A PROFILE OF SOCCER FOR ATHLETES WITH CEREBRAL PALSY AND TRAUMATIC BRAIN INJURY: *WITH SPECIAL REFERENCE TO CLASSIFICATION*

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PhD 2016

A PROFILE OF SOCCER FOR ATHLETES WITH CEREBRAL PALSY AND TRAUMATIC BRAIN INJURY: *WITH SPECIAL REFERENCE TO CLASSIFICATION*

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A thesis submitted in partial fulfillment of the requirements of the Manchester Metropolitan University for the degree of Doctor of Philosophy

Department of Exercise and Sport Science *the* Manchester Metropolitan University

2016

ABSTRACT

The aim of this thesis was to examine the performance characteristics of Paralympic 7-a-side soccer (CP soccer). Classification of eligible impairments is central to equitable competition and participation opportunities in Paralympic sport. Therefore the impact of classification was a focus throughout. A multi-disciplined approach helped establish a profile of CP soccer. Field-tests uncovered lower performance levels in elite CP players compared to those previously observed in elite able-bodied (AB) players. Inter-class contrasts identified that anaerobic tests discriminated between the least impaired class (FT8) and other eligible classes (FT5, FT6, FT7). FT8 players were capable of running faster, jumping higher, and were more agile. Time-motion analysis showed FT8 players also executed these actions, associated with game-defining moments, more frequently in matches. Technical analysis of soccer identified that FT8 players executed more passes, shots and dribbles than FT5-FT7 player but no inter-class differences were found for skill success rates. Overall, classes primarily defined by type and topology of CP (FT5-FT7 classes) exhibited overlapping performance capabilities. The mild severity of impairment that distinguishes the FT8 class and underpins their performance superiority poses a challenge for the classification process and equitable competition in the sport. A participation by-law exists to address this issue and complement the classification process. Despite restrictions to FT8 class participation, the by-law failed to neutralise FT8 players' superiority during match-play; notational match analysis revealed that FT8 players' involvement in goal scoring actions was disproportionately high. Analysis also indicated that goal scoring patterns in CP soccer differ from those previously observed in AB soccer. There are several applied and research implications from this thesis: knowledge derived from the performance data could facilitate CP soccer specific training, coaching and talent identification; future research development of valid strength and anaerobic activity tests could aid the classification process; and exploring alternative participation by-laws that uphold equitable competition, without restricting participation opportunities for eligible individuals, may be beneficial.

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ACKNOWLEDGEMENTS

I have met many people over the last few years that have helped to make this work possible. Although I am indebted to all, special notes of thanks are conveyed to the following:

My Director of Studies, Dr Alun Williams for his invaluable expertise, guidance, advice, encouragement, support, and most of all....... patience.

My supervisors, Dr Simon Eaves, Dr Chris Morse, and Mr Neil Roach for their priceless feedback that has contributed to this Ph.D. Without the whole team's motivation, support, time, high standards, and constructive criticism, I wouldn't have completed this.

The Football Association, ParalympicsGB and key men, Jeff Davis, Lyndon Lynch, and Ayser Hussain. Without whom I'd never have got to work with such great Paralympians who also volunteered as fantastic participants, thank you.

My unwavering, diligent proof-reader, and rock, Anna, there are probably mistakes on this page as this is the only section that hasn't been scrutinised by her critical gaze.

Finally, I would like to thank my friends who believed it would eventually 'get done'. I raise a glass to you all - Gail, Marcie, Zoe, Paul, Sarah, Steph, Clare, Vicky, Steve, Osman, Alan, Kate and Shea (although she only barked encouragement).

CHAPTER 1

INTRODUCTION

1.1 THESIS OUTLINE

Cerebral Palsy (CP) is a condition caused by a pre-natal brain lesion that impairs normal neuromuscular control. It is a non-progressive condition and causes a broad range of problems for the individual sufferer (Bax et al., 2005). Approximately 17 million people worldwide suffer from CP and it is the most common physical disability found in childhood (Odding et al., 2006). Symptoms can include issues with speech, cognition and learning difficulties but most apparent is the disruption to musculo-skeletal control. Individuals exhibit impairment that affects tone and strength of muscle action as well as joint range of motion, posture, ambulation and limb-to-eye coordination. Gross motor activities of daily living such as walking, sitting, climbing stairs and carrying items can be affected. Additionally, CP can affect primary and essential manual skills like writing, using cutlery, dressing oneself or catching a ball (Lemmens et al., 2014).

CP can present itself in several different forms. The spastic form of CP affects 70-80% of sufferers, while athetosis or ataxic forms of CP equally affect a further 12%. While it is not uncommon for individuals to experience a combination of all of these forms of motor inhibition, around 58% of individuals with CP are able to walk independently (Centre for Disease Control, 2015). CP can affect different parts of the body with individuals experiencing impairment in all four limbs (quadriplegic/bilateral), the lower limbs (diplegic/bilateral) or down one side of their body (hemiplegic/unilateral). With the severity of each form of CP and the varying regions of the body affected, the presentation of CP from one individual to another can be diverse, unique and ultimately, complex.

The relatively high prevalence of CP in the general population has led to athletes with CP becoming a formally recognised disability group by the International Paralympic Committee (IPC). The IPC recognises five disability groups that encompass 10 forms of impairment: Amputee; Spinal Cord Injury; Visually Impaired; Les Autres, and Cerebral Palsy & Traumatic Brain Injury being the broad groups of disabilities that comprise the Paralympic movement (IPC, no date).

The essence of sport is competition and, for it to have value, one-sided competition is to be avoided (Gill, 1993; Vallerand and Rousseau, 2001). Paralympic sports therefore, require the evaluation of eligible disabilities and the classification of the severity of impairments that are exhibited by athletes. The IPC has developed systems of disability classification to minimise the impact of impairment on the outcome of competition (Tweedy and Vanlandewijck, 2011). Classification is therefore at the heart of Paralympic competition and is fundamentally important as both a philosophy and process in order to ensure fairness and equity for all participants and thus promote sports participation.

The IPC classification system is an interrelated system, derived from the World Health Organization's (WHO) document *The International Classification of Functioning, Disability and Health* (2001) and sporting classification that is based upon selection classification criteria. Broadly speaking, the classification process involves acknowledging minimal eligibility criteria, the assessment of the severity of the impairment and an evaluation of the performance limitations the impairment causes in a given event. The spectrum of disabilities, the severity of impairment and the nature of specific sports means that each sport or event will possess its own classification criteria for competition based upon the definitions and guidance set out by the IPC (Tweedy and Vanlandewijck, 2011).

The importance of classification is further highlighted in a sport where athletes compete pan-disability or in mixed-classification, that is when athletes with different forms of impairment and different severities of impairment compete directly against one another. Within the Paralympic movement, team sports and games commonly adopt this approach where multiple events for each sport are not practical. The most notable examples are wheelchair rugby, wheelchair basketball and 7-a-side soccer (CP soccer). These sports employ a further level of governance to facilitate the aim of equity and fairness in competition. In these particular cases, the application of a participation by-law manages player involvement from different classes within matches.

FIFA, the world governing body of soccer, recognises two official forms of soccer, 11-a-side soccer and futsal (5-a-side soccer). There are many other variations of soccer and several versions for players with disabilities. Naturally, the type of disability often dictates the variations within the sport. 'Pan-disability' soccer is common at grassroots level to encourage participation by all. However, officially governed versions of the sport exist for amputees, visually impaired, chair-bound, and CP players through a number of independent governing bodies. Within the Paralympic Games however, only futsal for athletes with near total blindness and CP soccer for athletes with CP and traumatic brain injury (TBI) are official events.

The International Federation for Cerebral Palsy Football (IFCPF) governs CP soccer. This is a relatively recent change in governance with the Cerebral Palsy International Sports and Recreation Association (CPISRA) administrating the sport until January 2015. The sport of CP soccer operates in adherence to the Laws of the Game (FIFA, 2015) with some law modifications, and a disability class system that includes four eligible classes of CP and TBI impairment. The nature of mixed-class competition means IFCPF apply an additional participation by-law to manage the number of players from the most and least affected eligible classes. CP soccer is therefore very different from either of the two officially recognised forms of soccer for AB players.

Soccer is arguably the most researched sport found within the literature across the breadth of sport science disciplines. Although there is empirical work focusing on tactical, technical and physiological aspects of soccer exhibited in AB soccer (Reilly and Thomas, 1976; Ekblom, 1986; Bloomfield et al., 2004; Bangsbo et al., 2006; Dellal et al., 2010) there is scant empirical data focused upon CP soccer. The vast amount of literature in AB soccer has increased the understanding of the demands of the sport and almost certainly informed changes in all aspects of coaching and preparation for match-play at all levels. However, given the uniqueness of CP soccer, it is questionable that the application of AB data to CP soccer is valid. The constraints characteristic of CP soccer, imposed by virtue of the modifications to the laws of the game, application of IPC classification of players and the by-laws for participation, suggest that it would be unwise to consider that the sport functions like 11-a-side soccer or futsal for AB players.

For sports to effectively and strategically develop, an evidence-based approach is essential. Governing bodies, coaches and sport science practitioners benefit greatly from scientifically derived knowledge regarding the dynamics of their sport, although the process has taken time to develop in many sports, including soccer (Gilbourne, 2000). Value exists in transferrable information from sister sports but understanding the specific dynamics of a sport is preferred for the development of players and teams (Reilly and Gilbourne, 2003). From talent identification, physical training and nutrition and skill development through to mental preparation and tactical team play, a sport's development benefits from focused sport-specific research. It is this level of insight and understanding that provides the confidence for practitioners to advance their teams and players toward high performance.

