1)\) line players spent a greater percentage of time at high speed compared to the FB \((p < .05\ 12.0\pm4.3)\) line.
The relationship between the movement demands of the two activities (competition and game-based training) was investigated using the Pearson product-moment correlation coefficient (Table 4). Across all measured variables, there was a clear relationship between competition and game-based training. For mean high speed distance and mean speed distance, significant correlations were found between competition and game-based training for players in the FB, HB, MF and FF lines ($p < .05$), with a strong relationship found (range $r = .811 - .964$ mean high speed distance and $r = .792 - .998$ mean speed). Analysis of mean sprint efforts and percentage at high speed found positive correlations across all the positional lines. A strong relationship was found with the FB ($p < .05$), HB ($p < .01$), MF and FF ($p < .05$) lines (range $r = .700 - .983$) for mean sprint efforts; and for percentage at high speed, a strong relationship was found with HB, MF, HF and FF (range $r = .972 - .999$, $p < .05$) lines.

Table 5.4: Pearson Correlations between Competition and Game based training across the positional lines

<table>
<thead>
<tr>
<th>Variable/Position</th>
<th>FB ($n = 6$)</th>
<th>HB ($n = 5$)</th>
<th>MF ($n = 3$)</th>
<th>HF ($n = 3$)</th>
<th>FF ($n = 6$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean High Speed (m/min)</td>
<td>.943**</td>
<td>.942*</td>
<td>.811 ($n = 7$)</td>
<td>.964 ($n = 4$)</td>
<td>.923**</td>
</tr>
<tr>
<td>Mean Sprint Efforts (no./min)</td>
<td>.844*</td>
<td>.983**</td>
<td>.700 ($n = 7$)</td>
<td>.374</td>
<td>.872*</td>
</tr>
<tr>
<td>Mean Speed (m/min)</td>
<td>.909*</td>
<td>.855 ($n = 6$)</td>
<td>.998* ($n = 6$)</td>
<td>.866 ($n = 6$)</td>
<td>.792 ($n = 7$)</td>
</tr>
<tr>
<td>Percentage at High Speed (%)</td>
<td>.312 ($n = 4$)</td>
<td>.972** ($n = 6$)</td>
<td>.972 ($n = 4$)</td>
<td>.999* ($n = 4$)</td>
<td>.885*</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level. If the number of players was increased to the number in brackets, then the correlation is significant at the 0.05 level.

5.5 Discussion

This study is the first to investigate the positional running demands of elite Gaelic football match-play and associated traditional training activities used to prepare players for competition over a full season. The running demands of skills-based training were found to be lower across all selected GPS variables compared to competition, game- and condition-based training. Condition-based training sessions significantly exceeded the high speed running demands found in competition, game- and skills-based training. A major finding was related to the positional differences that exist within elite Gaelic football; this trend was evident in both competition and training data. Another key finding
was the strong relationship evident between game-based training and competition across all the GPS variables, with position-specific similarities existing across all the lines.

This study is the first to differentiate players into the five outfield positional lines in a training environment and investigate the relationship between traditional Gaelic football training activities and the physical demands of competition. Condition-based training sessions significantly exceeded the high speed running demands of competition with the exception of sprint efforts. This suggests that condition-based training sessions include fewer, longer steady sprint efforts compared to that in competition. Furthermore, the large SD values evident within these sessions indicates the variation in conditioning methods which were used throughout the season. For example, longer steady state aerobic activities in early season compared to shorter anaerobic activities in season. This was also found by Gabbett, Jenkins, et al. (2012), suggesting modifications be made to future conditioning sessions to ensure the demands of competition are more accurately met to optimise performance preparation. The running demands of skills-based training were found to be lower across all the GPS variables than competition. The nature, structure and content of these sessions was somewhat similar as is evident by the small SD scores presented in figure 5.1. This was also found to be the case in a similar study within professional rugby league (Gabbett, Jenkins, et al., 2012). It must be noted that the skills-based sessions were designed as a non-invasive tapering measure used in proximity of competitive games to hone technical, tactical and team play skills as opposed to physically develop players for competition. Therefore, it was not expected that the movement demands in these sessions would be related to the demands of competition. The large standard deviation within the training activities, can be reflected in the variability of duration within the field based sessions and is visible in table 5.2. This was differing with competition duration, whereas an inter-county match will always remain 70min and average 75min. Additionally, training variation, tactical/technical elements and playing style will significantly impact on the variance in standard deviation.

The current research adds to the body of literature in elite Gaelic football (Malone et al., 2015; Malone et al., 2016) confirming that position-specific differences exist, similar to other field-based sports such as rugby league (Austin, Gabbett, & Jenkins, 2011; Evans et al., 2015), soccer (Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007) and Australian football (Coutts, Quinn, Hocking, Castagna, & Rampinini, 2010; Wisbey et al., 2009). These positional differences are to be expected, based on the field-based
literature, due to the nature of the game and are very much in agreement with a recent study by Malone et al. (2015) who found that the middle eight (HB, MF, HF) positions have the greatest running demands in comparison to the inside lines (FB, FF). Specifically, within the current study the HF line players were found to have the greatest running values in comparison to the other four positional lines; this was evident across all the GPS variables. This contrasts with Malone et al. (2015) who found that MF line players covered the greatest volume. This disparity could be due to the tactical style of play that was implemented by the particular coaches. For example, a common style of play in modern Gaelic football involves the players in the HF line fulfilling attacking roles to support the FF line and defensive roles supporting the HB and FB lines. In comparison with professional sports, the current study found that independent of position, elite Gaelic football players had a mean speed distance (104±17 m/min) which was lower than professional soccer players (118 m/min) (Suarez-Arrones et al., 2014) and Australian football players (139 m/min) (Mooney, O’Brien, & Cormack, 2011) but greater than rugby union backs (71.9 m/min) (Cunniffe, Proctor, Barker, & Davis, 2009). However, Gaelic football HF’s were found to cover similar mean speed distance (119±13 m/min) to professional soccer players. The mean speed distance covered (m·min⁻¹) per minute of competition and/or training has been found to be a key metric when reporting GPS data, as it enables coaches to make comparisons not only within the sport but also with other sports (Aughey, 2011; Cummins et al., 2013).

This is the first research study within elite Gaelic football to examine the position-specific running demands of training activities relative to competition, thus adding to the applied scientific literature in the field. An in-depth analysis was carried out on the relationship between game-based training and competition as this training type was implemented with the greatest frequency (approx. 60% of all training activities) and aimed to prepare athletes for the position-specific movement demands of competition. The current research found a strong relationship between the position-specific running demands in game-based training and competition. Previous research from a variety of sports has found that this type of training can improve not only physical fitness, but also the tactical and technical aspects of the game (Gabbett, 2002b; Gamble, 2004; Sassi, Reilly, & Impellizzeri, 2005). This approach places the athlete in an environment where they must practice performing under pressure in a game-based context similar to what they face in competition (Gabbett, Jenkins, & Abernethy, 2009). In doing so, it presents athletes with additional mental and physical challenges that they would not normally be exposed to in traditional
conditioning-based or skills-based training sessions. Furthermore, a study of training practices among AF players (Berry, Abernethy, & Côte, 2008) found that the expert decision-makers had experienced a greater number of invasion sports in their development years and thus partaken in a greater number of deliberate practices compared to their non-expert counterparts. These findings would suggest that a game-based training approach is effective in preparing athletes for the physical, technical and tactical demands of team based sports such as Gaelic football.

An interesting finding in the current research was that mean speed scores for game based training was lower when compared to these scores in a competition context. This trend was most pronounced among players in the half forward line (Table 5.4). A possible explanation for this is that in a game based training context there would be time allocated for transitioning between activities, water breaks, and for coaches to impart technical and tactical knowledge. Such breaks would have impacted on the relative speed scores that were calculated in this research and would have had the greatest impact on the HF line as these players were found to have the highest scores across all mean speed variables in competition (Table 5.3). Further research could attempt to trim game based sessions to remove breaks and to assess the relationship between each of these individual game based activities and the movement demands of competition. Based on this information game based activities could be modified to make them more specific to competition. Across a number of sports research has been conducted on the impact of constraints to a game-based training activity to increase the running demands. Specifically constraints have included modification of pitch size, specific game duration, rules and player number per team (Cummins et al., 2013; Gabbett, Abernethy, & Jenkins, 2012).

The findings from the current study must be viewed in context of the limitations within the investigation. The GPS system used in this research did not have tri-axial accelerometer and gyroscope, therefore data relating physical contact such as the tackle was not analysed. Future research should aim to apply recent technological advances in this field to evaluate other physiological demands such as contact force (i.e. tackles), which have been proven to have a significant physical impact on match intensity in other contact/field based sports (Austin & Kelly, 2014; Evans et al., 2015; Gabbett, Jenkins, et al., 2012). Additionally, match-to-match variation, playing style, and tactical/technical elements within a game have been shown to impact on running performance in other sports (Gregson, Drust, Atkinson, & Salvo, 2010); these were not analysed as part of this
study. Future research in Gaelic football should focus on the integration of video analysis with GPS to evaluate these elements in a Gaelic Football context. Furthermore, the results may have been influenced by the individual coaching style of the head coach and therefore may not give a complete account of all elite Gaelic football teams. A larger sample sizes comprised of a number of elite teams would serve to verify these findings.

5.6 Practical Applications

Positional differences exist within elite Gaelic football, with the middle eight positions covering significantly more distance than the inside lines. There is a need for modifications to traditional condition-based training to better prepare players for the demands of competition relative to position. There is a need for coaches to plan conditioning sessions with greater levels of prolonged high speed running for players in the middle 8 positions and for greater sprint efforts among players in FB and FF lines. The primary purpose of training is to prepare athletes for competition, irrespective of the session type or methodology employed. The current study has found that the physical running demands of carefully planned and structured game-based training sessions are strongly related to the demands of competition. This provides support for the use of a game-based training approach as a method of preparing players for the movement demands of competition in elite Gaelic football.
Chapter 6: Match-play running demands and technical performance among elite Gaelic footballers: Does divisional status count?

This study has been accepted for publication following peer-review. Full reference details are:

6.1 Abstract

Purpose: The aim of the current study was to compare positional differences in running demands and technical performance variables among elite Gaelic football teams from separate Divisions. Data were obtained from a Division 1 (26.7 ± 2.9 years, 179.2 ± 21.3 cm, 89.9 ± 21.2 kg) and a Division 3 (25.7 ± 3.5 years, 183.0 ± 4.7 cm, 84.4 ± 6.5 kg) team. Match-play running variables were collected using 4-Hz global positioning system (GPS) units (VX Sport, New-Zealand) (Match data sets; Division 1: n = 107, Division 3: n = 97). Selected variables assessed were high speed running distance (HSR) (≥17 km·h⁻¹), number of high-speed efforts (HSE) (≥ 17 km·h⁻¹), relative high-speed distance (RHSD) (≥ 17 km·h⁻¹; m·min⁻¹) and percentage of time at high speed (%HS). Each variable was analysed across the 5 positional lines in Gaelic football (full-back, half-back, midfield, half-forward, full-forward). The same 25 competitive games were analysed using GPS and the Sports Code video analysis system (Sports Code Elite V9, Sportstec, NSW, Australia). Technical performance variables selected for analysis were total kick/hand passes, tackles, shots and percentage of time in possession. HSR running demands were differentiated between the divisions: the Division 3 team demonstrated significantly greater HSR, HSE, RHSD and %HS than the Division 1 team (p <0.05). Positional-specific analysis found that the Division 3 fullback and midfield positional lines had significantly greater HSR, RHSD and %HS than their Division 1 counterparts. The Division 1 team made a greater number of total tackles, with significantly more tackles in the middle third (p <0.05). The Division 3 team performed a significantly greater number of hand passes and unsuccessful shots per game (p <0.01). The results of the present study indicate that overall technical proficiency, rather than high-speed running profiles, differentiate Division 1 and 3 Gaelic football teams.

Key words: GPS, divisional-differences, Gaelic games, video-analysis
6.2 Introduction

The best Gaelic footballers in each of the 32 counties in Ireland are selected to represent their county team who compete in the All-Ireland Championship and the National League competitions (Bradley, 2007). The All Ireland Championship competition, the most prestigious competition in Gaelic football, is played by all county teams in a knock out cup format. In the National Football League competition, the second most prestigious competition, the teams are divided into four rank ordered divisions with 8 teams in each division (Mangan, Malone, Ryan, McGahan, O’Neill, et al., 2017). Teams have the possibility of being promoted or relegated from their respective divisions based on their performance in the National League. In the high performance Gaelic football inter-county environment, considerable time is devoted to the development of the physical running demands amongst other technical and tactical performance-related variables (Malone et al., 2015).