The dearth of research in CP soccer and the unique nature of the sport have resulted in the situation where a number of interrelated questions are yet to be addressed. The most apparent are those fundamental questions that are being answered by extensive research in, and for, AB soccer. However, a unique characteristic of CP soccer remains the central pillar of Paralympic sport, disability classification. The interesting issues are the performance capabilities of athletes with impairments in a sport where extensive evidence already exists but is not established in this specific form of soccer. Consequently, the following research questions arise.

1.2 RESEARCH QUESTIONS

Generic research question:

What are the performance characteristics of Paralympic CP soccer and soccer players with cerebral palsy and traumatic brain injury?

Specific research questions:

What are the physiological capabilities and anthropometric profiles of CP players?
How does match-play influence players' performances?
What are the technical actions of the players?
What form does match-play take?
What contrasts exist between the competing Paralympic classes?

1.3 AIMS

i. To describe four key areas of performance in elite Paralympic CP soccer in order to establish the first evidence-based profile of the sport and its players.
ii. To identify contrasts between players of different Paralympic class.
iii. To provide evidence-based information relevant to practitioners working in Paralympic CP soccer to improve performance and advance the sport

1.4 PRÉCIS OF THE CHAPTERS

The research described here takes a multidisciplinary approach in order to profile CP soccer and its players. The following chapters address these aims and a summary of their content is provided here.

In Chapter 2 a literature review of relevant topics is presented. The condition of cerebral palsy and other neuromuscular impairments eligible in CP soccer is examined in relation to the physical and biomechanical implications. Paralympic classification is discussed and issues are highlighted. Aspects of AB soccer and CP soccer are discussed, while methodological approaches and knowledge derived from associated research areas to this thesis are appraised. In Chapter 3, the physiological and anthropometric profiles of CP players are investigated. This study is a field-based examination of elite players, their profile and capacities. A time-motion analysis of CP player activity in match-play is addressed in Chapter 4. Here, the players' physical performance data in an international tournament is the focus of the investigation. The technical (Chapter 5) and tactical (Chapter 6) aspects of CP soccer are then examined. Notational analysis is employed analysing the 2012 Paralympic CP soccer tournament, in which players were analysed for their execution of key performance indicators (KPIs) relating to technical skills and their level of involvement in team play. The sport is described in terms of the patterns of play leading to a goal.

Throughout, discussion refers to the unique players that participate in CP soccer as a function of their Paralympic classification. Finally, Chapters 7 and 8 discuss then draw conclusions from the preceding studies, synthesising relevant findings in order to address the research questions and the aims set out in sections **1.2** and **1.3**.

CHAPTER 2

LITERATURE REVIEW

2.1 CEREBRAL PALSY AND RELATED NEUROLOGICAL CONDITIONS

Cerebral palsy (CP) is not a single entity, but a homogenous term used to describe several conditions of posture and motor impairment. CP is a non-progressive disorder that results in pre-natal damage to the brain and spinal cord, impairing the neural impulses from which voluntary movement originates (Myklebust et al., 1982; Bax et al., 2005).

CP is the most common paediatric, physical disability (Odding et al., 2006), with a spectrum of symptoms evident across individual sufferers. The secondary physical impairments associated with the condition are shared with a number of post-natal neurological conditions and traumatic brain injuries (TBI). This section discusses the types and assessment of associated motor impairment, and considers subsequent issues for movement, coordination and fitness of individuals who live with the conditions.

2.1.a Motor impairments associated with CP and TBI

CP and TBI are umbrella terms. CP is a consequence of oxygen deprivation in the developing foetus that leads to damage to different parts of the brain, such as the basal ganglia, motor cortex and the cerebellum (Graham and Selber, 2003). Contrastingly, TBI can result from numerous acute or chronic lifestyle events, and leads to similar lesions in the same regions of the brain. Conditions that commonly lead to a diagnosis of TBI include, stroke, Friedreich's ataxia, Kugelberg Weylander Syndrome, Fahr’s Syndrome, spinocebellar degenerative disorders, Parkinson's disease and acute head injuries (CPISRA, 2011).

Both conditions impair central nervous system function by decreasing input to the reticulo-spinal and cortico-spinal tracts from the cerebral cortex, and create hyper-excitability within motor neurons (Sheean, 2002). The effects on motor control are due to a reduced number of motor unit innervations and subsequent reduction in proprioception, resulting in muscle weakness and abnormal control of musculo-skeletal actions (Damiano and Abel, 1998). Inhibitions affecting range of motion (ROM), balance, posture and coordination are common problems associated with the conditions. The long-term effects of such dysfunction can include bone deformities and muscle atrophy that make postural and movement corrections difficult later in life (Burtner et al., 1998).

Disorders associated with CP and TBI are classified by type and topological distribution and the severity of the disorder varies between individuals (Graham and Selber, 2003). There are three types of motor impairment: athetosis, ataxia, and spasticity. Spasticity is the most prevalent (70-80%), while athetosis and ataxia are considerably less common (both 6%) (CDC, 2015). Spasticity is a velocity dependent condition, where agonist and antagonist muscles experience hypertonia and co-contraction that leads to reduced ROM and sometimes bone deformities and postural issues (Sanger et al., 2003). Ataxia presents itself as shaking and twitching and can lead to problems with balance and sense of positioning in space. Athetosis is characterised by uncontrollable movements, hypertonia and hypotonia, which lead to problems with coordination of fine motor tasks.

All three types of motor impairment can present themselves in all body parts. Quadriplegia denotes impairment that affects all four limbs, while diplegia describes impairment of the lower limbs, and hemiplegia describes impairment of limbs on one side of the body. In the case of diplegia and hemiplegia, some impairment may still be evident in the upper limbs or opposite side of the body, respectively, but this is minor in comparison. Some individuals suffer from a combination of symptoms (often termed mixed-CP), but the most common is spastic hypertonia in hemiplegic, diplegic and quadriplegic states (Graham and Selber, 2003). The presence of varying types, severities and combinations of CP in different regions of the body poses a significant challenge for clinicians assessing motor impairment (Rosenbaum et al., 2006).

The extent of the impairments CP and TBI present is clinically assessed using several different international scales, most notably the Gross Motor Function Classification System (Palisano et al., 1997) and the Ashworth Scale or Modified Ashworth Scale (Bohannen and Smith, 1987).

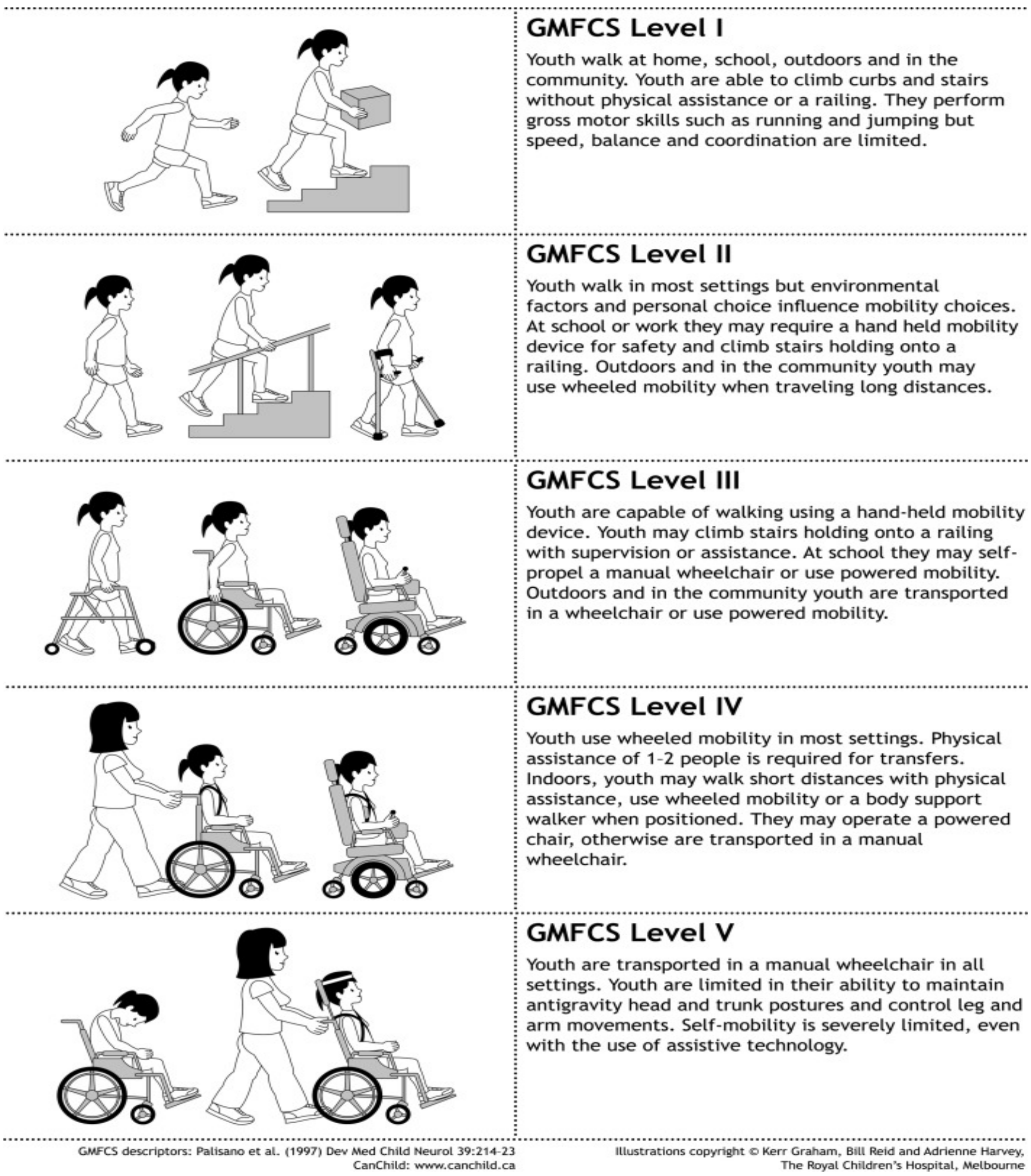

Figure 2.1 Gross Motor Function Classification System (reproduced from Palisano et al., 1997)

The Gross Motor Function Classification System (Figure 2.1) is widely used in clinical settings to describe and evaluate the impact of CP in children. It assesses the functional and practical implications of CP, rather than impairment type and severity, so an individual's classification can change over time. Level I describes the mildest impairment that permits unaided walking, stair climbing and carrying of objects, while Level V is the most severe impairment, characterised by permanent chair-bound living and problems with posture that require supporting orthopaedic aids. This scale tends to favour assessment of the lower limbs and is less effective when assessing upper limbs (Rosenbaum et al., 2006). Gross Motor Function Classification System provides a useful occupational health evaluation but does not aim to specifically identify antecedents for an individual's capabilities.

In contrast, the Ashworth Scale and Modified Ashworth Scale specifically assess muscle spasticity (Bohannen and Smith, 1987). They evaluate passive resistance to a velocity dependent stretch and are qualitative and ordinal in nature. The assessments use physical palpation and passive movement through the range of the affected joint, while monitoring the resistance to movement (Table 2.1).

These are not direct alternatives to the Gross Motor Function Classification System; moreover they purport to qualitatively assess spasticity, rather than whole body movement capability. Work by Damiano et al. (2002) and Pandyan et al. (1999) have shown that, compared to quantified passive resistance using isokinetic dynamometry, the Ashworth Scale provides a less consistent relationship with passive resistance, and that dynamometry is a more valid method of assessment. Inconsistencies also exist between the original Ashworth Scale and the modified version by Bohannen and Smith (1987), and both are vulnerable to inter and intra-assessor discrepancies (Clopton et al., 2005; Pandyan et al., 1999).

Table 2.1 Ashworth and Modified Ashworth Scales (Bohannen and Smith 1987)

Score	Ashworth Scale (1964)	Modified Ashworth Scale (1987)
0 (0)	No increased tone	No increase in muscle tone.
1 (1)	Slight increase in tone catch when limb moved.	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when affected part(s) is moved in flexion or extension.
1+ (2)		Slight increase in muscle tone manifested by a catch, followed by minimal resistance throughout the remainder of the ROM.
2 (3)	Marked increase in tone limb easily moved.	More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved
3 (4)	Passive movement difficult.	Considerable increase in muscle tone, passive movement difficult.
4 (5)	Limb rigid.	Affected part(s) rigid in flexion or extension

2.1.b Assessing motor impairment associated with CP and TBI

In attempting to establish criteria and norms for classifying gait, several approaches have been taken. Studies have used EMG (Winters et al., 1987; Kadaba et al., 1991) and 2D and 3D kinematic and kinetic analysis (Rodda et al. 2004; O'Byrne et al., 1998). Dobson et al. (2006) suggested however, that there are issues with creating reliable classification of CP gait, and that these are attributable to some key discrepancies. Sample sizes have been variable and of convenience, single-plane analysis has been prevalent, despite the condition affecting movement in all planes, operational definitions have been missing or vague, and reliability testing has often been omitted. Consequently, conflicting classifications have emerged. Simon et al. (1978) used n=15 and categorised gait into three classes, whereas Kadaba et al. (1991) included n=30, and categorised gait into 10 classes. Although Winters et al. (1987) and Hullin et al. (1996) used the same methods of gait analysis, the studies concluded that there should be 4 and 5 gait categories, respectively. Additionally, Winters et al. (1987) did not provide statistically significant support for their defined classes. Kadaba et al. (1991), O'Byrne et al. (1998) and Hullin et al. (1996) omitted reliability testing and failed to provide clear operational definitions. Methodological differences combined with the complexity of the conditions pose significant barriers to valid and reliable classification of CP and TBI impairment. Agreement is therefore a challenge for clinicians.

2.1.c Muscle function issues associated with CP and TBI

Spastic-affected muscle exhibits stiffness, due to heightened co-contraction of the agonist-antagonist (Poon et al., 2008). Hypertonia in paired muscles reduces ROM and movements become jerky and uncoordinated. When the impairment affects multiple joints to different degrees, asymmetrical gait is common (Alhusaini et al., 2010; Barber et al., 2011). Although the root cause does not alter, without activity, and over time, secondary musculo-skeletal issues can worsen, muscles become weak, the muscle-tendon structure is altered, becoming fibrous, and atrophy occurs in affected limbs (Hanna et al., 2009).

The functional issues apparent in individuals with CP or TBI are a consequence of three key characteristics: smaller cross sectional muscle area, decreased agonist activation, and changes in activation patterns (Hussain et al., 2014). The consequence is reduced force generation in the affected limbs. Hussain et al. (2014) showed a six times higher level of co-activation in paretic gastrocnemius muscle, compared to non-paretic and controls, in adults with hemiplegic spastic CP. Poon et al. (2008) presented similar findings in children (two to three times higher co-activation in plantar / dorsiflexors). Both research groups showed weakness in these muscles. However, Ross et al. (2001) and Anderson et al. (2003) demonstrated that spasticity is not the only factor affecting strength; showing that increases in strength in children with CP, with no increases in spasticity, are possible through training. Furthermore, the reduction of spasticity through surgical procedures did not lead to improvements in strength.

Ultrasonography has revealed muscle architecture differences between affected limbs, non-affected limbs and controls. Mohagheghi et al. (2007) compared typically developing limbs with spastic, hemiplegic CP non-paretic and paretic limbs. They demonstrated a difference in-vivo in gastrocnemius muscle volume, muscle length and fascicle length across the groups during resting ankle dorsiflexion. Subsequently, the reduced fascicle length neurologically affects muscle recruitment and is exacerbated by the velocity-dependent nature of the impairment (Goldstein, 2001; Burtner et al., 1998). Leiber et al. (2004) also cited shortened fibre-length in spastic muscle as the single most important characteristic affecting force generation.

2.1.d Responses to physical activity and training in CP and TBI

Most CP research has been conducted in paediatric populations, with limited work on adults and trained athletes. Nevertheless, research has shown that impaired gait poses significant issues for individuals with CP or TBI. Unnithan et al. (1996) showed a three times greater energy cost for children with CP during walking activity. Keefer et al. (2004) reported similar issues, while Bar-Or and Rowland (2004) suggested that the lower economy leads to early onset of fatigue, and increased fatigue, and that the higher energy costs mean a reduced metabolic reserve (Unnithan et al., 2007). In able-bodied (AB) individuals, exercise induced fatigue is also detrimental to balance and gross motor coordination (Nardone et al., 1997). This is more pronounced in persons with spastic CP, with neuromuscular control temporarily affected by heightened levels of spasticity (Heller et al., 2002). The greater reliance upon vestibular and visual information (Damiano and Abel, 1998) means that head movements during dynamic actions disrupt this information, exacerbating balance issues. Anaerobic performance has also been examined in children with CP. Wingate Anaerobic Tests (WAnT) have shown capacity for work to be two to four SDs lower than in AB children, with studies reporting that CP children display a 27-46% deficit in peak power output (Balemans et al., 2013; Verschuren et al., 2010; Parker et al., 1992).

Although CP and TBI are permanent disabilities, the secondary impairments can respond to training. Studies have shown improvements are possible in strength, ROM, and aerobic capacity for individuals with CP or TBI (Millet et al., 2002; Nordmark et al., 1997; Engsberg et al., 2000; Zhao et al., 2011). Verschuren et al. (2007) found that anaerobic capacity (25% increase) and agility (15% increase) could be improved through focused training over an eight-month schedule. Similarly, Damiano et al. (1998) demonstrated that strength gains in hemiplegic children reduced the asymmetrical nature of impairments. Post training differences between affected and unaffected side was 24%, in comparison to pre-training differences of 45%. Unnithan et al. (2007) conducted a 12-week training study, demonstrating that combined strength and aerobic training can improve arm-cranking performance. Here, reductions in O_2 cost and improved gross motor function in children with CP were evident, while Balemans et al. (2013) showed that aerobic capacity was lower than in AB children, but interestingly, did not find differences across the Gross Motor Function Classification spectrum. In contrast, WAnT over 20 s identified differences between children across the Gross Motor Function Classification spectrum. Earlier, Parker et al. (1992) examined upper and lower limb WAnT performance in children with CP, also reporting differences between severities of CP for anaerobic work. These studies suggested that economy of movement could be key to improved physical capability, which is most detectable in anaerobic based activity.

2.1.e Summary of cerebral palsy and associated neurological conditions

This section has highlighted that there are three distinct secondary motor impairments associated with the umbrella terms CP and TBI. The most common of these is spastic motor impairment, which presents significant ROM, postural, coordinative and strength issues, due to heightened co-contraction of the agonist and antagonist muscles, smaller muscle cross sectional area and alterations to muscle architecture. The diversity in the severity and topology of the conditions illustrates that CP and TBI can present in very different ways across individuals. This, in turn, poses significant challenges for clinicians in agreeing impairment classification.

Movement dysfunction is the most apparent issue and results in early onset of fatigue for many CP and TBI individuals. Fatigue, due to neuromuscular impairment, can manifest itself in a similar fashion to AB individuals, where coordination, balance, and metabolic capacity become compromised. Although CP and TBI are permanent, non-progressive conditions, the neuromuscular system retains a degree of plasticity and is adaptable to training stimuli. Studies have shown that improvements are possible in strength and ROM, leading to more efficient gait and increased capacity for physical activity through lower relative energy cost.

2.2 PARALYMPIC CLASSIFICATION

The central tenet to fair and equitable competition in Paralympic sport is a classification system that permits individuals with eligible impairments to compete against others of similar functional ability. This section discusses the principles and applications of classification that pertain to Paralympic sport and key issues surrounding participation in CP soccer.