The running demands of elite Gaelic football players have been examined for over twenty five years, with an initial emphasis on video and time-motion analysis (Keane & Hughes, 1993; O’Donoghue et al., 2004). Given the advancement in technology, global positioning systems (GPS) have been the tool of choice to investigate the running demands of the modern Gaelic football player (Collins, 2013; Malone et al., 2015; Mangan, et al., 2017; Reilly et al., 2014). Early research highlighted differences between the 5 positional lines (i.e. full back, half back, midfield, half forward, full forward) with regard to the respective running demands during match-play (Malone et al., 2015). The study found significant differences among the middle 8 players (half-backs, midfielders and half-forwards) covering greater distances (8700 – 9523m) than the inside line players (full-back 6892m and full-forwards 7090m respectively). However, it should be noted that this study only investigated the running demands of one team within one division of the National Football League (NFL). A more recent paper by Mangan, et al. (2017) examined changes in running demands across a playing season using multiple teams. It was found that teams who progressed to the latter part of the All-Ireland Championship were found to increase their running demands, with these running demands closely related to the score-line of the match (Mangan, 2017).

Despite the growth of research investigating the running demands in elite Gaelic football, presently there is a lack of published literature across technical performance variables.
More recently Carroll (2013) investigated specific technical elements of performance from teams of different standards, concluding that differences in technical performance between teams vary as a result of opposition characteristics. The study also found that attack efficiency (total number of shots divided by the total number of attacks) and total number of shots were higher for the higher ranked teams when compared to lower ranked teams. Similar findings have been reported within soccer (Liu, Gómez, Gonçalves, & Sampaio, 2015; Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2009) and Australian Rules Football (AF) (Gabbett, Polley, Dwyer, Kearney, & Corvo, 2014) where total shots, shots on target, passes and number of tackles separate the top and bottom ranked teams.

Currently within Gaelic football there is dearth of research comparing the high-speed running demands across standards of play (Mangan, 2017). Although numerous studies have examined the positional demands (Malone et al., 2015; Reilly et al., 2014) none have differentiated teams by success rates or divisional status. Studies in AF (Aughey, 2013; Brewer et al., 2010) rugby league (Gabbett, 2013) and soccer (Mohr et al., 2003) have reported that elite players record greater running demands when compared to their counterparts playing at the sub-elite level. However, in contrast to these studies, it has been reported that soccer and rugby league teams competing in higher divisions of competition cover less total distance and less high-speed running distance than teams competing in lower divisions (Di Salvo et al., 2013; Hulin et al., 2014). It has been hypothesized that this is due to their increased technical abilities. Furthermore, Di Salvo et al. (2009) found that the bottom 5 teams in the English Premier League covered greater high-speed running distance than the teams in the top 5 positions. However, it is unclear whether similar patterns exist within elite Gaelic football match-play.

To date, there is no published literature that has investigated the differences in high-speed running and technical performance variables between different divisional teams in elite Gaelic football. Analysis of such differences would serve to assist coaches in identifying the key characteristics of performance and could help to increase prospects of promotion to higher divisions. Therefore, the purpose of the current study was to investigate the match-play high-speed running demands and technical performance variables of Division 1 and Division 3 players in elite Gaelic football.
6.3 Methods

6.3.1 Experimental Approach to the Problem

Data were collected across a full Division 1 and Division 3 season (9 months, Jan-Sept) which consisted of 25 competitive games in total (Division 1: \( n = 13 \); Division 3: \( n = 12 \)). Data included League games (Division 1: \( n = 7 \); Division 3: \( n = 8 \)) and Championship games (Division 1: \( n = 6 \); Division 3: \( n = 4 \)). Post-season ranking placed both teams in the top 3 of their respective divisions. Only full individual match data sets (i.e. players who completed the full match 75-80min) were selected for analysis (Division 1: \( n = 107 \); Division 3: \( n = 97 \)). Notably, an initial analysis revealed no significant difference between the running and technical demands of each team across their respective league and championship competitions, therefore all matches, irrespective of phase of season, were analysed together. Players were sub-categorized via the five positional lines in Gaelic football, full-back (Division 1: \( n = 29 \); Division 3: \( n = 23 \)), half-back (Division 1: \( n = 30 \); Division 3: \( n = 22 \)), midfield (Division 1: \( n = 13 \); Division 3: \( n = 19 \)), half-forward (Division 1: \( n = 15 \); Division 3: \( n = 16 \)) and full-forward (Division 1: \( n = 20 \); Division 3: \( n = 17 \)).

6.3.2 Subjects

Forty seven Gaelic football players from two elite teams volunteered to participate in the study; 23 from a Division 1 team (26.7 ± 2.9 years, 179.2 ± 21.3 cm, 89.9 ± 21.2 kg) and 24 from a Division 3 team (25.7 ± 3.5 years, 183.0 ± 4.7 cm, 84.4 ± 6.5 kg). This study received ethical approval from the host institution’s Research Ethics Committee. Players were provided with a detailed explanation and completed a consent form prior to commencement of data collection.

6.3.3 Procedure

Running Demands

The running-based movement demands were assessed using VX Sport 4 Hz GPS units (VX Sport; Visuallex Sport, Lower Hutt, New Zealand, Firmware: V1.60 28). The unit was worn on the upper back between the shoulder blades; players wore the same unit across all competitive matches. All devices were activated by the side of the pitch,
The VX Sport GPS unit has been found to be a valid and reliable tool for the measurement of intermittent activity in field sports (Malone, Collins, et al., 2014). The running variables assessed were high speed running distance (HSR) (≥17 km·h⁻¹), number of speed efforts (HSE) (≥17 km·h⁻¹), relative high speed distance (RHSD) per min (m·min⁻¹) and percentage of time spent at high speed (% HS). Acceleration were defined as a change in speed by 2 km·h⁻¹ within 1 second. The change was triggered over a minimum time of 2 seconds. The acceleration stopped when the player decelerated to <75% of maximum speed reached in the forgoing sprint effort (Malone et al., 2015). These variables were analysed for all 5 out-field positional groups. Selected thresholds and metrics used in the current study have been used previously in the GAA literature (Collins, Solan, et al., 2013; Malone et al., 2015; Malone et al., 2016).

Video Analysis
Sports code video analysis (Sports Code Elite V9, Sportstec, Warriewood, New South Wales, Australia) was used to determine the technical performance of Gaelic football match-play on an iMac (version OS X 10.9.4). A specific coding template was developed to best understand the technical variables within match-play. Each technical variable analysed was assigned an operational definition to determine what was deemed to be a successful or unsuccessful outcome (Table 1). For the purpose of this research, the Gaelic football pitch was divided into 3 distinct sections (Table 1). An intra-rater reliability test was conducted by a qualified sports analyst, this also ensured confidentiality in the data. Two games were chosen at random to perform test-retest reliability on the coding of technical actions. This involved re-coding the 2 games 7-10 days after the original coding. Test-retest reliability was conducted for each of the variables using paired sample t-tests. There was a very low percentage error for all variables (<2%).
Table 6.1: The technical variables quantified and their specific definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total kick passes</td>
<td>The number of attempts made to transfer the ball by foot to a teammate. Successful and unsuccessful.</td>
</tr>
<tr>
<td>Total hand passes</td>
<td>The number of attempts made to transfer the ball by hand to a teammate. Successful and unsuccessful.</td>
</tr>
<tr>
<td>Tackle</td>
<td>The number of situations where the defending player made physical contact with an opponent player while contesting the ball.</td>
</tr>
<tr>
<td>Shots from play</td>
<td>The number of attempts to score, over or above the cross bar from play. Successful and unsuccessful.</td>
</tr>
<tr>
<td>Percentage of possession</td>
<td>The overall percentage of time a team had in possession of the ball whilst it was in play.</td>
</tr>
<tr>
<td>Gaelic football 3 distinct sections</td>
<td>The defensive section was from the defending team’s end-line to their 45m line. The area between the two 45m lines was categorized as the middle section (50-60m). The area from the opposition’s 45m line to the opposition’s end-line was categorized as the attacking section.</td>
</tr>
</tbody>
</table>

6.3.4 Statistical Analysis

All data are reported as mean ± standard deviation unless stated. Preliminary assumption testing was conducted to check for normality (Shapiro Wilk test), while Levene’s test was used to test the homogeneity of variances. Independent sample t-tests were used to compare the mean performance scores (independent of position) of both teams for all GPS and technical performance variables. The statistical significance was set at \( p < 0.05 \). Further position-specific independent sample t-tests were used to compare GPS variables between players in the same positional lines on both teams. Eta squared effect size (95% CI) was used to determine the magnitude of any statistical difference (Trivial effect \( \eta^2 < 0.01 \); Small effect: \( 0.01 \leq \eta^2 < 0.06 \); Medium effect: \( 0.06 \leq \eta^2 < 0.14 \); Large effect: \( \eta^2 \geq 0.14 \) (Cohen, 1988). All data was analysed using IBM SPSS (Statistical Package for Social Studies), Version 22.
6.4 Results

There were significant differences across all the GPS variables HSR ($p = .001$, $\eta^2 = .054$, $ES = \text{small}$), HSE ($p = .024$, $\eta^2 = .025$, $ES = \text{small}$), RHSD ($p = .002$, $\eta^2 = .047$, $ES = \text{small}$) and % HS ($p = .002$, $\eta^2 = .049$, $ES = \text{small}$) with the Division 3 team consistently demonstrating significantly higher scores than their Division 1 counterparts (Table 2).

Position-specific analyses (5 positional lines) comparing running demands between Division 1 and Division 3 players is illustrated in Table 2. The Division 3 full-backs had higher HSR ($p = .002$, $\eta^2 = .177$, $ES = \text{large}$), RHSD ($p = .002$, $\eta^2 = .174$, $ES = \text{large}$) and % HS ($p = .001$, $\eta^2 = .208$, $ES = \text{large}$) than their Division 1 counterparts. Division 3 midfielders also performed significantly more HSR ($p = .001$, $\eta^2 = .520$, $ES = \text{large}$), RHSD ($p = .001$, $\eta^2 = .508$, $ES = \text{large}$), %HS ($p = .001$, $\eta^2 = .431$, $ES = \text{large}$) and additionally more HSE ($p < .01$, $\eta^2 = .301$; $ES = \text{large}$) than their Division 1 counterparts (Figure 1). There were no significant differences between half-backs, half-forwards and full-forwards for any of the GPS variables.

The technical performance data of the Division 1 and Division 3 teams are presented in Table 3. The Division 3 team demonstrated a significantly greater number of total hand passes ($p = .007$, $\eta^2 = .278$, $ES = \text{large}$) and missed shots per game ($p = .007$, $\eta^2 = .279$, $ES = \text{large}$) than the Division 1 team. There were no significant differences between the teams for total kick passes ($p = .102$, $\eta^2 = .112$, $ES = \text{medium}$), shots scored from play ($p = .606$, $\eta^2 = .012$, $ES = \text{small}$) and percentage of time in possession ($p = .539$, $\eta^2 = .017$, $ES = \text{small}$). The Division 1 team made a greater number of total tackles than the Division 3 team, with significantly more tackles in the middle third ($p = .044$, $\eta^2 = .072$, $ES = \text{medium}$).
<table>
<thead>
<tr>
<th>Variable by Position</th>
<th>All Positions</th>
<th>Full Back</th>
<th>Half Back</th>
<th>Midfielders</th>
<th>Half Forwards</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR (m)</td>
<td>1145 ± 456</td>
<td>796 ± 235</td>
<td>1339 ± 433</td>
<td>1221 ± 216</td>
<td>1500 ± 548</td>
</tr>
<tr>
<td>HSE (no.)</td>
<td>64 ± 21</td>
<td>47 ± 16</td>
<td>75 ± 13</td>
<td>75 ± 10</td>
<td>10.7 ± 1.7</td>
</tr>
<tr>
<td>RHSD (m/min)</td>
<td>14.9 ± 5.7</td>
<td>10.4 ± 3.3</td>
<td>17.5 ± 5.6</td>
<td>12.1 ± 3.0</td>
<td>12.1 ± 3.0</td>
</tr>
<tr>
<td>HSR (%)</td>
<td>11.2 ± 2.8</td>
<td>9.2 ± 1.8</td>
<td>11.9 ± 3.2</td>
<td>9.2 ± 1.8</td>
<td>9.2 ± 1.8</td>
</tr>
<tr>
<td>Difference 95% CI</td>
<td>-336.973 to -98.30</td>
<td>-1.443 to 2.167</td>
<td>-1.443 to 2.167</td>
<td>-5.678 to -1.3408</td>
<td>-5.678 to -1.3408</td>
</tr>
</tbody>
</table>

| Division 1 (n = 107) |                  |          |           |             |               |
|-----------------------|                  |          |           |             |               |
| HSR (m)               | 1358 ± 462      | 1072 ± 340 | 1339 ± 289| 1762 ± 296  | 1659 ± 254    |
| HSE (no.)             | 71 ± 24^*       | 55 ± 14  | 73 ± 17   | 93 ± 15^*   | 10.7 ± 1.7    |
| RHSD (m/min)          | 17.6 ± 6.1^*    | 13.9 ± 4.5| 17.3 ± 3.7| 22.9 ± 3.9^*| 13.9 ± 1.9^* |
| HSR (%)               | 12.5 ± 3.4^*    | 11.9 ± 3.2| 12.7 ± 2.0| 9.2 ± 1.8   | 9.2 ± 1.8     |

| Division 2 (n = 97) |                  |          |           |             |               |
|---------------------|                  |          |           |             |               |
| HSR (m)             | 1303 ± 428      | 1024 ± 320 | 1339 ± 289| 1762 ± 296  | 1659 ± 254    |
| HSE (no.)           | 69 ± 22^*       | 53 ± 13  | 77 ± 17   | 93 ± 15^*   | 10.7 ± 1.7    |
| RHSD (m/min)        | 16.9 ± 5.8^*    | 13.6 ± 4.4| 17.0 ± 3.5| 22.7 ± 3.9^*| 13.9 ± 1.9^* |
| HSR (%)             | 12.5 ± 3.4^*    | 11.9 ± 3.2| 12.7 ± 2.0| 9.2 ± 1.8   | 9.2 ± 1.8     |

| Difference 95% CI   | -336.973 to -98.30 | -1.443 to 2.167 | -1.443 to 2.167 | -5.678 to -1.3408 | -5.678 to -1.3408 |

| Division 3 (n = 97) |                  |          |           |             |               |
|---------------------|                  |          |           |             |               |
| HSR (m)             | 1358 ± 462      | 1072 ± 340 | 1339 ± 289| 1762 ± 296  | 1659 ± 254    |
| HSE (no.)           | 71 ± 24^*       | 55 ± 14  | 73 ± 17   | 93 ± 15^*   | 10.7 ± 1.7    |
| RHSD (m/min)        | 17.6 ± 6.1^*    | 13.9 ± 4.5| 17.3 ± 3.7| 22.9 ± 3.9^*| 13.9 ± 1.9^* |
| HSR (%)             | 12.5 ± 3.4^*    | 11.9 ± 3.2| 12.7 ± 2.0| 9.2 ± 1.8   | 9.2 ± 1.8     |

| Difference 95% CI   | -336.973 to -98.30 | -1.443 to 2.167 | -1.443 to 2.167 | -5.678 to -1.3408 | -5.678 to -1.3408 |