2.2.a Classification of impairments and assessment of limitation

Olympic and Paralympic sports alike must protect against uneven or unfair competition. Participation, interest, growth and excellence in sports are threatened by undesirable determinants and therefore, classification is employed to minimise any impact these may have on sporting performance. Classification is a process whereby a group of entities are given order into a number of smaller units (or classes) (Bailey, 1994). Two main forms of classification exist. *Performance classification* orders competitors by ability level, such as divisional competitions in soccer so teams compete against other teams of similar ability. Alternatively or sometimes in tandem, sports are classified by age, sex or body mass; this is termed *selective classification,* which is used to prevent these variables pre-determining the outcome of performance (Tweedy and Vanlandewijck (2011).

Paralympic sports must consider permanent physical and cognitive impairment as additional determinants of performance; as such, *selective classification* is utilised, to reduce the determinism associated with impairments of different types and severities (Tweedy and Vanlandewijck, 2011). This, in turn, means that performance variability should be relative to the impact of desired factors, such as training status, psychological skill and tactical ability *(IPC, no date).*

The IPC recognises ten impairment types, eight of which are physical (IPC, no date): impaired muscle power; impaired passive range of movement; limb deficiency; leg length difference; short stature; hypertonia; ataxia; athetosis; visual impairment; and intellectual impairment (see APPENDIX A.1 for full details). These impairments originate from five disability groups:

Amputee; Spinal Cord injury; Visually Impaired; Les Autres; and Cerebral Palsy and Traumatic Brain Injury.

Historically, limb deficiency, spinal cord injury and brain or neuromuscular impairments were separated from each other, and individuals were assigned to a single class for all sports; this reflected the rehabilitation structure within hospitals (Howe, 2008). Early forms of Paralympic sport would place two wheelchair-bound individuals possessing the same limitation of activity in separate competitions, if their impairment was different. Moreover, if individuals participated in different sports, their competitive class would not change, even though the impact may be more or less severe in different sports.

As the Paralympic movement developed, a functional classification system replaced the initial medical classification (Tweedy and Howe, 2011). The main focus in functional classification is the assessment of how much the impairment impacts sports performance. In functional classification, a double-leg amputee and a spinal cord injured athlete (with a lesion at lumbar vertebrae 2 (L2)), both wheelchair-bound, would have similar impairment and therefore be similarly limited in wheelchair propulsion; they could therefore compete against each other in wheelchair racing. Moreover, impairment may have a great effect in one sport, but a lesser effect in another. Consequently, the IPC has adopted '*sport-specific functional classification'*, tailored to the demands of individual sports (Tweedy, 2002; CPISRA, 2011).

Paralympic sports are either governed directly by the IPC or by associated federations overseen by the IPC (Reina, 2014). As functional classification is sport-specific, governing bodies are responsible for their sport's classification process, but all must adhere to the basic principles set out by the IPC. To assist with classification, the IPC has adopted a framework and language, derived from the World Health Organization's (WHO) 'International classification of functioning, disability and health document' (ICF) (WHO, 2001).

The ICF provides a common language for classifying individuals with health conditions, their ability to function in a standard environment (i.e. level of capacity), and what they do in their normal environment (i.e. level of performance). '*Disability'* is an umbrella term used for body impairments, activity limitations and participation restrictions. '*Functioning'* is a broad term that refers to body function, activities and participation, while '*impairment*' describes the extent and type of an individual's permanent physical or cognitive state. Finally, the term '*limitation'* infers the extent to which the '*impairment'* affects sporting performance (WHO, 2001).

Classification systems should describe:

(1) the minimum eligibility criteria, in terms of *type* and *severity* of impairment,

(2) the methods of classifying eligible impairments, in relation to the extent of the limitation they cause in an activity

(Tweedy and Vanlandewijck, 2011)

2.2.b Classification in CP soccer

Paralympic 7-a-side soccer offers participation opportunities for individuals who are eligible for one of the Paralympic classes C5 to C8 (specifically in soccer: FT5; FT6; FT7; FT8). The inclusion criteria encompass neurological impairments only, which lead to secondary symptoms of spastic hypertonia, athetosis, ataxia and dystonia (mixed-CP). To be eligible, the condition must elicit coordinative or strength impairments, originating from the brain, causing a permanent and verifiable activity limitation. The level of neurological impairment associated with these conditions must disadvantage athletes, in the context of competing in high performance AB sport (CPISRA, 2011; IFCPF, 2015). CP soccer caters for a spectrum of impairments that have three distinct components: type, topology and severity. As such, the assessment to assign impairment to one of the four eligible classes must account for each component. Table 2.2 outlines the basic governing descriptors for each class. APPENDIX A.2 gives more full descriptions of each class.

The eligibility criteria describe impairment type, topology and severity. FT5, FT6 and FT7 classes are fundamentally based on the type of impairment and topology that is most apparent and these could be considered 'natural' classes. The severity of impairment in these classes is considered to be moderate (Grade 2-3); more severe impairments are not eligible in CP soccer, as they limit individuals to wheelchairs, walking frames or crutches (C1-C4). The FT8 class accommodates all forms of eligible impairment that limit activity function described in FT5-FT7, however the impairments are minor (Grade 1-2). Severity is key to the assignment of an impairment to FT8, so a linear relationship exists between FT8 and each of the other classes. This is not the case between FT5, FT6 and FT7, where the dominant type / topology of impairment governs assignment to a discrete class.

Table 2.2 Paralympic 7-a-side soccer classes and basic descriptors of limitation for eligible impairments (Reina, 2014)

Class	Impairments eligible	Description
FT5	Diplegia, assymmetric diplegia, double hemiplegia, dystonia.	Moderate involvement with spasticity grade 2-3; involvement of both legs, which may require splints/orthotics for walking; asymmetric diplegia or double hemiplegic athlete, with involvement on both sides, where lower limbs more affected than upper limbs. Athletes with dystonia, where the lower limbs are most affected.
FT6	Athetosis, dystonic, ataxic or mixed cerebral palsy or TBI	Moderate involvement in all four limbs; athlete ambulates without assistive devices, but may need orthotics/splints; athetosis, dystonia or ataxia is most prevalent, but sometimes evident issues with ataxia mixed with spasticity; athletes with dystonic athetosis in all four limbs belong here, unless impairment is minimal.
FT7	Spastic hemiplegic	Grades 2-3 in one half of the body; walk/run with a limp due to lower limb spasticity; hemi gait pattern 2, 3 or 4 as per grouping described in Winters et al., (1987). Usually a good functional ability on the other side.
FT8	Diplegia, asymmetric diplegia, double hemiplegia, and/or dystonia.	Hemiplegia with grade 1-2, monoplegia with spasticity grade 1 or 2 in major lower limb joints; athetosis, dystonia, ataxia or mixed cerebral palsy or other neurological conditions.

2.2.b.i The classification process – During classification, all players undergo four stages of assessment conducted by a multi-disciplined team of accredited classifiers, including medical doctors, physiotherapists and tertiary trained physical trainers (Tweedy and Vanlandewijck, 2011). The first stage involves clinical diagnosis of a health condition that leads to an eligible impairment (IPC, 2015). During stages two and three, the player must exhibit impairments cited in Table 2.2. Techniques used to establish the impairment eligibility involve muscle strength testing, joint ROM tests, and the use of the Ashworth

Scale for hypertonia (IPC, 2015). Coordination tests are also employed, but vary in usage and type and are not fully detailed in the literature.

The final stage of classification involves determination of the final Paralympic class. The severity of impairment and the functional capacity for the sport are established here. Some tests are functional yet novel, while others are sport specific. The novel tasks comprise movements that are unlikely to have been practiced and are therefore discriminatory with regard to limitation extent. Sport specific tasks include activities such as sprinting, stopping, turning, checking, jumping, landing and controlling a ball (Reina, 2014). Final observations are made during competitive match-play, where assessors must agree upon the final class assignment and ensure the in-competition evaluation agrees with assessments made in stages two and three of the process (CPISRA, 2011; IFCPF, 2015).

2.2.b.ii The absence of objectivity in testing – The IPC Position Stand on Classification in Paralympic Sport (Tweedy and Vanlandewijck, 2011) states that impairment assessment measures should be: objective; reliable; precise; specific to the impairment; and resistant to training. Assessment tests should focus on a single impairment type, accounting for the greatest range of variability in performance and assess complex movement simultaneously. A valid, quantifiable test battery also reduces reliance upon the subjective opinions of classifiers (Tweedy and Vanlandewijck, 2011), and validated tests should provide norms, ranges and regression equations that permit future guidance on classification. Furthermore, sports should strive toward developing evidence-based classification systems (IPC, 2015).

Most apparent in CP soccer is the wholesale absence of evidence-based, objective tests and normative data for the four eligible classes. All classification tests conducted in CP soccer are descriptive and qualitative in nature, and the experience of the classifier and the dialogue between classifiers are crucial aspects, to ensure reliability in classification.

2.2.b.iii Issues with impairment tests - Difficulties materialise during the second stage of classification, when assessing strength, coordination and motor control (Reina, 2014). Manual muscle testing in CP soccer is based on the Ashworth Scale for spasticity, although several authors have cited inherent subjectivity and suggest caution with its use (Pandyan et al., 1999; Bohannen and Smith, 1987). Assumptions regarding the passive resistance to joint ROM relationship underpin Ashworth's 6-point grading system for spasticity, but these do not consider other factors that can affect muscle stiffness, such as velocity of movement, ROM starting point and limb segment position during testing. Furthermore, Tweedy et al. (2010) suggested that muscle testing could suffer from inter-rater reliability issues, as muscle activation limitation is not strongly associated with muscle testing outcomes. This creates difficulties with linking measures of impairment to measures of performance. Tweedy et al. (2010) suggested five key modifications that would attenuate reliance upon classifier skill in manual muscle tests: restrict tests to those that assess actions in the sport; avoid testing movements not relevant to the sport; standardise a single test technique for movement strength; a movement should only cater for the joint ROM required for the sport; and finally, utilise body positions during testing that reflect those common in the sport.

Validation of quantifiable tests for classification is evident in other Paralympic sports (Vanlandewijck et al., 2004; Beckman and Tweedy, 2009; Vanlandewijck et al., 2011; Beckman et al., 2014; Connick et al., 2015; Beckman et al., 2016), and some of these could be useful for the assessment of strength, coordination and ROM assessment in CP soccer players. Beckman and Tweedy (2009) developed a battery of tests for running in track and field athletics. Five supplementary tests (standing broad jump, four bounds for distance, 10 m speed skip, running in place and split jumps) underpinned the performance test of a flying 30 m sprint, to establish AB norms and relationships between tests. The supplementary tests isolated physical elements that explain variance in running performance. Standing broad jump, and four bounds for distance (r = >.80) were strongly correlated with the criterion measure (with 75% explained variance), while split jumps, speed skips and running in place showed weaker relationships, but these may be stronger in individuals with hypertonia, ataxia or athetosis.

2.2.b.iv Soccer-specific tests - Sport-specific functional tests should also feature in classification (Tweedy and Vanlandewijck, 2011), but objective and quantifiable tests have so far proved elusive for CP soccer. Unfortunately, several CP soccer studies have been conducted without addressing what would seem a crucial aspect of mixed-classification Paralympic sport: inter-class differences (Andrade et al., 2005; Kloyiam et al., 2011; Camara et al., 2013; Yanci, 2015 and Yanci et al., 2016). This has left the sport without a database of sport-specific functional capabilities for each class.

Reina et al. (2016) did analyse inter-class differences when examining CP players' performance in the Illinois Agility Run and Modified Agility Test. They also aimed to establish validity and reliability of the tests for use in classification. A performance distinction was established between FT8 and the other classes, but not between FT5, FT6 and FT7. Findings suggest that the classes, differentiated by types of impairment, may overlap in functional capability. The study sample was drawn from elite players representing national teams, but in order to establish validity, tests must be able to discriminate across the full range of eligible impairments, not just those evident at the highest level (Tweedy and Vanlandewijck, 2011). The data showed a good degree of reliability (ICC = 0.82-0.95 and SEM = 2.5-5.8%), but also a high co-efficient of variation (CoV) within individuals. A large CoV could make interpretation of true capability difficult, or alternatively, enrich the information for a classifier. However, with only two trials per participant, further work with more diverse samples would be required to establish the validity of the tests, before their implementation as classification tools.

Like Reina et al. (2016), Molik et al. (2010) assessed inter-class differences in anaerobic performance. They examined wheelchair basketball players, comparing the functional classes in an arm crank WAnT. They found that classes were not distinguishable from adjacent classes. In fact, individuals in functional classes 1 to 2.5 (4 classes) showed no differences in mean power, peak power and fatigue index, and nor did participants in classes 3 to 4.5 (4 classes). When grouped together, differences were evident between classes 1-2.5 (more impaired) and classes 3-4.5 (less impaired), with the latter group having greater mean power and peak power, but also a greater fatigue index. This study showed that the less impaired classes were more capable, but also more susceptible to performance declines. Although the results suggest that the classes are not 'balanced' in terms of functional limitation, they concurred that classes can overlap in capability. Morgulec-Adamowicz et al. (2011) also highlighted inconsistent contrasts between classes in wheelchair rugby. Once again, the functional classes were not different from adjacent classes, only from classes one removed or more. It was noticeable that, like Molik et al. (2010), anaerobic tests were more sensitive to contrasts between classes than aerobic testing. Findings by Morgulec-Adamowicz et al. (2011) were consistent with Hutzler et al. (1998) and Bhambani (2002), where differences were only evident between the highest and lowest functional classes. Vanlandewijck et al. (2004) observed inter-class contrasts, focusing on players' technical and tactical skills, showing that higher functioning players performed better than lower functioning players in skills deemed important to the game (shots, rebounds, dribbles, interceptions). They also concurred that adjacent classes were not statistically different from each other.

DeGroot et al. (2012) also considered skilled actions in classification testing. These researchers conducted a battery of field tests for wheelchair basketball, and were able to confirm the validity of speed-based tests in discriminating between classes, but questioned the use of skill-based tests, due to poor reliability and the absence of differences evident in passing and shooting. Mason et al. (2010) concur with this, and cite numerous factors that affect skilled performance, such as training status and years of experience, adding that such tests cannot truly assess physicality alone.

2.2.b.v Referral to classification descriptors - The outcomes of physical and sport-specific tests in CP soccer classification can be referred to the Guidance for Classification (CPISRA, 2011; IFCPF, 2015). This document should provide a seamless, objective continuum of criteria to make classification judgments, but descriptors of functional impairments are ambiguous and inconsistent (Reina, 2014). Class descriptors regarding balance ability effectively illustrate this; static and dynamic balance is mentioned in FT5 and FT6 class descriptors, but not FT7 and FT8 (CPISRA, 2011; IFCPF, 2015).

Furthermore, what constitutes functionality in movements is poorly defined; terms such as 'normal', 'good' or 'better' are common. This places further reliance on classifiers' experience, and their expertise becomes a critical factor in final class assignment. The most contentious decision is whether impairment is sufficiently minor to be assigned to the FT8 class, or sufficiently severe to be allocated to FT5, FT6 or FT7 class (Reina, 2014). The thresholds of severity between FT5, FT6 or FT7 and FT8 theoretically form linear relationships, but in reality, they remain qualitative. Reina et al. (2013) previously cited difficulties in establishing a cut-off point between FT8 class and the other classes, and this poses an increased risk of incorrect impairment classification. Incorrect classification could affect the participation opportunities afforded to an individual, as CP soccer operates with a participation by-law to manage issues associated with mixed-classification competition. Section 2.3.c.ii explores this issue in more depth.

2.2.b.vi Match-play observations as an assessment tool - In the final stage of classification, players are assessed in competitive matches, to ascertain the extent to which limitations observed in previous stages of assessment manifest in the sport itself (CPISRA, 2013; IFCPF, 2015). Classifiers should be able to confirm their opinion from the previous stages and determine a final class. However, some researchers contest the merits of this aspect of classification. Higgs et al. (1990) suggested that statistical differences between the classes should be evident, and that sport-specific skilled performance should be measurable. In CP soccer, this would involve consideration of dribbling, tackling, passing and shooting, as they depend upon strength, speed, agility and endurance, with the latter physical aspects affected by impairment. Strohkendl (2001) however, suggested that only physical performances (aerobic, anaerobic, power, agility etc.) should be assessed; not sport-specific skill, as only physical impairment is to be classified.

The dynamic nature of soccer means individual's match performance is not merely grounded in their physical capability, but also their skilled behaviour (Grehaigne et al., 1997; McGarry et al., 2002). In turn, skilled performance is not solely dependent on physical capability, as skills are inextricably linked to visual perception, decision-making, and a player's own sense of affordances (Abernethy, 1987; Reilly et al., 2000a; Davids et al., 2013). Highly skilled players make appropriate decisions about actions they believe they can execute successfully, while avoiding actions they perceive to be too risky (Williams, 2000). Some CP soccer players, who have suffered life changing TBIs, may have trained for and competed in AB sport prior to acquiring their disability (UK Sport, no date). It is likely that previous experience would facilitate more refined decision-making and appropriate skill selection (Williams, 2000; Mason et al., 2010). As such, the ease at which individuals seem to execute skills is not necessarily indicative of physical impairment or subsequent physical limitations.

The contamination of physical performance by skilled behaviour is a problem for classifiers attempting to be objective in finalising classification. There is little empirical data on match-play in CP soccer (a single study by Yanci (2015)), and no literature on the extent to which physical impairment affects match performance or skilled actions. Therefore, it may be difficult for classifiers to objectively distinguish other contributory aspects of performance from the physical limitation they seek to evaluate. Classifiers should be mindful of this and not unduly classify players to the 'milder' impairment class of FT8, if the neurological impairment is more severe and truly warrants classification into FT5, FT6 or FT7.

2.2.c Summary of Paralympic classification

Current classification guidelines place classifiers' level of experience and expertise at the centre of the process. Guidelines for assessors do not provide clear criteria for the cut-point issues that arise when determining final classification. Although the IPC stresses the importance of objective, evidence-based tests and normative profiles, these do not currently exist in CP soccer. Limited studies have attempted to validate sport-specific tests, although isolated impairment tests do exist in other sports and may be transferable. Confounding factors must also be considered, in order to establish objective classification: training status, misrepresentation of physical state, and motor-control factors that contribute to skill execution. These issues inevitably threaten Paralympic sport’s desired fair and equitable competition.

Paralympic classification is not the only governance of participation in CP soccer. Due to the mixed-class nature of the sport, management of class involvement is required, to ensure fairness. The issues and implications for performance surrounding the specific laws and by-laws of CP soccer are discussed in the next section, as part of a review of the demands of CP soccer.

2.3 PARALYMPIC 7-A-SIDE FOOTBALL (CP SOCCER)

CP soccer is a version of the official FIFA sanctioned 11-a-side soccer, with Paralympic classes FT5, FT6, FT7 and FT8 eligible to participate (CPISRA, 2013). This section examines the laws and by-laws of the sport, the current literature available in CP soccer, with regard to match-play characteristics, player attributes, and comparative literature in AB soccer.

The International Federation of Cerebral Palsy Football (IFCPF) has governed CP soccer since January 2015; previously, governance was the responsibility of the Cerebral Palsy International Sports and Recreation Association (CPISRA). The IFCPF currently works under the umbrella of the International Paralympic Association (IPC). The IFCPF's responsibilities are to ensure the CP soccer's integrity for fair and equitable competition, facilitate its growth and development, and delineate the official rules of the sport. CP soccer is a small-sided game (SSG) adhering to the FIFA Laws of the Game (FIFA, 2015), with some notable modifications and additional IFCPF by-laws regarding player class participation.