Note: HSR = High Speed Running, HSE = High Speed Efficiency, RHSD = Relative High Speed Distance.
<table>
<thead>
<tr>
<th></th>
<th>HSE (no.)</th>
<th>RHSD (m/min)</th>
<th>HS (%)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1051 ± 250</td>
<td>1030 ± 578</td>
<td>10.0 ± 4.2</td>
<td>Small</td>
<td>-24.073 to 1.473</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Small</td>
<td>-5.9757 to 2.5440</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.8 ± 3.1</td>
<td>13.4 ± 7.5</td>
<td>Small</td>
<td>-2.8838 to 1.0804</td>
<td></td>
</tr>
<tr>
<td>Full Forwards</td>
<td>11.4 ± 23</td>
<td>21.4 ± 3.3</td>
<td>14.0 ± 1.5</td>
<td>Small</td>
<td>-293.825 to 333.748</td>
</tr>
<tr>
<td></td>
<td>56 ± 32</td>
<td>57 ± 12</td>
<td>Trivial</td>
<td>-16.649 to 17.560</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.4 ± 7.5</td>
<td>13.8 ± 3.1</td>
<td>Trivial</td>
<td>-3.6813 to 4.4742</td>
<td></td>
</tr>
</tbody>
</table>

Difference mean value in high speed running (HSR), number of high speed efforts (HSE), relative high speed distance (RHSD) and percentage of time at high speed (HS %): Trivial effect $\eta^2 < 0.01$; Small effect: $0.01 < \eta^2 < 0.06$; Moderate effect $0.06 < \eta^2 < 0.14$; Large effect: $\eta^2 > 0.14$. CI, confidence interval. *Significant difference ($p < 0.05$) from division 1 team. **Significant difference ($p < 0.01$) from division 1 team.
Figure 6.1: Position specific mean (±SD) in high-speed running (m) demands of Division 1 and Division 3 players. Difference means values significant difference set at 0.05. ‡ Significantly different ($p<0.01$) from Division 1 team. * Significant difference ($p<0.05$) from Division 1 team.
Table 6.3: Mean (±SD) technical demands within elite Gaelic football competition with respect to Division 1 and Division 3 teams

<table>
<thead>
<tr>
<th>Variable</th>
<th>Division 1</th>
<th>Division 3</th>
<th>Effect Size</th>
<th>Difference 95% Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (n = 13 games)</td>
<td>Total (n = 12 games)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Hand passes</strong></td>
<td>131 ± 23</td>
<td>167 ± 36*</td>
<td>Large</td>
<td>-60.44 to -10.87</td>
</tr>
<tr>
<td><strong>Total Kick passes</strong></td>
<td>71 ± 11</td>
<td>62 ± 17</td>
<td>Medium</td>
<td>-2.07 to 21.53</td>
</tr>
<tr>
<td><strong>Shots Missed from Play</strong></td>
<td>9 ± 3</td>
<td>13 ± 3*</td>
<td>Large</td>
<td>-6.28 to -1.50</td>
</tr>
<tr>
<td><strong>Shots Scored from Play</strong></td>
<td>10 ± 4.1</td>
<td>11 ± 3</td>
<td>Small</td>
<td>-3.84 to 2.29</td>
</tr>
<tr>
<td><strong>Percentage of Possession</strong></td>
<td>49 ± 3</td>
<td>50 ± 4</td>
<td>Small</td>
<td>-4.09 to 2.19</td>
</tr>
<tr>
<td><strong>Tackles in Defensive Third</strong></td>
<td>56 ± 34</td>
<td>34 ± 10</td>
<td>Large</td>
<td>0.41 to 42.64</td>
</tr>
<tr>
<td><strong>Tackles in Middle Third</strong></td>
<td>54 ± 44</td>
<td>36 ± 11*</td>
<td>Medium</td>
<td>-9.51 to 44.09</td>
</tr>
<tr>
<td><strong>Tackles in Attacking Third</strong></td>
<td>12 ± 8</td>
<td>10 ± 4</td>
<td>Small</td>
<td>-3.30 to 7.32</td>
</tr>
<tr>
<td><strong>Total Tackles</strong></td>
<td>121 ± 71</td>
<td>80 ± 17</td>
<td>Large</td>
<td>-2.65 to 84.29</td>
</tr>
</tbody>
</table>

Difference mean value; Small effect: $0.01 < \eta^2 < 0.06$; Moderate effect $0.06 < \eta^2 < 0.14$; Large effect: $\eta^2 > 0.14$. CI, confidence interval. *Significant difference (p<0.05) from Division 1 team

6.5 Discussion

The current study is one of the first to investigate the high-speed running demands and technical performance variables in Gaelic football match-play between two elite teams with differing Divisional status. One major finding within this study was that the Division 3 Gaelic football team covered greater HSR, RHSD, performed more HSE and had a higher % HS running performance when contrasted to the Division 1 team. These differences were most pronounced in the full-back and midfield positional lines. A second major finding, there were a greater number of tackles, particularly in the middle third, executed by the Division 1 team. Finally, the Division 1 team's attacking efficiency in scoring attempts was higher when compared to the Division 3 team, with the latter found to have a greater number of hand passes completed than their Division 1 counterparts. Consistent with previous Gaelic football studies (Malone et al., 2015; Malone et al., 2016), the middle 8 positions (half-backs, midfielders and half-forwards) covered more
high-speed running when compared to the other two positional lines (full-back and full-forwards). These differences in running demands might be explained by the interchangeable and roving tactical role typically assigned to the middle 8 players within Gaelic football (winning possession and transitioning from defence to attack). In agreement with the previous literature (Malone et al., 2015; Malone et al., 2016), the Division 3 midfield line recorded the greatest high speed running values in comparison to the other four positional lines. However in contrast, the findings within the current study, found the Division 1 team’s half-forward line covered the greatest high speed running distances. This difference may be due to a tactical ploy among the Division 1 team.

A novel finding within the present study was that the Division 3 full-back and midfield lines had higher running profiles (i.e. HSD, RHSD, HSE and %HS) when compared to their Division 1 counterparts. There are several possible explanations for this finding. Firstly, the lack of tackles by Division 3 team in the middle third may have resulted in an increase in match-play involvements for the full-back line, therefore resulting in greater running demands placed upon them. This is in direct contrast to the Division 1 team who had higher tackle count within the middle third and lower running profiles. Notably, the Division 3 team completed a significantly greater number of hand passes; this finding is not surprising as anecdotal evidence suggests that Division 3 teams will engage in a style of play that is hand pass oriented with the aim of keeping possession and working the ball up the pitch (Carroll, 2013), which in turn would increase these teams’ running demands. In contrast, the Division 1 team had a greater number of kick passes than their Division 3 counterparts; this may directly explain the lower levels of high-speed running observed for these players as the ball is consistently traveling a greater distance thus lowering the running demands.

The present findings are in agreement with other research (Di Salvo et al., 2009; Di Salvo et al., 2013; Hulin et al., 2014; Mangan, Malone, Ryan, McGahan, O’Neill, et al., 2017; Rampinini et al., 2009), that suggest increased high-speed running does not necessarily ensure success. These studies indicate that there are technical and tactical variables at play which are a greater predictor of success than high-speed running. Similar to Hulin et al. (2014) who examined successful and less successful teams in rugby league, the present study found no significant difference between the two teams with regard to the percentage of time in possession of the ball. Previous research has found that the team with less time
in possession completes greater amounts of high-speed running defending and chasing 
(Gabbett, 2013; Gabbett et al., 2014) this was not the case in the present study with both
teams having possession of the ball for approximately 50% of the time.

Another unique finding within the present study was the Division 1 team’s execution of
a greater number of total tackles across all three distinct sections of the field. Similar
findings were found in rugby league (Hulin et al., 2014) with successful teams making
greater number of collisions than unsuccessful teams. Another potential explanation for
the greater amount of tackles associated with the Division 1 team is the tactical approach
adopted. Currently, within Gaelic football, there is an increase in teams adopting a high
press on kick outs, in an attempt to dispossess the opposition in the middle third of the
pitch. This may have impacted a number of findings within the current study, such as the
Division 1 team completing a greater number of tackles in the middle third, resulting in
the team winning possession higher up the pitch, which in turn reduced the need for the
midfield line to complete high-speed running in their defensive third. Although not
statistically significant, the Division 1 team completed 22 more tackles in the defensive
third when compared to the Division 3 team. This may be due to the pressure imposed on
the opposition in the middle third (Table 6.3), resulting in poor execution of passes into
attack. This could provide an opportunity for Division 1 defenders to get close to their
opponent to execute the tackle. Finally if possession is re-gained through this high-press
tactic, it will result in the exclusion of the defensive lines from completing high-speed
running during the ensuing phases of play.

The Division 1 team demonstrated a higher shot efficiency than the Division 3 team. The
‘shots missed’ category was greater in the Division 3 team, which may suggest the
presence of better decision-making and technical proficiency in front of goal in higher
level teams. This finding is consistent with Carroll (2013) who found this to be a major
difference between higher and lower ranked Gaelic football teams. The efficiency, rather
than the quantity of shots, has also been shown to differentiate top and bottom teams in
previous soccer studies (Lago-Peñas, Lago-Basilestes, Dellal, & Gómez, 2010; Liu et
al., 2015; Liu, Gómez, Lago-Peñas, Sampaio, 2015; Liu, Hopkins, & Gómez, 2016; Yue,
Broich, & Mester, 2014).

The findings from the current study must be viewed in context with the limitations within
the investigation. The use of a 4-Hz GPS system to accurately track high-speed
movements must be considered (Malone, Collins, et al., 2013). In addition, the absence of a tri-axial accelerometer and gyroscope, which provides information on physical contact such as a tackle, could have provided additional information related to match-play demands. Future research should aim to apply recent technological advances in this field to evaluate other physiological demands such as contact force (i.e. tackles), change of direction and associated heart rate variability. Furthermore, this study did not examine positional differences in technical performance. Future research should aim to examine the technical performance by position, by team and how these potentially fluctuate across the season. While this study examines differences in movement demands and technical performance variables across divisions, it does not examine differences within teams competing in the same division. Similar to the findings of Carroll (2013), a team’s style of play and prevalence of technical skill may vary depending on the opponent. Future research in Gaelic football should examine differences in the aforementioned variables from multiple teams within the same division to gather a more overview and representation of performance measures. Finally, future studies in Gaelic football must examine match to match variation in running performance with a team across multiple divisions and seasons. Taking into account the quality of opposition, styles of play, styles of coaching and the margins that are associated with winning and losing, to get a better understanding of the contextual factors that impact running and technical demands across divisions.