2.3.a. Laws of the Game and by-laws of CP soccer

2.3.a.i Laws of the Game - CP soccer is a 7-a-side game; six outfield players and a nominated goalkeeper. Pitch dimensions range from 70-75m in length and 50-55m wide, with proportionally smaller penalty areas, goals and other accompanying pitch features compared to 11-a-side soccer (Figure 2.2).

Matches consist of two periods of 30 min, with three substitutions permitted per team. Law variations apply to throw ins: players are permitted to roll the ball one handed or play from behind their head, as standard practice dictates. Defending teams must retreat 7 m for set-plays, and significantly, Law 11 "offside" does not apply (IFCPF, 2015). These differences distinguish CP soccer from FIFA's 11-a-side, as well as futsal and the International Blind Soccer Association's (IBSA) futsal. The two respective futsal versions consist of 5 players per team and are played on a smaller court, with fewer players, over a shorter duration.

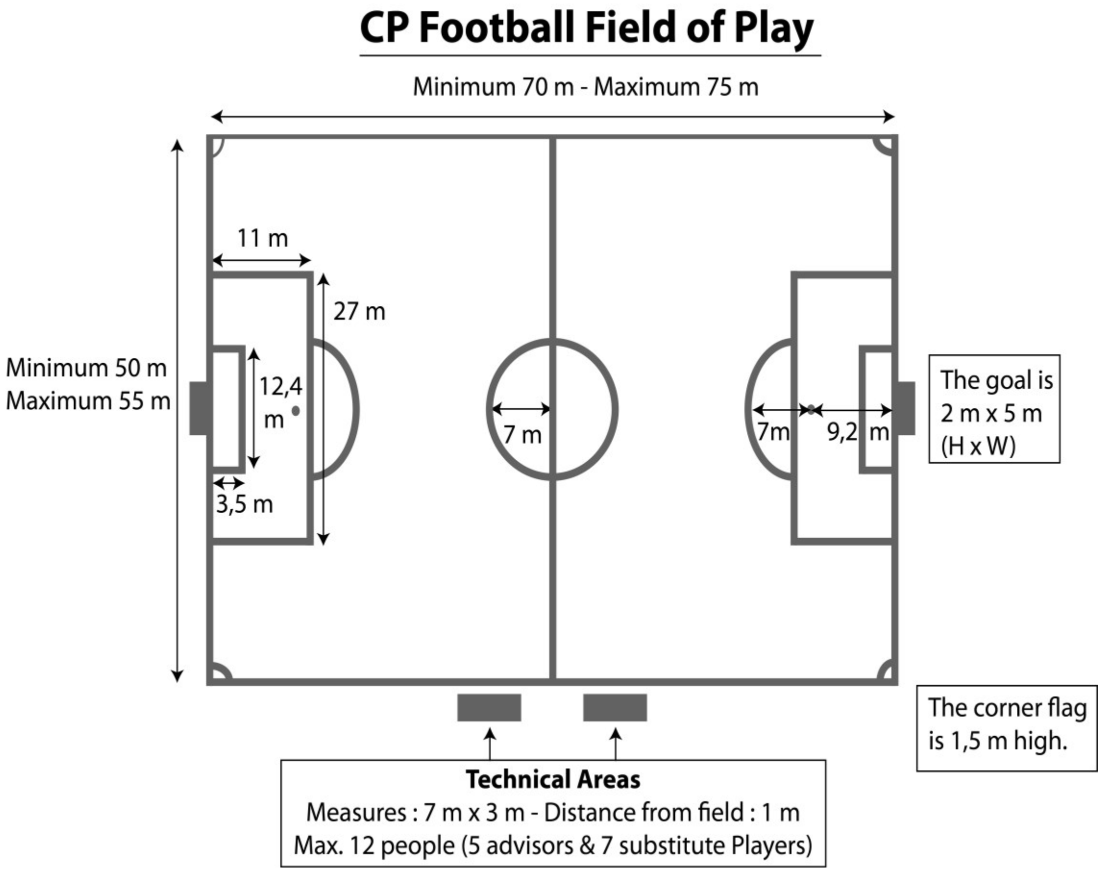

Figure 2.2 Pitch dimensions for 7-a-side CP soccer (image taken from IFCPF, 2015)

2.3.a.ii By-laws of CP soccer - CP soccer is a mixed-class competition sport. This means that teams consist of players from across the four eligible Paralympic classes; separate events do not exist for each Paralympic class. Although the role of classification is to ensure fair competition, mixed classification sport means that individuals allocated to different classes, possessing varying impairment severity, compete directly against one another. The IFCPF apply a by-law to manage the participation of players, preventing teams from selecting players solely from the more capable classes. The participation by-law functions in tandem with the Paralympic classification of players in an attempt to create fair and equitable competition.

In 2014, CPISRA (the previous governing body) amended the participation by-law, to state that each team must field a minimum of one FT5 or FT6 player, while only permitting the inclusion of one FT8 player at any time

(IFCPF, 2015). No restrictions are placed upon FT7 participation. Any substitutions during matches must maintain this class balance. Prior to 2014, two FT8 players were permitted to participate per team at any time (CPISRA, 2013). There are no documented studies or evidence-based rationale for the original by-law or the recent change. Reina (2014) suggested further changes are likely after the Rio 2016 Paralympic Games, where the IFCPF have proposed to increase the participation of FT5 / FT6 to two players at all times, in turn completing a swing in the class participation distribution from the previous governing body's by-law (CPISRA, 2013).

Wheelchair basketball and wheelchair rugby also operate mixed-class competition in Paralympic sport, but adopt a different approach to managing disparity between classes. These sports do not impose participation restrictions on specific classes, but instead aggregate the sum of class points on the match court and impose a maximum number of points per team. Selected from eight classes (0.5-4.0), wheelchair basketball permits a maximum of 14 points for the five players. In wheelchair rugby, four players (from seven classes, 0.5-3.5) can total a maximum of 8.0 points (IWBF, 2014; IWRF, no date).

2.3.b Characteristics of soccer and soccer players

Sport is a dynamical self-organising system (McGarry et al., 2002), where the interaction of environmental conditions, the task or goal, and the performer attributes, predicate emergent actions and behaviours (Newell, 1986). In soccer, players' actions are related to time, space, the information available and the organisation of teams (Grehaigne et al., 1997). Although CP soccer, 11-a-side and futsal all adhere to the Laws of the Game (FIFA, 2015), Section 2.3.a. described the significant differences that exist between them with regard to these interacting variables.

The study of soccer has led to extensive research on technical and tactical analysis of match-play (Reep and Benjamin, 1968; Reilly and Thomas, 1976; Bloomfield et al., 2004; Yiannakos and Armatas, 2006; Wright et al., 2011), time-motion analysis of movement and actions (Rampinini et al., 2007;

Bradley et al., 2009; Di Salvo et al., 2010; Gregson et al., 2010), and the physiological characteristics of players (Reilly et al., 2000b; Portes et al., 2015). Studies report varied findings for different levels of play, playing positions and team tactics, which reflect the dynamic nature of soccer.

To date, there have been very few studies investigating CP soccer or CP soccer players. Thus, limited information is available regarding the specific characteristics of this form of soccer. Of the studies that have been conducted, most have focused on the physiological attributes of players (Andrade et al., 2005; Kloyiam et al., 2011; Camara et al., 2013; Yanci et al., 2016; Reina et al., 2016). Yanci (2014) conducted the only examination of CP soccer match analysis, while the only study concerning time-motion analysis in CP soccer was derived from Study TWO of this thesis (Boyd et al., 2016) (APPENDIX D) and is discussed in Chapter 4.

Soccer is a multiple sprint sport, incorporating bouts of high and very high intensity activity, interspersed with low intensity activity, often constituting recovery periods. Typically, players perform a sprint once every 90 s, and a high intensity effort once every 30 s, with these anaerobic activities often associated with crucial moments of the game, such as winning ball possession or scoring or conceding goals (Bangsbo, 1994; Reilly et al., 2000b; Bloomfield et al., 2007). High intensity actions can be 2-10 s in duration and therefore utilise anaerobic energy pathways (Ekblom, 1986; Gaitanos et al., 1993; Bangsbo, 1994). Large portions of time are spent walking and standing, but despite this, soccer demands a great deal from the aerobic energy system, with mean and peak heart rates of around 85% and 98% maximum heart rate (HR_{max}) respectively, and mean VO_2 values around 70% VO_{2max} (Ekblom, 1986; Bangsbo, 1994; Krustrup et al., 2005).

The assessment of players' physical attributes provides coaches and sport science practitioners with an insight into the profile of players that participate at a given level or in specific positions, assisting in monitoring fitness levels, training effects and supplementing talent identification strategies (Bangsbo, 1994; Svensson and Drust, 2005; Drust et al., 2007).

2.3.b.i Physiological characteristics of soccer players – Broadly speaking, agility, speed, strength, anaerobic and aerobic power and capacity are areas of interest, when analysing soccer players' physiological characteristics (Wisloff et al., 1998; Reilly et al., 2000b; Portes et al., 2015). Elite male soccer players have been shown to exhibit VO_{2max} values ranging from 50-65 $ml \cdot kg^{-1} \cdot min^{-1}$ (Raastad et al., 1997; Wisloff et al., 1998; Reilly et al., 2000b), while anaerobic power testing has consistently demonstrated 10 m sprint times <1.9 s and jump heights $\geq$40 cm (Strudwick et al., 2002; Wisloff et al., 2004; Little and Williams, 2006; Le Gall et al., 2010). To perform at such levels, players often present body fat percentage (BF%) values around 8-11% (Davis et al., 1992; Arnason et al., 2004; Hencken and White, 2006; Sutton et al., 2009). Variations in data reported reflect the nature of the sub-groups of soccer players studied. There is general agreement that higher physiological capacity for work is associated with higher playing standards of teams (Mohr et al., 2003; Krustrup et al., 2005; Rampinini et al., 2007; Di Salvo et al., 2009; Bradley et al., 2010).