6.6 Practical Application

Findings from the current research suggest that greater amounts of high-speed running are not necessarily related to team ranking in elite Gaelic football. Scoring accuracy, in addition to a higher frequency of tackles, particularly in the middle third, were characteristics more associated with the higher ranked team. It is beneficial for coaches to be aware of the relevant running and technical performance measures associated with higher divisional status. Greater knowledge in this regard would facilitate coaches to structure their training to optimise performance. Currently within Gaelic football, there is an increased emphasis on the physical development of athletes. However these findings highlight the importance of technical competence in differentiating between higher and lower-ranked teams. It is recommended that coaches at all levels place these elements as a central tenet of their coaching philosophy to maximize the development of the key performance skills required during match-play. Finally, this study highlights the
importance of technical skill proficiency, rather than running performance capability, in distinguishing between higher and lower ranked teams within elite Gaelic football.
Chapter 7: Variation in training load and markers of wellness across a season in an elite Gaelic football team

This study has been accepted for publication following peer-review. Full reference details are:
7.1 Abstract

Purpose: To examine the variation in training load and wellness across a season in an elite Gaelic football team. Methods: Weekly external and internal load were obtained from thirty elite Gaelic football players (25.7 ± 3.5 years, 183.0 ± 4.7 cm, 84.4 ± 6.5 kg) across a full season (33 weeks, 8 seasonal blocks). External training loads (TL) of total distance and high speed running distance were measured using 4-Hz GPS units. Internal TL, assessed via s-RPE, was recorded for each training activity and game. Psychometric data were recorded each morning upon rising using an athlete monitoring system, which calculated a readiness to train (RTT) score for each player. Results: Across both external TL variables, independent paired comparisons found a large difference between Pre-Season 2 and In-Season 4 GPS scores relative to In-Season 6. For total s-RPE, large differences were found between Pre-Season 2 and In-Season 4 in comparison to In-Season 2, In-Season 5 and In-Season 6. There were significant differences in RTT across the eight seasonal blocks (p < .001, ES = .363), with mean scores at their lowest during Pre-Season 1, Pre-Season 2 and In-Season 4, reflecting the TL findings above. Conclusion: This study provides critical information regarding elite Gaelic football players’ training response (RTT) to the external (GPS) and internal (s-RPE) training and game loads across a season. External and internal load was at its greatest in the pre-competition preparation blocks (Pre-Season 2 and In-Season 4); this was found to be inversely related to wellness scores.

Key words: GPS, s-RPE, readiness to train, RTT, wellness, internal load, external load
The amateur status of Gaelic football means coaches have limited access to players across a training week (maximum 2-3 collective pitch sessions). Therefore, careful planning for these sessions is imperative to ensure that technical development and tactical awareness is developed in conjunction with physical fitness. A multitude of factors contribute to the higher emotional and physical fatigue in elite Gaelic football athletes compared to their sub-elite counterparts (Burns, 2014). The management of this fatigue is compounded by the fact that these athletes are involved in multiple teams (Club, County and in some cases University). With most players either in full time employment or at university, the frequency of, and travel associated with, matches and training means that players rarely have adequate time to fully recover (O’Neill et al., 2007).

The goal in training competitive athletes is to provide training loads that are effective in improving performance (Meeusen et al., 2013). Season long competition schedules in sport create challenges for coaches in balancing the requirements of developing and maintaining physical fitness, optimizing recovery as well as adjusting the training load before and between games (Gastin et al., 2013). Previous research has highlighted the importance of seasonal variation in training load in order to enhance athletic performance, with changes in performance attributable to varying periods of intense and light training (Gabbett & Jenkins, 2011; Lambert & Borresen, 2010). Advances in sports technology have resulted in the development of cutting-edge player monitoring tools (e.g. online platforms) to provide coaches with subjective information detailing the internal load (i.e. rate of perceived exertion and wellness markers) of athlete’s training in response to the external load (Killen et al., 2010).

Global positioning systems (GPS) have been used as a means to measure the external load prescribed by coaches to players within given training sessions, allowing the monitoring of running demands in training and competition (Petersen et al., 2010; Wisbey et al., 2009). Knowledge of these running demands can assist coaches in the planning of position-specific training programs and recovery protocols for their athletes.

Internal training load is often measured using the session rate of perceived exertion (s-RPE) scale (Borg, 1998). Additionally, s-RPE has been used to measure the various training activities that are undertaken by team-sport athletes, such as resistance training
(Sweet et al., 2004), pitch-based conditioning and skills-based sessions (Clarke et al., 2013; Williams et al., 2017). Within Gaelic football, s-RPE has been found to have a moderate to very large correlation with external loads measured via GPS (Malone, Hughes, Mangan, Roe, & Collins, 2017). Thus, the s-RPE metric represents a highly practical tool for monitoring the internal training loads of athletes within Gaelic football.

Training response to a prescribed load can be assessed using markers of wellness. The monitoring of markers of wellness has the potential to reduce periods of overtraining and fatigue among sports participants (McLean et al., 2010). Therefore, sports practitioners are encouraged to not only measure training load (TL) but also incorporate some form of psychometric monitoring questionnaire (e.g. stress, mood state, fatigue) to assess the players’ training response to the previous day’s activity.

The ability to monitor both subjective and objective measures of TL is critical to the quantification of training, maintaining physical fitness and optimizing recovery. While previous research has examined internal TL across the season within Gaelic football (Malone, Roe, et al., 2017) and external load and internal loading reported in other sports (Malone, Di Michele, et al., 2014; Moreira et al., 2014; Ritchie et al., 2016), there is a dearth of research within Gaelic football that focuses on external loading (GPS) and subjective wellness. Therefore, the purpose of this study was to explore the variation in total external (GPS) and internal (s-RPE) load (training + game), in addition to selected wellness variables, across pre-determined stages of an elite Gaelic football season.

7.3 Methods

7.3.1 Experimental Approach to the Problem

The current observational study investigated the seasonal variation in TL and markers of wellness in an elite Gaelic football team across the 2015/16 season (Figure 1: 8 months, 33 weeks Dec-July). The season was divided into eight distinct blocks, incorporating the two main competitions; the National League and All Ireland Championship. Pre-Season was divided into 2 blocks (Pre-Season 1 and Pre-Season 2) prior to the commencement of the National League. The competition phase was divided into six blocks, 2 blocks (In-Season 1 and In-Season 2) across the National League, 2 further blocks (In-Season 3 and In-Season 4) between the League and Championship, and finally 2 blocks (In-Season 5

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and In-Season 6) across the Championship. Pre-Season 2 and In-Season 4, incorporated three pre-competition challenge games across both blocks immediately prior to the National League and Championship competitions.

Training type was categorized as ‘field based training’ \((n = 60)\), strength and conditioning \((n = 48)\) and ‘games’ \((n = 23)\). External training load (TL) was measured via selected GPS measures; total distance (TD) and high speed running distance (HSR). The combined field based training and game data for TD and HSR was also analysed. The VX sport GPS units used in the current study were limited to use in outdoor settings. Therefore, strength and conditioning sessions were not included in the analysis of external training load. Internal TL (RPE x session duration) was recorded for each training activity post-session; the sum of both field based training and game data for each block was also analysed. The psychometric data (wellness markers) were recorded each morning upon rising using the Metrifit athlete monitoring system (Health and Sport Technologies Ltd, Dundalk, Ireland). Subjects were familiar with the rating system having completed an educational workshop during Pre-Season.

### 7.3.2 Subjects

Thirty elite Gaelic football players \((25.7 \pm 3.5 \text{ years}, 183.0 \pm 4.7 \text{ cm}, 84.4 \pm 6.5 \text{ kg})\) from one elite county team participated in this study. Ethical approval was sought and granted from the host institution’s Research Ethics Committee (Cork Institute of Technology). Subjects were provided with a detailed explanation of the research process and completed a consent form prior to commencement of data collection. The team observed across the research period were promoted from their respective league finishing 2\(^{nd}\), winning 9 and losing 5 competitive games across the season.
Figure 7.1: Schematic diagram showing the training load structure of the seasonal blocks across the season. The season was divided into eight distinct periods including the two main competitions, the National League and All Ireland Championship.
7.3.3 Procedure

External training load

External training load was objectively assessed using the VX Sport 4 Hz GPS units (VX Sport; Visuallex Sport, Lower Hutt, New Zealand, Firmware: V1.60 28). The unit was worn on the upper back between the shoulder blades; players wore the same unit across the full season. All devices were activated, satellite locked and established for a minimum of 30 minutes prior to the commencement of each game or field-based session (Maddison & Ni Mhurchu, 2009; Malone et al., 2015). Following each event, data were downloaded using the VX software suite (VX Sport View, New Zealand V1.60 28). Each file was trimmed to ensure that only data recorded when the player was in competition or training was included for analysis. Total Distance (TD) and High Speed Running (HSR) distance (≥17 km h⁻¹) were the variables monitored (Gabbett & Ullah, 2012; Malone et al., 2015; Reilly et al., 2014). Selected thresholds and metrics used in the current study have been used previously in the GAA literature (Malone et al., 2015; Malone et al., 2016; Mangan, et al., 2017; McGahan, et al., 2018). The VX Sport GPS unit has been found to be a valid and reliable tool for the measurement of intermittent activity in field sports (Malone, et al., 2014).

Internal Training Load

Internal training load was measured using the session rating of perceived exertion (s-RPE, Scale of effort 1-10 x time (mins) session duration) (Herman et al., 2006). Each player’s s-RPE was collected verbally approximately 30 minutes after completion of every pitch session or game (after cool down and debriefing by the coach). This timing ensured that the perceived effort was reflective of the entire session as a whole rather than the most recent exercise intensity (Herman et al., 2006; Impellizzeri et al., 2004). Each player’s s-RPE was then entered into the athlete monitoring smartphone application and expressed as Arbitrary Units (AU) for reporting purposes.

Readiness to Train

Upon rising each morning, players completed a psychometric questionnaire to assess general wellness reflective of the previous day’s exertions. This task was recommended to be completed in private and at the same time each morning. All wellness data were collected using the Metrifit athlete monitoring application (Health and Sport Technologies Ltd, Dundalk, Ireland). The stated questions were designed based on
previous recommendations from related athlete monitoring and training literature (Gastin et al., 2013; Hooper & Mackinnon, 1995; Kellmann, 2010; McLean et al., 2010) and were used to assess general indicators of the player’s readiness to train (RTT). The questionnaire comprised 6 questions relating to perceived energy levels, sleep quality, muscle readiness, stress levels, mood state and diet on the previous day. Each question was scored on a five-point scale with 1 and 5 representing poor and very good wellness ratings respectively. Each question contributed a percentage weighting based on importance found in previous literature (McGuigan, 2017), and was calculated using an in-built algorithm within the platform to formulate an overall daily RTT percentage score for each individual player (Energy levels 20%, Sleep quality 19%, Muscle soreness 19%, Mood 14%, Stress 14% and Diet 14%). Mean weekly RTT scores were subsequently calculated to reflect the associated weekly external and internal TL scores. For inclusion in the weekly score, players were required to have completed 4 days RTT across the respective 7-day period. Throughout the observational period, the mean weekly compliance rate for these measures of wellness was 93% (28 ± 1.25 players per week).

7.3.4 Statistical Analysis

All data were analysed using IBM SPSS Version 22. Only full training and game data sets were included within the final analysis. When players experienced an injury (where load was modified), data were excluded from the point of injury to the point of full return to training (Ritchie et al., 2016). The mean load from training sessions and games was taken, summed together to calculate the weekly total load (Figure 1). TL in each block represented the mean of all the weekly total loads within that given block, allowing for the difference in number of weeks within some blocks (Ritchie et al., 2016). Missing data were accounted for by creating missing data categories. Mean and standard deviations were used to summarize the data. Appropriate use of Analysis of Variance (ANOVA) presupposes that certain distributional characteristics of the variables involved are at least approximately achieved. Therefore, preliminary assumption testing was conducted to check for normality (Shapiro Wilk test), while Levene’s test was used to test the homogeneity of variances. One way ANOVA was used to assess variations in each of the seasonal blocks for GPS (total distance and high speed running), s-RPE and RTT in field-based training, games and combination of both. Where significance was found (5% level of significance) involving multiple variables, once the assumption of homogeneity of variances was met, Tukey post hoc test was used to identify these differences. All results
were complemented by the corresponding measure of strength using Cohen’s $d$ effect size (Small effect: $0.2 \leq d < 0.5$; Moderate effect: $0.5 \leq d < 0.8$; Large effect: $d \geq 0.8$) (Cohen, 1988). While external and internal total load data was not found to be significant, medium to large effect sizes were found across the blocks. Therefore further analysis using independent paired comparisons was used to assess the nature of these differences.

**7.4 Results**

Seasonal variations in GPS variables are presented in Table 1 and Figure 2. No significant difference was found across the seasonal blocks for total training load data measured via GPS for both total distance ($p = .832, ES = .773$) and high speed running ($p = .923, ES = .648$). Analysis of effect sizes found a moderate difference for both variables across the seasonal blocks. Independent paired comparisons, used to investigate the nature of these differences, found a large difference between Pre-Season 2 with In-Season 1 ($ES = 1.096$), In-Season 2 ($ES = 1.127$), In-Season 5 ($ES = 1.194$) and In-Season 6 ($ES = 3.242$) for total distance. A large difference was also found for In-Season 4 with In-Season 1 ($ES = 0.810$) and In-Season 6 ($ES = 1.850$). Analysis of high speed running revealed a large difference between Pre-Season 2 and In-Season 1 ($ES = 0.826$) and In-Season 6 ($ES = 1.008$). A large difference was also found with In-Season 4 and In-Season 6 ($ES = 0.931$).

No significant difference was found across the eight blocks for total distance in field-based training ($p = .583, ES = 1.019$) and games ($p = .961, ES = .644$), although large and moderate differences found. For high-speed running in both field-based training ($p = .838, ES = .783$) and games ($p = .936, ES = .721$), there were no significant differences across the seasonal blocks with a moderate difference found for both variables respectively.
Table 7.1: Seasonal variation of weekly field based training and game GPS load throughout each block for duration, total distance and high-speed running. Standardized differences are denoted by letters and expressed by effect size. Data are shown as mean ± SD

<table>
<thead>
<tr>
<th>Block</th>
<th>Time Duration (min)</th>
<th>Total Distance (m)</th>
<th>High Speed Running (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field-based (^L)</td>
<td>Game (^M)</td>
<td>Total (^L)</td>
</tr>
<tr>
<td>Pre-season 1</td>
<td>207 ± 118</td>
<td>—</td>
<td>207 ± 118</td>
</tr>
<tr>
<td>Pre-season 2</td>
<td>153 ± 45</td>
<td>90 ± 37</td>
<td>243 ±18 (^L)</td>
</tr>
<tr>
<td>In-season 1</td>
<td>125 ± 24</td>
<td>95 ± 32</td>
<td>196 ±44 (^L)</td>
</tr>
<tr>
<td>In-season 2</td>
<td>99 ± 25</td>
<td>78 ± 1</td>
<td>157 ± 42</td>
</tr>
<tr>
<td>In-season 3</td>
<td>166 ± 78</td>
<td>76 ± 1</td>
<td>203 ± 89</td>
</tr>
<tr>
<td>In-season 4</td>
<td>197 ± 72</td>
<td>79 ± 5</td>
<td>236 ±37 (^L)</td>
</tr>
<tr>
<td>In-season 5</td>
<td>147 ± 81</td>
<td>99 ± 43</td>
<td>185 ± 41</td>
</tr>
<tr>
<td>In-season 6</td>
<td>125 ± 57</td>
<td>78 ± 2</td>
<td>164 ± 53</td>
</tr>
</tbody>
</table>

Superscripts indicate moderate (M) and large (L) effect sizes across the seasonal blocks.

*Total GPS Duration:*
Pre-season 2 and in-season 4: L vs in-season 1, in-season 2, in-season 5 and in-season 6.
In-season 1; L vs in-season 2

*Total GPS Total Distance:*
Pre-season 2 and in-season 4; L vs in-season 1 and in-season 6.
Pre-season 2; L vs in-season 2 and in-season 5

*Total GPS High Speed Running:*
Pre-season 2 and in-season 4; L vs in-season 6.
Pre-season 2; L vs in-season 1

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Seasonal variation in s-RPE load for each block is presented in Table 2. There were no significant differences for total s-RPE load between blocks, although a large effect size were evident \((p = .306, ES = 1.216)\). Subsequent independent paired comparisons revealed a large difference between Pre-Season 2 and In-Season 2 \((ES = 1.730)\), In-Season 5 \((ES = 1.202)\) and In-Season 6 \((ES = 1.827)\). A large difference was also found between In-Season 4 and In-Season 2 \((ES = 1.503)\), In-Season 5 \((ES = 1.193)\) and In-Season 6 \((ES = 1.735)\). Further analysis of s-RPE between games and field-based training revealed no significant difference across the seasonal blocks for internal load with moderate \((p = .931, ES = .773)\) to large \((p = .375, ES = 1.185)\) differences found respectively. There were large significant differences across the eight seasonal blocks for s-RPE loads recorded after strength and conditioning sessions \((p = .001, ES = 2.850)\). Post hoc analyses revealed In-Season 6 \((221 ± 41 AU)\) s-RPE to be significantly lower than Pre-Season 2 \((570 ± 61 AU, p = .020, ES = 6.736)\), In-Season 1 \((647 ± 71 AU, p = .002, ES = 7.346)\), In-Season 2 \((587 ± 56 AU, p = .008, ES = 7.463)\), In-Season 3 \((516 ± 208 AU, p = .045, ES = 1.968)\) and In-Season 4 \((613 ± 21 AU, p = .007, ES = 12.006)\). It was also found that In-Season 5 \((350 ± 112 AU, p = .015, ES = 3.168)\) was significantly lower than In-Season 1 \((647 ± 71 AU)\).

Changes in RTT and both external load and internal load across the seasonal blocks are presented in Figures 2 and 3 respectively. Analysis of Variance revealed significant differences in RTT across the eight seasonal blocks with a small effect size \((p = .001, ES = .363)\). Post hoc analysis revealed Pre-Season 2 RTT \((73.4 ± 8.3\%)\) was significantly lower than In-Season 1 \((76.7 ± 7.7\%, p = .043, ES = .413)\), In-Season 2 \((77.5 ± 7.6\%, p = .005, ES = .263)\) and In-Season 6 \((77.0 ± 8.5\%, p = .019, ES = .429)\). RTT scores for In-Season 4 \((73.8 ± 8.2\%, p = .015, ES = .468)\) and Pre-Season 1 \((73.8 ± 7.4\%, p = .020, ES = .473)\) were significantly lower than In-Season 2 \((77.5 ± 7.6\%)\).
Table 7.2: Seasonal variation of weekly training and game s-RPE load throughout each block for total load, games, field-based training and strength and conditioning. Standardized differences are denoted by letters and expressed by effect size. Data are shown as mean ± SD

<table>
<thead>
<tr>
<th>Block</th>
<th>Total Load (AU)</th>
<th>Game (AU)</th>
<th>Field Based Training (AU)</th>
<th>Strength &amp; Conditioning (AU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-season 1</td>
<td>1812 ± 1070</td>
<td>—</td>
<td>1515 ± 807</td>
<td>446 ± 194</td>
</tr>
<tr>
<td>Pre-season 2</td>
<td>2172 ± 311</td>
<td>672 ± 272</td>
<td>1072 ± 323</td>
<td>570 ± 61*</td>
</tr>
<tr>
<td>In-season 1</td>
<td>2052 ± 257</td>
<td>751 ± 263</td>
<td>841 ± 168</td>
<td>647 ± 71*‡</td>
</tr>
<tr>
<td>In-season 2</td>
<td>1708 ± 217</td>
<td>612 ± 17</td>
<td>662 ± 214</td>
<td>587 ± 56*</td>
</tr>
<tr>
<td>In-season 3</td>
<td>2052 ± 649</td>
<td>612 ± 30</td>
<td>1230 ± 715</td>
<td>516 ± 208*</td>
</tr>
<tr>
<td>In-season 4</td>
<td>2202 ± 411</td>
<td>615 ± 106</td>
<td>1435 ± 626</td>
<td>613 ± 21*</td>
</tr>
<tr>
<td>In-season 5</td>
<td>1460 ± 778</td>
<td>779 ± 309</td>
<td>803 ± 725</td>
<td>350 ± 112</td>
</tr>
<tr>
<td>In-season 6</td>
<td>1386 ± 523</td>
<td>731 ± 1</td>
<td>855 ± 637</td>
<td>221 ± 41</td>
</tr>
</tbody>
</table>

Superscripts indicate moderate (M) and large (L) effect sizes across the seasonal blocks. * Significant difference (p<.05) in-season 4. ‡ Significant difference (p<.05) in-season 3

S-RPE Total Load:
Pre-season 2, in-season 1 and in-season 4: L vs in-season 2, in-season 5 and in-season 6.
In-season 2; L vs in-season 6
In-season 3; L vs in-season 5 and in-season 6
Figure 7.2: Weekly GPS combined total distance for field based training and game, with mean weekly readiness to train (RTT) throughout each block during the season. Data are shown as mean ± SD.
Figure 7.3: Weekly session-RPE total training load, with mean weekly readiness to train (RTT) throughout each block during the season. Data are shown as mean ± SD
7.5 Discussion

The current study is the first to examine the seasonal variation in load across a full season in elite Gaelic football, using a combination of external (GPS) and internal (s-RPE) load in addition to selected wellness markers (RTT). Variation in training load was evident across the seasonal blocks, with targeted periods of loading within Pre-Season 2 and In-Season 4, in addition to strategic unloading within In-Season 2 and In-Season 6, evident for both external and internal load. RTT was significantly lower in the blocks pre- and post-National League (Pre-Season 2 and In-Season 4) compared to In-Season 2 and In-Season 6 where external and internal load was at its greatest, demonstrating an inverse trend between markers of wellness and training load. In contrast, RTT was at its highest during In-Season 2 and In-season 6.

The findings of the current study contrast those of previous studies from rugby league (Killen et al., 2010), soccer (Jeong et al., 2011) and Australian Football (Moreira et al., 2014) that found that pre-season training load was significantly greater than in-season training load. In the current study, no statistically significant differences were found for either external or internal total training loads between pre-season and in-season blocks. However, a notable trend was evident with an associated increase in both external and internal TL observed with a large difference found between In-Season 4 and In-Season blocks 5 and 6. This may be explained by the coaches knowingly prescribing a 2nd mini pre-season, referred in the literature as a ‘maintenance dose’ of training load during the in-season (Ritchie et al., 2016), with the main aim of maintaining the physical competences developed during pre-season while also ensuring optimal readiness for competition (Ritchie et al., 2016). Furthermore, the protective effect of higher chronic loads has recently emerged in the literature (Windt et al., 2017). There is an absence of Gaelic football-specific periodisation models within the literature, consequently it is often left to the coach’s own discretion and expertise to develop their own sport-specific periodisation models. Therefore, the increase in duration within In-Season 4 may have reflected the coach’s decision to target fitness and game play in preparation for the All-Ireland Championship (Malone, Roe, et al., 2017), which consequently increased both internal and external load. Interestingly, RTT was considerably lower in the blocks pre- and post-National League, and at its lowest within blocks Pre-Season 2 and In-Season 4 where the external and internal load was at its greatest. These findings demonstrate the challenges associated with planning a training year within Gaelic football, particularly
the blocks between the two major competitions. Furthermore, it presents important questions for coaches when planning training loads within the competitive period of the season (Ritchie et al., 2016).

This is the first study within elite Gaelic football to examine players' GPS distances across seasonal blocks. It was found that within In-Season 6, mean total distance accumulated in field-based training was 9320 ± 4548m. This is much higher than the in-season training range (6182 ± 1841m) for professional soccer players reported by Malone, Di Michele, et al. (2014), but somewhat less than the figures reported by Ritchie et al. (2016) for Australian footballers (10400 ± 3300m), placing elite Gaelic football training workload in a comparable category with their professional sports counterparts. The large standard deviation (Pre-season 1 and In-season 3) in total internal and external load for field based training sessions should be noted. Possible explanations for this are the variability in number field based training session and games within a block, for example reduced sessions due to Christmas break (Pre-season 1) and players released for club competition (In season 3). These findings (i.e. GPS distances) across the seasonal blocks have considerable practical application for coaches and sport scientists by providing greater knowledge and awareness of associated training load numbers, which can serve to inform the design of more accurate and appropriate periodised plans. For example, coaches can use this information to modify training sessions for players across a full squad, individually managing their overall load and mode of training programmed within the various seasonal blocks.

The internal loads for strength and conditioning sessions demonstrated significant differences across blocks, however they were notably lower within In-Season 5 and 6. This difference in s-RPE load, and the distribution of training loads within In-Season 6, may have been a strategy by the coach to reduce the impact of training fatigue and allow for optimum performance for the latter part of the All-Ireland Championship. This type of periodization is supported in the work of Slattery, Wallace, Bentley, & Coutts (2012), who demonstrated that physical performance during prolonged, high-intensity intermittent exercise was improved by reducing the load in the week prior to competition. Although the current study shows a reduction in strength and conditioning load during the in-season, the field-based training session loads revealed no statistically significant difference across the seasonal blocks.
A novel aspect of the current study was the monitoring of elite Gaelic footballers’ perceptual wellness across a full season. An in-depth analysis was conducted on the training responses of athletes to the external and internal TL using selected wellness markers. The weekly athlete compliance with this wellness monitoring was 93%. An interesting finding was that RTT was significantly different across the seasonal blocks. RTT was considerably lower in the blocks pre- and post-National League, and was at its lowest within the Pre-Season 2 and In-Season 4 blocks when the total s-RPE load was at its highest; thus presenting an inverse trend to training load. This maladaptive response to training load has been reported in previous literature within other field sports (Coutts & Reaburn, 2008; Lambert & Borresen, 2006; Lambert & Borresen, 2010). RTT was also significantly lower within In-Season 4, which contained higher total distance and high speed running loads than any other block across the season. This finding was substantiated in a study of professional soccer players that found a strong correlation ($r = -0.51, p < .001$) between total high speed running and self-reported fatigue (Thorpe et al., 2015). The use of $r$ in this case may not in fact demonstrate a strong correlation. The correlation can give misleading results, $r$ does not take into account other variables at play, such as the accuracy of the assessment used and the diversity of the population reporting. In this case, with Thorpe et al the effect size is in fact small, if the statistic used to report as $r$ squared. However, these findings suggest that RTT is sensitive to subtle changes in external training and game load. Conversely, RTT scores increased during the two main competition blocks of the season (i.e. In-Season 2 and In-Season 6 where load management was a priority in the preparation of the team for League and Championship competitions. This finding is consistent with a previous study of Australian football players (Gastin et al., 2013), which showed that as game day approached, in-season wellness markers significantly improved. The current findings also support those of Gastin et al. (2013), demonstrating that perceptual wellness scales offer a useful tool to monitor adaptive responses and are sensitive to subtle changes in training and game load within elite athletes.