No study in CP soccer has established a profile of CP players, with a number of studies focusing upon single parameters. Kloyiam et al. (2011) examined running economy and aerobic power. In comparison to AB players, YO-YO test performances were 43-50% lower in CP players. Kloyiam et al. (2011) attributed this to turning ability, another key action in soccer. The study did not present predictions of aerobic power, but concurred with clinical studies that CP adversely affects walking and running economy, and attributed this to changes in gait (Stackhouse et al., 2005; Unnithan et al., 1996; Keefer et al., 2004). However, the study was unable to provide insight into inter-class differences, with a limited sample size (n=12) across the four classes. The study cited issues with players' maximal effort, but still reported attainment of HR_{max}, as well as stating that 'lower' classes outperformed 'higher' classes (FT5 v FT8).

Sprint ability over short distances (5-30 m) is often assessed in soccer players, but no study has examined this fundamental aspect of performance in CP soccer. Beckman et al. (2009) developed a battery of field tests for CP track athletes, to assess 30 m sprint performance and associated tests of strength and coordination, but this is yet to be employed in CP soccer. However, Reina et al. (2016) has examined sprint performance in a functional test assessing coordination and agility in CP soccer players.

Turning, changing direction and speed are often seen as determinant characteristics of soccer performance (Chaouachi et al., 2012; Chaouchi et al., 2014). Reina et al.'s (2016) examination of these attributes provided some useful information. The Illinois agility run and Modified agility test (Sassi et al., 2009) were used to evaluate CP soccer players' movement capabilities. CP inhibits force development, so it is unsurprising that CP players were slower than the AB controls in both tests (Illinois agility run: AB = 15.91 s v CP $\geq$17.75 s: Modified agility test AB = 5.99 s v CP $\geq$7.09 s). This study also examined inter-class differences and found that FT8 players (17.75 s and 7.09 s) were faster than FT5 (19.49 s and 8.59 s), FT6 (19.34 s and 8.22 s) and FT7 (18.67 s and 7.94 s) players, in both agility tests. These findings are aligned with the classification guidelines that discriminate FT8 from other classes by mild impairment, while FT5, FT6 and FT7 are defined by type and topology of impairment (Reina et al., 2013; IFCPF, 2015; Reina, 2014).

Although they do not provide direct measures of force production, jump tests also assess muscular strength and anaerobic power (Baker, 1996). They are the preferred modality of evaluating functional strength and anaerobic power in soccer players (Reilly and Gilbourne, 2003). Camara et al. (2013) presented one of two studies examining jump performance in CP players and focused on landing characteristics of elite Spanish CP soccer players. Due to higher vertical ground reaction forces and weak correlations between landing variables, the study concluded that CP players were less capable of landing effectively, and therefore more susceptible to injury. With no control group and a small sample from across the spectrum of eligible impairments (n = 13), Camara et al. (2013) did not comment on interclass differences or jump height. Yanci et al. (2016) also assessed jump capabilities of CP players, while examining the broader parameter of anaerobic capacity, using the WAnt. Squat jump and counter movement jump heights were markedly lower (~49%) than in AB elite players from previous work (McLellan et al., 2011; Siegler et al., 2006; Castagna and Castellini, 2013). Yanci et al. (2016) also found that

CP players were able to attain greater increases in jump height than AB players (Castagna and Castellini, 2013), when the counter-movement jump was compared to the squat jump performance study of AB players (19% increase v 8% increase). In CP players, it is likely that the apparent benefit of the counter movement is a product of poorer explosive strength exhibited in the squat jump performance, since deficits in strength are characteristic of individuals with CP (Damiano and Abel, 1998; Burtner et al., 1998).

Yanci et al.'s (2016) assessment of peak power and mean power using the WAnt showed CP players were inferior to AB controls, and the data were in line with previous work comparing Paralympic CP cyclists with AB cyclists (Runciman et al., 2015a). Although no insight was derived from jump testing, with regards to classification, the study did find relationships between WAnT performance and classification. However, the authors suggested to the contrary, that WAnt performance is not indicative of CP soccer class, as it is not sport specific. Andrade et al. (2005) used isokinetic dynamometry, rather than field-testing, to study CP soccer players' leg strength. Paretic leg knee extensors were shown to be were weaker than expected and weaker than the non-paretic limb, with no anomalies present in flexor / extensor ratios. The study did not attempt to associate leg strength with any field-based testing or examine inter-class differences. A more insightful study in TBI track athletes, conducted by Beckman et al. (2016), examined leg strength associated with 60 m running. Here, a stronger relationship was found between strength and running performance than in a control group of AB athletes. This suggests that isometric strength testing is a useful assessment tool for TBI and CP athletes, even though weaker associations have been observed in AB populations (Baker et al., 1994).

2.3.b.ii Movement demands of soccer – Often cited within literature as the demands of the game, the study of physical performance during match-play observes patterns of activity that reflect the symbiosis of the environment, the task / goal and player attributes (McGarry at al., 2002). Advances in tracking technology have lead to widespread use of global positioning satellite (GPS) and semi-automated camera tracking systems, such as Prozone and Amisco, in the measurement of player movement (Carling et al., 2008). Consequently, research focusing on time-motion analysis has evolved rapidly (Reilly and Thomas, 1976; Mayhew and Wenger, 1985; Bangsbo et al., 1991; Bangsbo, 1994; Bloomfield et al., 2004; Bradley et al., 2009; Di Salvo et al., 2010), with studies commonly associating the measurement of performance variables with physiological demands (Mohr et al., 2003; Rampinini et al., 2007; Bradley et al., 2011; Barnes et al., 2014).

Early time-motion analysis studies emphasised total distances covered (TD) during match-play (Reilly and Thomas, 1976; Mayhew and Wenger, 1985), but the importance of this parameter in evaluating physical performance has been questioned (Bangsbo, 1994). More recently, research has focused on high intensity activity in soccer, which is widely regarded as a key discriminating factor of playing level and training status (Mohr et al., 2003; Krustrup et al., 2005; Rampinini et al., 2007; Bradley et al., 2010). Successful teams and teams of a higher standard tend to exhibit greater distance covered at high intensity during matches (Rampinini et al., 2007; Di Salvo et al., 2009). High intensity activity is also a discriminatory variable between positions (Di Salvo et al., 2007; Bradley et al., 2009), but this can vary greatly (3-15%) across players and officials from match to match, due to tactical variations, player condition and environmental differences (Rampinini et al., 2007, Gregson et al., 2010).

During 11-a-side soccer matches, players have been known to cover approximately 8-10% of total distance at a high intensity (Reilly et al., 2000b; Rampinini et al., 2007; Bradley et al., 2009), with wide-midfield players covering the most distance and central defenders the least (Bradley et al., 2009; Di Salvo et al., 2010; Di Mascio and Bradley, 2013). Carling et al. (2012) found that central midfield players performed the most high intensity actions, while full backs performed repeated bouts of high intensity activity, further illustrating the differences between positions and the influence of formation (Bradley et al., 2011). Studies show that fatigue sets in over time, and significantly less high intensity activity is performed in the final 15 minutes of matches, compared with earlier periods, with recovery time between bouts of high intensity activity consequently increasing in the latter stages (Mohr et al., 2003; Bradley et al., 2009). The breakdown of activities shows that players are exposed to approximately 150-250 short, intense actions during a game, which indicates that the rates of creatine phosphate utilisation and glycolysis are frequently high. Heart rate response places players in excess of 80% HR_{max} for most of the match, as recovery from anaerobic activity occurs while working at lower activity levels (Bangsbo et al., 2006). Muscle glycogen is likely the most important substrate for energy production, and fatigue towards the end of a game, indicated by reduced movement activity, may be related to the depletion of glycogen, as increased free fatty acid utilisation has been observed late in matches (Bangsbo, 1994; Reilly, 1997; Krustrup et al., 2003; Mohr et al., 2005; Bangsbo et al., 2006).

Despite its popularity and status as FIFA's second official code of soccer, few studies have examined professional futsal players. Castagna et al. (2009) conducted a comprehensive study examining physiological responses to futsal. They found that players covered 121 $m \cdot min^{-1}$ during matches, with 5% of total distance covered during sprinting (>18.3 $km \cdot hr^{-1}$) and 12% during high speed running (>15.5 $km \cdot hr^{-1}$). This resulted in players sprinting approximately every 79 s, more frequently than in 11-a-side soccer (every 90 s). Players also spent 52% of match time above 90% HR_{max}. Barbero-Alvarez et al. (2008) used different speed zones, but reported comparable HR values (83%) above 85% HR_{max}. These researchers also cited that time above 85% HR_{max} was lower in the second half of matches. Distance covered while sprinting constituted 8.9% of total distance, but significantly, sprinting was defined as >25 $km \cdot hr^{-1}$. Bueno et al. (2014) showed that fatigue is evident in the 2nd half of matches in Brazilian league futsal players, through an increase in walking and standing, although the roll-on, roll-off nature of substitutions has been identified as maintaining high intensity activity throughout matches (Alvarez et al., 2002).

2.3.b.iii Technical and tactical characteristics of soccer – The statistical analysis of soccer match-play has long been established, with seminal work stimulating what has become a popular research area in soccer (Reep and Benjamin, 1968; Reilly and Thomas, 1976; Withers et al., 1982; Mayhew and

Wenger, 1985).