While these findings are novel, there are some limitations in the current study that warrant discussion. Firstly, it should be acknowledged that this investigation is a study of one elite Gaelic football team. The results may have been influenced by the individual coaching style and philosophy of the head coach, therefore may not represent the periodization strategies of all elite Gaelic football teams. A larger sample size comprising a number of elite teams would serve to verify these findings. Furthermore, it was not possible to
document the external loads performed outside of the team environment (e.g. Club or University training and competition) and the implications for such undocumented loads accrued may have influenced subsequent internal TL and markers of wellness responses. The external loads presented in the current study only reflect the training and game data while performing for the team under investigation. The external load associated with individual players' club and university training and games should be examined using GPS to provide a precise overview of the additional external loading placed upon these athletes. The current research has included external and internal load data relating to elite inter county activity only. These players also engage in training activities and competitive games with their university and/ or club. To gain a complete understanding of training load of each athlete and to be able to develop a more individualised method of monitoring internal and external load this data could also be included and analysed. Finally, RTT was examined over a series of blocks (4 weeks), which may have concealed subtle changes within or between these weeks such as recovery days during the week and/or whether games were won or lost. Future research in Gaelic football should focus on RTT within weeks across a season, investigating each player's individual RTT metrics and their association with injury risk.

7.6 Practical Application

Within Gaelic football, seasonal loading appears to be stable with little fluctuations in internal and external training loads. Perceptual ratings of wellness were shown to be sensitive to changes in both external and internal training load. Knowing when these scores return to baseline relative to the mesocycle may allow coaches to prescribe the heaviest load within that week or block. The use of morning-measured psychometric perceived ratings of wellness has unique potential as a simple, non-invasive assessment of the training response in elite Gaelic players across a season. The potential to predict the loading for a given session or training week may allow coaches and performance staff to be more agile in their planning practices within Gaelic football.
Chapter 8: Thesis Conclusions and Recommendations for Future Research
8.1 Introduction

This thesis examined the training load and markers of wellness among elite Gaelic football players. The aims of this comprehensive research process focused on separate, but related, areas of investigation in the broad thematic areas of training load and wellness, namely:

- Training load and readiness to train in a pre-competition training camp
- Analysis of the positional running demands in training and competition
- Analysis of high intensity running demands of match play across different divisions
- Variation in training load and markers of wellness across a season.

Each of the research hypotheses will be discussed in the context of the findings of the respective studies. The significance of these findings, and how this research will contribute to the existing body of literature, will be further developed in this context also. Finally, a number of key recommendations relating to the development of the running demands in Gaelic football and the improvement to the monitoring of the external and internal load in elite Gaelic footballers will be proposed.

8.2 Discussion

\( H_0 \): There will be no significant relationship between training load (internal & external) and wellness markers (RTT) in a pre-competition training camp among elite Gaelic footballers

The purpose of Study 1 was to investigate the relationship between TL and readiness to train on the following day in a pre-competition training camp. The key findings from this study were that (i) TD, HSR distance and internal TL varied significantly from day to day, but (ii) neither the external or internal TLs that the players were exposed to were found to adversely affect RTT or CMJ scores on the following day. Specifically, while total internal TL for the week was 2310 AU, which was considerably greater than the average in-season Gaelic football training week of 1000 – 1200 AU observed prior to the pre-competition training camp, this was not found to adversely impact on markers of wellness. Furthermore, there was no significant differences in RTT and CMJ scores between high or low ‘loaders’ when data was stratified based on volume of HSR, which further substantiates the camp’s design and purpose. Finally, RTT was sensitive to subtle
changes in the previous day’s HSR training load, with an inverse trend evident between associated RTT scores and HSR high loaders from the previous day.

**H0 2: There will be no significant difference in the running demands recorded between training sessions and match-play in an elite Gaelic football team**

The purpose of this study was to assess the position-specific running demands of both competition and training of an elite Gaelic football team across a full season. A major finding was related to the positional differences that exist within elite Gaelic football; the middle eight (HB, MF, HF) positions have the greatest running demands in comparison to the inside lines (FB, FF), this trend was evident in both competition and training data. Another key finding was the strong relationship evident between game-based training and competition across all the GPS variables, with position-specific similarities existing across all the lines. The game-based approach places the athlete in an environment where they must practice ‘performing under pressure’ in a context similar to what they face in competition (Gabbett, Jenkins, et al., 2009). In doing so, it presents athletes with additional mental and physical challenges that they would not normally be exposed to in traditional conditioning-based or skills-based training sessions. These findings would suggest that a game-based training approach is effective in preparing athletes for the physical, technical and tactical demands of team based sports such as Gaelic football.

**H0 3: There will be no significant differences in the match-play high-speed running demands and technical performance variables of Division 1 and Division 3 players in elite Gaelic football**

The purpose of this study was to investigate the match-play high-speed running demands and technical performance variables of Division 1 and Division 3 players in elite Gaelic football. It was found that the Division 3 Gaelic football team covered greater HSR and RHSD, performed more HSE and had a higher % HS running performance when compared to the Division 1 team. These differences were most pronounced in the full-back and midfield positional lines. Analysis of technical skill variables found a greater number of tackles, particularly in the middle and defensive third, executed by the Division 1 team. The Division 1 team’s attacking efficiency in scoring attempts was higher when compared to the Division 3 team, with the latter found to have a greater number of hand passes completed in general match-play (as opposed the more challenging execution of kick passes). The present findings suggest that increased high-speed running does not necessarily ensure success and alternatively indicates that there are technical and tactical
variables at play that are a greater predictor of success. Another unique finding within this study was the evidence of greater technical proficiency relating to tackling and shooting executed by the Division 1 team. The ‘shots missed’ category was greater in the Division 3 team, which may suggest the presence of better decision-making and technical proficiency in front of goal in higher ranked teams.

**H0 4: There will be no significant differences in training load and wellness across a season in an elite Gaelic football team**

The purpose of this study was to investigate training and competition load of selected external (GPS), internal (s-RPE) and wellness (psychometric questionnaire) variables across a full season in an elite Gaelic football team. Variation in training load was evident across the seasonal blocks, with targeted periods of loading (internal and external) prevalent in the pre-competition phases of Pre-Season 2 and In-Season 4, in addition to strategic unloading within the competition phases of In-Season 2 and In-Season 6. RTT was significantly lower in the blocks pre- and post-National League (Pre-Season 2 and In-Season 4) compared to In-Season 2 and In-Season 6 where external and internal load was at its greatest, demonstrating an inverse trend between markers of wellness and training load. In contrast, RTT was at its highest during In-Season 2 and In-season 6.

These findings suggest that RTT is sensitive to subtle changes in external training and game load. Conversely, RTT scores increased during the two main competition blocks of the season (i.e. In-Season 2 and In-Season 6) where load management was a priority in the preparation of the team for League and Championship competitions. The current findings also support those of Gastin et al. (2013), demonstrating that perceptual wellness scales offer a useful tool to monitor adaptive responses and are sensitive to subtle changes in training and game load within elite athletes.

### 8.3 Practical Applications of this Research

This research examined a range of factors relating to training load and monitoring of wellness markers among elite inter-county Gaelic footballers. The following practical implications are proposed based on the research process undertaken and associated findings. These practical implications will assist coaches, strength and conditioning coaches, physiotherapists and sports scientists in the field.
This research further supports the use of s-RPE as an accurate and appropriate method of monitoring TL. In Study 1, a strong relationship was found between internal TL (s-RPE) and the GPS TD \((r = .846)\) covered during the training sessions. There was also a positive relationship between the volume of HSR, measured via GPS, during the training sessions and internal TL (s-RPE) \((r = .677)\). Furthermore, in Study 4, s-RPE was found to have an inverse relationship with markers of wellness. While many teams may not have access to GPS units, s-RPE is a simple and cost effective monitoring tool. These findings further contribute to the body of literature that supports the mechanism of s-RPE with regard to the monitoring of TL and increases the understanding of the relationship between internal and external training load.

In an amateur team sport such as Gaelic football, coaches are constantly examining how best to utilize the limited time that they have with their team to optimise performance. This study highlights that a 5 day pre-competition training camp consisting of 7 pitch sessions can be performed without inducing excessive neuromuscular fatigue or adversely affecting RTT. The findings suggest that a combination of RPE, CMJ, GPS and wellness markers can provide critical information in the process of monitoring training response in such a condensed training environment.

This research found that positional differences exist within elite Gaelic football, with the middle eight positions (HB, MF & HF) covering significantly more distance than the inside lines (FB & FF) (Study 2). The findings suggest a need for coaches to plan conditioning sessions with greater levels of game-specific high speed running for players in the middle 8 positions, and for greater sprint efforts among players in FB and FF lines. Additionally, Study 2 found that the physical running demands of carefully planned and structured game-based training sessions are strongly related to the demands of competition. This provides support for coaches to use a game-based training approach as a method of preparing players for the movement demands of competition in elite Gaelic football.

Division 1 team's execution of a greater number of total tackles across all three distinct sections of the field. Similar findings were found in rugby league (Hulin et al., 2014) with successful teams making a greater number of collisions than unsuccessful teams. Although not statistically significant, the division 1 team completed 22 more tackles in the defensive third and 18 in the middle third. These findings should encourage coaches to adopt a more defensive approach in their
own attacking third in an attempt to dispossess the opposition in the middle third or put enough pressure to allow contact be made in the defensive third of the pitch.

- The findings within Study 3 suggest that greater amounts of high-speed running are not necessarily related to team ranking in elite Gaelic football. Scoring accuracy, in addition to a higher frequency of tackles, particularly in the middle third, were characteristics more associated with the higher ranked team. The ‘shots missed’ category was consistently greater in the Division 3 team, which may suggest the presence of better decision-making and technical proficiency in front of goal in higher ranked teams. These findings highlight the importance of technical competence in differentiating between higher and lower-ranked teams. It is recommended that coaches at all levels place these elements as a central tenet of their coaching philosophy to maximize the development of the key performance skills required during match-play. GAA Games Development Committees should strongly promote development of technical competence in youth development programmes.

- Perceptual ratings of wellness were demonstrated to be sensitive to changes in both external and internal training load. Knowledge of when these scores return to baseline relative to the respective meso-cycle may provide coaches with the necessary and accurate information required to prescribe the heaviest load within that week or block. Therefore, the potential to predict the loading for a given session or training week may allow coaches and high performance support staff to be more agile in their planning practices within Gaelic football. This is of particular importance in an amateur sport environment where most players are either in full time employment or at university; and the frequency of, and travel associated with, matches and training means that players rarely have adequate time to fully recover.

### 8.4 Limitations

The findings from this series of related studies must be taken into context relative to the limitations within the research process. Such limitations are outlined below.

- A 4-Hz GPS system was used in each study to track high-speed movements. The absence of a tri-axial accelerometer and gyroscope, which both provide
information on physical contact such as a tackle, could have provided additional information related to match-play demands.

- While studies have investigated the reliability and validity of the VX sport GPS and s-RPE, there were no such studies conducted with this cohort prior to commencing the study.

- While this research examines differences in movement demands and technical performance variables across divisions, it does not examine differences within teams competing in the same division.

- The external loads presented in this research solely reflect the training and game data while performing for the team under investigation. It was not feasible or practical to document the external loads performed outside of the team environment (e.g. Club or University training and competition) and the implications for such undocumented loads accrued may have influenced subsequent internal TL and markers of wellness responses. For future research in this area, external load associated with individual players' club and university training and games should be examined using GPS to provide a precise overview of the additional external loading placed upon these athletes.

- A limitation of research using both internal and external load relating to competitive games relates to controlling for periods of warm up and cool down pre and post competition. For external load calculation, GPS data was trimmed to remove these periods and therefore running demands associated with these periods were excluded. For internal load, the primary researcher calculated the duration of competition, excluding the warm up and cold down periods. It should be noted however that running demands associated with warm up and cool down periods may have impacted on individual's scores on the RPE scale. This is a limitation of this type of research and one which is difficult to control for. The approach adopted in this research follows the methodological approach of others in the field such as, Pustina et al (2017) in a study using players from NCAA Division I men's soccer team.

- It should be acknowledged that no reliability and validity study of RTT was conducted. Saw et al (2017) explains it is becoming a flawed concept with studies investigating the use of wellness markers by solely justifying there use as "similar to that used previously." Therefore, to avoid the field progressing down an undesirable path, it is a critical for applied research using wellness questionnaires
to ensure that scientific rigor is upheld and such studies should be conducted beforehand.

- RTT was examined over a series of blocks (4 weeks) in Study 4 (Chapter 7), which may have concealed subtle changes within or between these weeks such as recovery days during the week and/or the potential impact of victory or defeat in competitive action. For example, when the team experienced an unexpected defeat within In-Season 6, RTT did not return to baseline for 4 days, consequently skewing the data from this 4 week block.

- Finally, it should be acknowledged that this research was based on the physical and performance outcomes of two elite Gaelic football teams across separate seasons. The results may have been influenced by the individual coaching style and philosophy of the head coach and therefore may not be representative of all Gaelic football teams with regard to the presented training periodization or tactical strategies.

8.5 Future Research

A number of recommendations that future research should consider are outlined below.

- Study 1 provides data relating to the 5 days of the aforementioned training camp. Future research could include pre- and post-camp data, thus providing a more meaningful contextual understanding of the findings from this short intervention relating to health, fatigue, injury or illness of the athletes. This will provide further information regarding the impact of intensified periods of training on athletic performance.

- The GPS system used in this research did not have tri-axial accelerometers or gyroscopes, therefore data relating to physical contact such as the tackle was not available for analysis. Future research should aim to apply recent technological advances in this field to evaluate other physiological demands such as contact force (i.e. tackles), which have been proven to have a significant impact on match intensity in other contact/field based sports (Austin & Kelly, 2014; Evans et al., 2015; Gabbett, Jenkins et al., 2012).

- While preliminary work was conducted in this research using both video and GPS analysis, there is further scope to extend related research in this space. For example, future research in Gaelic football should focus on the integration of
video analysis with GPS to evaluate match-to-match variation, playing style and tactical/technical elements within a game. These elements have been shown to impact on running performance in other sports (Gregson et al., 2010; Rampinini et al., 2007). Additionally, such research should aim to examine technical performance by position and by team, and how these potentially fluctuate across the season, to aid in subsequent tailored technical development training processes.

- The findings presented Study 3 provided data from one team in one division. Future research should examine differences in the movement demands and technical performance variables from multiple teams within the same division to gather a more balanced overview and representation of such performance measures.

- In order to safeguard the well-being of the individual as they progress from adolescence into adulthood (Faigenbaum et al., 2009), it is of great importance that future research monitors the training load and RTT among young athletes in Gaelic football ‘Development Squads’. Effective management of training load is imperative to avoid overtraining in this population as invariably, they play on multiple teams (e.g. School, Club & County) across multiple sports.

- While the current research included longitudinal data from one team across 2 consecutive seasons where they were promoted from Division 3 to Division 2, no analysis was conducted on differences in respective movement demands across divisions. Studies in Gaelic football should examine the running performance of a team across multiple divisions and seasons, taking into account the quality of opposition, styles of play and the margins that are associated with winning and losing. This would serve to provide a better understanding of the contextual factors that impact on the running demands across various levels of performance (i.e. rank ordered divisional status).

- Finally, this data could be pooled as part of a larger research study that could examine the variation in RTT on a weekly basis across a season; thus exploring each player's individual RTT metrics and the association with injury risk.

8.6 Conclusion

The findings from this series of studies established that a pre-competition training camp can provide a dedicated period of time to develop tactical and team play elements while not adversely impacting levels of fatigue. Results also provide support and value for the
application of a game-based training approach as a method of preparing players for the physical demands of competition in elite Gaelic football. Also, it was found that overall technical proficiency, rather than high-speed running profiles, differentiated Division 1 and 3 team performances. Finally, variation in training load was prevalent across the seasonal blocks, with targeted periods of loading and unloading clearly evident across different stages of the season as identified by associated wellness scores. This research provides critical information regarding elite Gaelic football players' training response (RTT) to the external (GPS) and internal (s-RPE) training loads across a competitive season, which enables coaches to be more accurate and agile in their planning and practices to optimise performance.
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PART II: APPENDICES

A thesis submitted to Cork Institute of Technology in fulfilment of the requirement for the award of Doctor of Philosophy

By

Jason Hugh McGahan

Department of Sport, Leisure and Childhood Studies

Candidate Supervisor(s) of the research:

Dr. Cian O’Neill & Dr. Con Burns
Appendix A: Publications


A.5 Conference Papers

- Poster Presentation at the 2nd All-Ireland Post-Graduate Conference in Sport Sciences, Physical Activity and Physical Education, University of Limerick, 23/1/2015

- Poster Presentation at the 11th UK Strength and Conditioning Association Annual Strength and Conditioning conference, Leicestershire, 31/07/2015
• Poster Presentation at the GAA National Games Development Conference, Croke Park, Dublin, 22/01/2016

• Oral Presentation at the 3rd All-Ireland Post-Graduate Conference in Sport Sciences, Physical Activity and Physical Education, Waterford Institute of Technology, 29/4/2016

• Poster Presentation at the GAA National Games Development Conference, Croke Park, Dublin 06/01/2017

• Poster Presentation at the 4th All-Ireland Post-Graduate Conference in Sport Sciences, Physical Activity and Physical Education, Institute of Technology Carlow, 21/4/2017

• Poster Presentation at the 11th International Council for Coaching Excellence, Global Coach Conference, John Moores, Liverpool, 31/07/2017

• Poster Presentation at the 13th UK Strength and Conditioning Association Annual Strength and Conditioning Conference, Leicestershire 05/08/2017

• Poster Presentation at the 2nd World Conference in Physical Therapy Conference, Belfast, 06/10/2017

Appendix B: GPS

B.1 GPS Vest and Unit

B.2 GPS Units

Appendix C: Metrifit

C.1 Metrifit Athlete Daily Wellness screen on the smartphone App

C.2 Metrifit Coach Wellness report screen
A.1 Published Paper: Match-play running demands and technical performance among elite Gaelic footballers: Does divisional status count

Relationship between load and readiness to train in a Gaelic football pre-competition training camp

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An investigation into the relationship between match play performance characteristics and post-match RPE responses in professional rugby union players
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Introduction

The burden of congested competition schedules in sport creates challenges for coaches in balancing the requirements of developing and maintaining physical fitness, optimising recovery as well as adjusting the training load before and between games (Gastin et al., 2013). Monitoring player fatigue and the subsequent planning of training load is critical for optimum recovery in sports performance. Recent advances in sports monitoring technology have resulted in Global Positioning Systems (GPS) being used to quantify external training load. Key match play performance characteristics associated with fatigue, such as high-intensity efforts and collisions, can be recorded and analysed with these technological advancements. Internal training load is an individual’s psycho-physiological subjective perception of intensity of effort, for which the RPE scale has been found as a valid and reliable measure (Herman et al., 2006). Currently, there is a paucity of research that has examined the relationship between external and internal training loads. An increased understanding of this relationship will assist coaches in planning appropriate recovery strategies and subsequent optimum training loads between games. The purpose of this study is to assess the relationship between match play performance characteristics, specifically collision analysis and high speed running, and RPE responses in professional rugby union players.

Methods

Thirty eight professional rugby union players (age 25.29 ± 3.9; range 20-35yrs ) from the same European club are participating in this study. Data will be collected across 16 competitive matches during a 4-month competition block during the 2014/15 European League season. Match play performance characteristics will be assessed objectively using Catapult’s S4 10Hz GPS tracking system (Catapult Innovations, Melbourne, Australia). Such characteristics will include tackle detection, measured via a tri-axial piezoelectric linear accelerometer system imbedded within the unit, and high speed running (repetitions >5 m·s⁻¹). Subjective markers of fatigue will be obtained using session-RPE values (CR10-scale) recorded post-match. Internal training load will then be calculated by multiplying the match intensity RPE (0-10) by the duration of the minutes played and reported in arbitrary units.

Significance

Both GPS and subjective RPE values have been used by coaches and practitioners to prospectively tailor individual recovery strategies and subsequent training loads following match play. However, there is a dearth of research examining the distinct
relationship between these markers of external and internal load. An increased knowledge and understanding of this relationship could prove invaluable to management and coaching teams in the game of rugby union. In addition, numerous studies have reported varying position-specific training load variables in the game. Therefore, an enhanced understanding of both external and internal training loads, and the relationship between these variables, has the potential to positively influence programme prescription into the future.

References


Monitoring markers of health, fatigue and GPS output during a pre-competition training camp in elite Gaelic football players

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Purpose

A primary objective of a ‘pre-competition’ training camp is to consolidate all of the cumulative facets of training undertaken to that point and to ensure a coherent and effective focus of the same to facilitate optimal performance in competition. This contrasts with the more orthodox ‘pre-season’ training camp where the focus is primarily dedicated to the development of a broader fitness base for the impending season and where training loads (TL) may be up to 2-4 times greater than at pre-competition (Jeong et al., 2011). The precise control of TL’s and associated individual response is critical for maximizing training adaptations and optimising recovery in preparation for competition (Borresen et al., 2009). The purpose of this study was to assess and monitor the daily variations of selected physiological and psychometric variables during a pre-competition training camp in elite Gaelic football players to ensure excess TL was not being placed on players close to competition (8-13 days pre-event).

Methods

Thirty one elite Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) participated in this study. Data was collected during a 5 day warm weather pre-competition training camp. Sport-specific high speed running distance (GPS), countermovement vertical jump (Electronic Jump Mat) and internal TL (session RPE x session duration) were recorded for each session. Psychometric data was recorded each morning upon rising using Metrifit athlete monitoring system and a readiness to train (RTT) score was calculated for each player pre-training.

Results

There was no significant day to day variations in RTT (coefficient of variation, CV: 15%, P = 0.06) and countermovement jump (CMJ) scores (8%, P = 0.40). While high speed running (HSR) distance (CV: 48%) and internal TL (CV: 38%) varied significantly from day to day (P <0.01) they were found not to be adversely affecting RTT (r = .001, P > .05) or CMJ (.05, P > .05) scores on the following day.

Conclusion

The objective of this training camp was to refine technical skills, develop tactical play and improve decision making. This study highlights that over a 6 day camp with 7 pitch sessions, it was possible to develop these elements without inducing excessive fatigue and adversely affecting RTT. Results presented provide encouraging findings related to the use of pre-competition training camps in team sports such as Gaelic football as an effective strategy to develop team-play without negatively influencing performance potential.
References


Monitoring markers of health, fatigue and GPS output during a pre-competition training camp in elite Gaelic football players

McGahan, J., O’ Neill, C., Burns, C.
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Purpose

A primary objective of a ‘pre-competition’ training camp is to consolidate all of the cumulative facets of training undertaken to that point and to ensure a coherent and effective focus of the same to facilitate optimal performance in competition. This contrasts with the more orthodox ‘pre-season’ training camp where the focus is primarily dedicated to the development of a broader fitness base for the impending season and where training loads (TL) may be up to 2-4 times greater than at pre-competition (Jeong et al., 2011). The precise control of TL’s and associated individual response is critical for maximizing training adaptations and optimising recovery in preparation for competition (Borresen et al., 2009). The purpose of this study was to assess and monitor the daily variations of selected physiological and psychometric variables during a pre-competition training camp in elite Gaelic football players to ensure excess TL was not being placed on players close to competition (8-13 days pre-event).

Methods

Thirty one elite Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) participated in this study. Data was collected during a 5 day warm weather pre-competition training camp. Sport-specific high speed running distance (GPS), countermovement vertical jump (Electronic Jump Mat) and internal TL (session RPE x session duration) were recorded for each session. Psychometric data was recorded each morning upon rising using Metrifit athlete monitoring system and a readiness to train (RTT) score was calculated for each player pre-training.

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Conclusion

The objective of this training camp was to refine technical skills, develop tactical play and improve decision making. This study highlights that over a 6 day camp with 7 pitch sessions, it was possible to develop these elements without inducing excessive fatigue and adversely affecting RTT. Results presented provide encouraging findings related to
the use of pre-competition training camps in team sports such as Gaelic football as an effective strategy to develop team-play without negatively influencing performance potential.

References


Quantifying positional match running demands in elite Gaelic football using global positioning system tracking

McGahan, J., Burns, C., O’ Neill, C.
Department of Sport, Leisure & Childhood Studies, Cork Institute of Technology

Introduction
In the high performance Gaelic football environment, considerable time is devoted to the development of physical qualities amongst other performance-related variables, but the extent to which these physical qualities influence team selection and performance is unclear. While specificity is considered a fundamental principle of training, it is impossible to replicate the demands of competition if those demands are not known to a high degree of accuracy. Global Positioning Systems (GPS) are gaining popularity in field based sports as a means for coaches to assess movement demands of their athletes in training and competition (Peterson et al., 2010). GPS has been found to provide a valid, reliable measure of movement demands in team sports and can provide substantial information relating to distance covered, maximum velocity, high sprint efforts and distance covered at specified speed zones (Wisbey et al., 2009). The purpose of this study was to assess the positional match demands of an elite Gaelic football team during a full season using selected variables from the GPS athlete tracking system.

Methods
Competitive match-day data (n=13) was obtained from 40 elite intercounty Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) across a full GAA season. To ensure the principles of validity and reliability were adhered to, only data files of players who played the full game were included (n=105). Data was collected using 4-Hz GPS units (VX Sports, NZ) which have been found to be a valid and reliable measurement tool to monitor the demands of a team sports (Coutts & Duffield 2010). Sport-specific running variables assessed consisted of total distance (m), high speed distance (>16.6 km/h), maximum velocity (km/h), and number of high speed efforts (>16.6 km/h). These variables were analysed across the 5 out-field positional groups: full back (FB), half back (HB), midfield (MF), half forward (HF), full forward (FF).

Results
There were significant trends evident in movement patterns across the field positions. For total distance, the HB (8245±921m), MF (8703±565m) and HF line (8480±1188m) covered significantly greater distances than the FB (6515±1024m) and FF (6987±600m) lines (p<.05). This trend was also evident in the number of sprint efforts that HB, MF and HF line players recorded reporting similar scores (77.9±18) which were significantly higher than the full back (49±16) and full forward line (58±12) respectively (p<.05). For high speed running distance, the HB, MF, HF and FF lines covered similar distances (Range 1129 [FF] - 1544m [HF]) compared to the FB line (838±286m). There was no
significant difference of maximum velocity across the five positional lines (Range MF 28.6±1.41 - HB 29.6±1.81 km/h)(p=0.451).

Conclusion

The use of integrated technology such as GPS can contribute to significant improvements in the preparation of athletes and recovery aspects following performance. The main findings from this study show positional differences do exist within elite Gaelic football. Knowledge of these differences will assist coaches to plan more specific training sessions that replicate the movement demands of competition and can contribute to a more informed understanding of the individual positional demands of the game.

References


THE EFFECTIVENESS OF GAME BASED TRAINING IN PREPARING ELITE GAELIC FOOTBALLERS FOR COMPETITION

McGahan, J., O’ Neill, C., Burns, C.

Department of Sport, Leisure & Childhood Studies, Cork Institute of Technology

Introduction

Traditional Gaelic Football training involves the use of conditioning-based running sessions (high intensity running without the ball) to prepare players for the physical demands of competition. Game-based training involves an integrated approach using activities such as small sided games in an attempt to develop physical fitness in addition to tactical, technical and team play elements of performance. Previous research from other sports has found that a game-based training approach tends to simulate overall movement patterns of competition but offers an insufficient training stimulus to simulate the high intensity, repeated sprint demands of competition [1,2].

The purpose of this study was to investigate the effectiveness of a game-based training approach to prepare an elite Gaelic football team for the running demands of competition.

Methods

Data was obtained from thirty elite intercounty Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) across a full GAA season (13 competitive matches & 44 game based training sessions). For each game/training session, only players who completed the full activity were included in the analysis (Game=107; Training=857). Data was collected using 4-Hz GPS units (VX Sport, New Zealand). Selected running-based variables included Relative High Intensity Distance (RHID: m/min) and Percentage Distance at High Intensity (%HI) with high speed set at ≥17 km h. These variables were analysed across the 5 positional groups: Full Back (FB), Half Back (HB), Midfield (MF), Half Forward (HF), Full Forward (FF).

Results

Data from game-based training and competition were found to be similar across the five positional lines. For RHID the mean differences between game-based training and competition ranged from 0.7 m/min for players in the full back line to 7.1 m/min for players in the half forward line (Figure 1a). For %HI mean differences between game based training and competition ranged from 0.1% for players in the full back line to 1.8% for players in the half forward line (Figure 1b).

The relationship between competition and game-based training was explored using Pearson product-moment correlation coefficient (Table 1). For RHID there was a strong positive correlation (r>.5) [3] between game-based training and competition across all the positional groups. The relationship was found to reach statistical significance for the FB, HB and FF lines (p<.05).

For %HI, a strong positive relationship (r>.5) was found between game-based training and competition for the HB, MF, HF, and FF lines, with a moderate relationship (r= .3.1)
found for the FB line. The relationship was found to reach statistical significance for the HB, HF and FF lines (p<.05).

Conclusion

The primary purpose of training sessions are to prepare athletes for competition. The current study has found that the physical running demands of carefully planned and structured game-based training sessions are strongly related to the demands of competition. This provides support for the use of a game-based training approach as a method of preparing players for the movement demands of competition.

References


Introduction: To date, there is no research examining variation in high intensity running demands of match-play between successful and less successful teams in Gaelic football. It has been reported that soccer teams competing in higher divisions of competition cover less total distance and less high-speed running distance than teams competing in lower divisions (Di Salvo et al., 2013). Furthermore, from a within-competition perspective, Di Salvo et al. (2009) found that the bottom 5 teams in the English Premier League cover greater high-speed running distance than the teams in the top 5 positions. Whether these relationships remain consistent amongst other sporting codes, and in particular Gaelic football, remains unclear. The purpose of this study was to analyse the match-based high intensity running demands of elite Gaelic footballers from Division 1 and Division 3 of the National League and to examine the influence of playing position on such demands using selected GPS variables.

Methods: Data were obtained from forty seven elite intercounty Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) from two teams (Division 1 and 3) across 25 competitive games. Only players who competed for the full duration of the match were included for analysis (n=205 match data sets). Data were collected using 4-Hz GPS units (VX Sport, New Zealand). High intensity running variables assessed were high speed running (HSR) distance (>17 km h⁻¹), number of high intensity sprint efforts (HSE) (>17 km h⁻¹), relative high intensity distance (RHID) (>17 km h⁻¹ (m/min)) and proportion of time at high speed running (%HSR). A position-specific analysis was also conducted between the teams (full back [FB], half back [HB], midfield [MF], half forward [HF], full forward [FF]).

Results: The Division 3 team demonstrated significantly greater high intensity running than their Division 1 counterparts across all measured variables, HSR, HSE, RHID and %HSR (p<0.02 - 0.001). The magnitude of the differences in the means across all GPS variables was small to moderate (η² = .025 to .54). Position-specific analysis found that the FB and MF lines of the Division 3 team recorded significantly higher scores in all high speed running variables in comparison to their Division 1 counterparts (p<0.05). There was no significant difference between the other 3 positional lines respectively.

Conclusion: Results of the current study indicate that lower ranked teams appear to work harder in physical performance terms compared to teams in higher ranking divisions. This may indicate that higher levels of technical execution and tactical awareness, rather than higher levels of physical fitness, are more important in determining success in Gaelic football.

References

THE EFFECTIVENESS OF GAME BASED TRAINING IN PREPARING ELITE GAELIC FOOTBALLERS FOR COMPETITION

McGahan, J., O’ Neill, C., Burns, C.
Department of Sport, Leisure & Childhood Studies, Cork Institute of Technology, Ireland.

Introduction

Game-based training involves an integrated approach using activities such as small sided games in an attempt to develop physical fitness in addition to tactical, technical and team play elements of performance. Previous research from other sports has found that a game-based training approach tends to simulate overall movement patterns of competition but offers an insufficient training stimulus to simulate the high intensity, repeated sprint demands of competition [1,2].

The purpose of this study was to investigate the effectiveness of a game-based training approach to prepare an elite Gaelic football team for the running demands of competition.

Methods

Data was obtained from thirty elite intercounty Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) across a full GAA season. For each game/training session, only players who completed the full activity were included in the analysis (Game=107; Training=857). Data was collected using 4-Hz GPS units (VX Sport, New Zealand). Selected running-based variables included Relative High Intensity Distance (RHID: m/min) and Percentage Distance at High Intensity (%HI) with high speed set at ≥17 km/h. These variables were analysed across the 5 positional groups.

Results

For RHID the mean differences between game-based training and competition ranged from 0.7 m/min for players in the full back line to 7.1 m/min for players in the half forward line. For %HI mean differences between game based training and competition ranged from 0.1% for players in the full back line to 1.8% for players in the half forward line.

The relationship between competition and game-based training was explored using Pearson product-moment correlation coefficient. For RHID there was a strong positive correlation (r>.5) [3] between game-based training and competition across all the positional groups. The relationship was found to reach statistical significance for the FB, HB and FF lines (p<.05).

For %HI, a strong positive relationship (r>.5) was found between game-based training and competition for the HB, MF, HF, and FF lines, with a moderate relationship (r=.3.1) found for the FB line. The relationship was found to reach statistical significance for the HB, HF and FF lines (p<.05).

Conclusion

The primary purpose of training sessions are to prepare athletes for competition. The current study has found that the physical running demands of carefully planned and
structured game-based training sessions are strongly related to the demands of competition. This provides support for the use of a game-based training approach as a method of preparing players for the movement demands of competition.

References


An analysis of high intensity match play running demands across League Divisions in elite Gaelic football using GPS tracking

McGahan, J., Burns, C., O’ Neill, C.
Department of Sport, Leisure & Childhood Studies, Cork Institute of Technology

Introduction: To date, there is no research examining variation in high intensity running demands of match-play between successful and less successful teams in Gaelic football. It has been reported that soccer teams competing in higher divisions of competition cover less total distance and less high-speed running distance than teams competing in lower divisions (Di Salvo et al., 2013). Furthermore, from a within-competition perspective, Di Salvo et al. (2009) found that the bottom 5 teams in the English Premier League cover greater high-speed running distance than the teams in the top 5 positions. Whether these relationships remain consistent amongst other sporting codes, and in particular Gaelic football, remains unclear. The purpose of this study was to analyse the match-based high intensity running demands of elite Gaelic footballers from Division 1 and Division 3 of the National League and to examine the influence of playing position on such demands using selected GPS variables.

Methods: Data were obtained from forty seven elite intercounty Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) from two teams (Division 1 and 3) across 25 competitive games. Only players who competed for the full duration of the match were included for analysis (n=205 match data sets). Data were collected using 4-Hz GPS units (VX Sport, New Zealand). High intensity running variables assessed were high speed running (HSR) distance (≥17 km h), number of high intensity sprint efforts (HSE) (≥17 km h), relative high intensity distance (RHID) (≥17 km h (m/min)) and proportion of time at high speed running (%HSR). A position-specific analysis was also conducted between the teams (full back [FB], half back [HB], midfield [MF], half forward [HF], full forward [FF]).

Results: The Division 3 team demonstrated significantly greater high intensity running than their Division 1 counterparts across all measured variables, HSR, HSE, RHID and %HSR (p<0.02 - 0.001). The magnitude of the differences in the means across all GPS variables was small to moderate (η² = .025 to .54). Position-specific analysis found that the FB and MF lines of the Division 3 team recorded significantly higher scores in all high speed running variables in comparison to their Division 1 counterparts (p<0.05). There was no significant difference between the other 3 positional lines respectively.

Conclusion: Results of the current study indicate that lower ranked teams appear to work harder in physical performance terms compared to teams in higher ranking divisions. This may indicate that higher levels of technical execution and tactical awareness, rather than higher levels of physical fitness, are more important in determining success in Gaelic football.

References
Seasonal variation of training, competition load and markers of wellness in an elite Gaelic football team

McGahan, J., O’Neill, C., Burns, C.
Department of Sport, Leisure & Childhood Studies, Cork Institute of Technology

Introduction
The precise control of Training Loads (TL) and associated individual response is critical for maximizing training adaptations and optimising recovery in preparation for competition (Borresen et al., 2009). Key match play performance characteristics associated with fatigue, such as high-speed running can be recorded and analysed with Global Positioning Systems (GPS) to quantify external training load. Global Positioning Systems (GPS) has been found to be a valid and reliable tool to quantify external TL (Malone et al). Internal training load is an individual’s psycho-physiological subjective perception of intensity of effort, for which the RPE scale has been found as a valid and reliable measure (Herman et al., 2006). Monitoring of players’ training load and markers of wellness (e.g. stress, fatigue) has the potential to reduce periods of overtraining among sports participants (McLean et al., 2010). The purpose of this study was to assess and monitor the daily variations of selected physiological and psychometric variables during a full season in elite Gaelic football players to ensure excess TL was not being placed on players close to competition.

Methods
Data was obtained from thirty elite Gaelic football players (26.9 ± 3.5 years, 182.8 ± 6.1 cm, 84.6 ± 8.1 kg) across a full GAA season (Dec-July 2016). External TL was measured using 4-Hz GPS units (VX Sport, NZ), internal TL was calculated for each session (session RPE x session duration). Markers of wellness was recorded each morning upon rising using the Metrifit athlete monitoring system and a readiness to train (RTT) score was calculated from these metrics for each player pre-training. For the purpose of this research, the playing season was divided into 8 distinct blocks each of a 4 week duration. A one way ANOVA was used to assess differences between each training block, with Tukey post hoc tests used to identify the nature of these differences.

Results
TD in Preparatory Block 4 was significantly (p<.05) greater than Competition Blocks 1, 2 & 4 (figure 2). For TL, Competition Block 4 was found to be significantly lower (p<.05) than all other training blocks (figure 3). RTT in Preparatory Block 2 was found to be significantly lower (p<.05) than Competition Blocks 1, 2 & 4 (figure 4). While not reaching statistical significance there was a clear trend of higher RTT scores in the Competitive Blocks compared to the Preparatory Blocks.

Conclusion
This is the first study to quantify external TL (GPS), internal TL (RPE) and wellness markers (RTT) among an elite Gaelic football team across a complete season. It was found that Preparatory Blocks contained higher TL and lower RTT scores compared to...
Competitive Blocks. Careful planning and effective monitoring of these variables can assist in maximising athlete readiness to perform and provides a reference for coaches in the development of future training plans. An enhanced understanding of both external and internal training loads and the relationship between these variables has the potential to positively influence programme prescription into the future.

References


B.1 GPS Vest

B.2 GPS Units
C.1 Metrifit Athlete Daily Wellness login screen on the smartphone App

- **Mood State**: 3 - Less interested in others/activities than usual
- **Sleep Quality**: 3 - Reasonable/Just OK
- **Energy Levels**: Reasonable energy levels
- **Muscle Readiness**: Quite sore
- **Diet Yesterday**: Ate reasonably, some sugar/processed food intake, at least 1 serving of veg
- **Stress**: 3 - Reasonable / Just OK
- **Sleep Duration**: 
An asterisk (*) beside sleep duration indicates athlete has reported 6 or less hours sleep for the last 3 days.

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