The assessment of the technical performance of individual players' Key Performance Indicators (KPIs) is a common component of notational. Individual skills, such as passing, shooting, crossing, dribbling, running with the ball, heading, tackling, intercepting, and blocking are commonly captured by performance analysts evaluating AB soccer players. Hughes and Bartlett (2002) suggest that analysis should include the normalised frequency and relative success rates (%) of KPIs, as this is important to gain a full picture of a player involvement in matches.

Rampinini et al. (2009) and Dellal et al. (2010) examined individual KPIs associated with playing level, playing position and match-play fatigue. Rampinini et al. (2009) found that success rates of passes differed between players in successful and unsuccessful teams, while fatigue seemed to contribute to a decline in success rates and frequency of skills executed as matches progressed. Success rates of passing were broad (63-78% completion rates) and were lowest for defenders and attackers (Dellal et al., 2010). Dellal et al. (2010) found no differences in passing success, when comparing English and Spanish league soccer, although wide players in the English league gained more touches of the ball per game, and Spanish league players contested more headed duels. Although this form of analysis has merit in player evaluation, possible selection and talent ID, greater insight into player effectiveness is found in players' involvement in team play.

Notational analysis in AB soccer has also focused on team tactics and strategies, with particular emphasis on goal scoring behaviours. Recently, Yanci (2015) conducted the sole study focused on match analysis in CP soccer, in the Spanish domestic league. The study examined goal scoring, which is viewed as the ultimate measure of effective attacking play (Tenga et al., 2010). It is suggested that information on goal scoring provides information on patterns of play and behaviours employed by successful teams, and should therefore permit the identification of KPIs (Lago and Martin, 2007; Hughes and Bartlett, 2002). However, Yanci (2015) conducted only basic goal scoring analysis during two seasons of matches (23 matches, 173 goals). Most goals were scored in the first half of matches, while 88.5% of goals were scored from within the penalty area or the immediate attacking third zone; only two goals were scored directly from a corner or free kick (1.2%). The study mirrors the goal scoring positions observed in AB soccer (Olsen, 1988; Dufour, 1990; Yiannakos and Armatas, 2006; Mitrotasios and Armatas, 2014), as would be expected, since goals are more likely to be scored from close range (Pollard et al., 2004). Contrastingly, the temporal distribution of goals was different from AB soccer, where more goals occur later in matches (Abt et al., 2002; Yiannkos and Armatas, 2006; Wright et al., 2011). Yanci (2015) suggested that the fatigue element might be more pronounced in CP players than AB players, which may contribute to fewer goals scored in the latter stages. This theory conflicts with AB soccer however, where fatigue is seen as a likely antecedent to more errors, and therefore more goals, late in games (Mohr et al., 2003).

Yanci (2015) also purports to provide insight into goal scoring patterns, however no information was reported regarding how goals were scored, apart from final contact with the ball. No information exists on which class of player is involved, the origin of the attack (type or pitch area), or whether passing sequences explain the variance in goals scored. Although Yanci (2015) has taken the first steps into CP soccer analysis, the study provided limited information.

McGarry et al. (2002) cites that perturbations in sport are key to identifying patterns. More extensive notational analysis studies explore effective possession sequences, types and origins of assists and turnovers in possession as useful indices of goal scoring strategies (James et al., 2002; Yiannkos and Armatas, 2006; Wright et al., 2011; Mitrotasios and Armatas, 2014). Most studies identify that short passing sequences (>4 passes) lead to goals (Hughes and Franks, 2005; Yiannkos and Armatas, 2006; Wright et al., 2011), and that regains of possession occur predominantly in the attacking half, often in central positions, while scoring from passes from wide areas (commonly termed crosses) is a frequent source of assist (Yiannkos and Armatas, 2006; Wright et al., 2011; Mitrotasios and Armatas, 2014). Central areas of the court are also important in futsal, where goals, regains and assists are prominent, although scoring goals from crosses is not (La Presa et al., 2013; Alvarez et al., 2004; Sarmento et al., 2016). Unlike 11-a-side soccer, futsal research does not identify discrete player positions, merely defensive and offensive situational roles (Baroni and Junior, 2010; Vilar et al., 2013); no further examination of positional differences exists in futsal. Possession length has long been a focus in attempting to discover successful tactics in soccer (Reep and Benjamin, 1968). More recently, opposing teams' relationships with each another has been examined (Tenga et al., 2010; Clemente et al., 2013), with defensive and offensive states of play analysed; compactness being key to defending shape, wide and long effective playing space being key to attacking shape, and the quickness of transition from one state to another being an integral part of team success (Clemente et al., 2013). Tenga et al. (2010) concurred; concluding that counter-attacking involving short passing sequences was most effective when confronted by an unbalanced defence. There was no such advantage of short passing sequences, however, when opposition defence demonstrated balanced positioning. Frequent possession turnover is often due to teams not being suitably positioned to maintain possession and why teams are vulnerable to conceding goals when unbalanced in defence (Tenga et al., 2010). Quickness of a possession involving short passing sequences can exploit such vulnerability.

2.3.c Summary of Paralympic 7-a-side soccer

CP soccer is a significantly different sport to FIFA's 11-a-side soccer and futsal. Alterations to the Laws of the Game mean that empirical research in AB soccer holds limited value in gaining an understanding of this Paralympic sport. Currently, there is a paucity of research profiling CP players; most existing studies are limited and overlook the key variable of classification. Indeed, research examining the technical and tactical match demands of CP soccer is virtually absent from the literature, with one single notational analysis study to date (Yanci, 2014).

2.4 MEASURING PERFORMANCE VARIABLES IN SOCCER

2.4.a Field-testing

The unpredictable nature of soccer match-play makes assessing the physiological, technical and tactical characteristics challenging (Reilly and Gilbourne, 2003). Irrespective of these challenges, research must consider the validity, reliability and sensitivity of the tests employed (Atkinson and Nevill, 1998; Drust et al., 2007; Currell and Jeukendrup, 2008). In soccer, a multitude of field-tests can be conducted to assess the range of physical components associated with performance. The general consensus is that lab-based tests are resource-heavy and the reduced ecological validity means that field-tests are the preferred method of assessing performance (Dunbar and Power, 1997; Svensson and Drust, 2005).

Field-testing involves assessing skilled movements that possess inherent biological and technical variations (Bagger et al., 2003) therefore establishing their reliability provides the capacity for measuring true performance and meaningful change in test-retest scenarios (Hopkins, 2000). Equipment precision and inter and intra-tester agreement also require consideration, but are threatened by systematic bias and random error. To ensure valid and reliable data collection, it is imperative that well-defined protocol administration is conducted during testing procedures (Currell and Jeukendrup, 2008), and reliability statistics should be reported. Reliability can be reported in numerous ways; recognised measures include: co-efficient of variation (CoV); Pearson's *r*; interclass correlation co-efficient (ICC); standard or typical error measurement (SEM or TEM); and limits of agreement (LoA), (Atkinson and Nevill, 1998; Currell and Jeukendrup, 2008).

In soccer research, field-tests of maximal speed and agility over game-specific distances are associated with skills such as passing, dribbling, shooting and intercepting (Bangsbo and Lindqvist, 1992; Bangsbo, 1994; Svensson and Drust, 2005, Chaouachi et al., 2012; Chaouachi et al., 2014). Sprints, flying starts and change of direction tests over distances of 10-30 m are realistic representations of sprint performance (Strudwick et al., 2002; Dawson, 2003). Small changes in performance must be detectable and variation must be established to contextualise data. Reina et al. (2016) examined agility running in CP soccer players, reporting good to excellent ICC and SEM values for the Illinois agility run (0.96, 2.5%) and Modified agility test (0.82, 5.84%), with significant (r = 0.736) relationships between the two tests. CoV values were high for both tests (Illinois agility run CoV ≥7.01%, Modified agility test CoV ≥10.01%). Limited test familiarity and the low number of trials (2) conducted per participant may have contributed to the high CoV. In contrast to Reina et al.'s (2016) reporting of reliability, Kloyiam et al. (2011), Yanci et al. (2016) and Camara et al. (2013) did not report equipment, protocol, or reliability of any description.

2.4.b Time-motion analysis

Methods of measuring soccer performance in matches have developed rapidly in recent years. Technological advances have facilitated greater insight into soccer match-play, using time-motion analysis with multi-camera systems (Di Salvo et al., 2007; Rampinini et al., 2007) and individual GPS units attached to players (Mohr et al., 2003; Barbero-Alvarez et al., 2008; Harley et al., 2010; Di Salvo et al., 2010; Gregson et al., 2010; Randers et al., 2010; Carling et al., 2012; Bradley et al., 2013; Barnes et al., 2014). A number of validation and reliability studies have attempted to establish the accuracy of the data from these commercially available systems (Peterson et al., 2009; Gray et al., 2010; Waldron et al., 2011; Akenhead et al., 2013; Varley et al., 2012).

Individual player GPS devices continue to develop, becoming lighter and smaller, but significantly, the sampling rate (Hz) at which data is collected is also improving. Developments in sampling rates from 1 Hz to 5 Hz improved the validity and inter-unit reliability of GPS units, as a measure of athlete movements (Petersen et al., 2009). The accuracy of 5 Hz systems was shown to exhibit valid and reliable measures of distance covered to a magnitude of <4% error and peak speed to a magnitude of <10% error (Jennings et al., 2010; Johnston et al., 2012). However, issues materialised with TEM recorded at >12%, when running speeds were in excess of 20 $km \cdot hr^{-1}$. Further issues surrounding rapid accelerations and sharp changes in direction were also identified, suggesting accelerometer measurements may be questionable (Waldron et al., 2011). Furthermore, an examination of 10 Hz units demonstrated three-fold greater accuracy compared to 5 Hz units, with six-fold greater inter-unit reliability (Varley et al., 2013). Akenhead et al. (2013) further examined aspects of acceleration in 10 Hz GPS devices and concluded that accelerations of <4 $m \cdot s^{-2}$ reported more reliable and valid data than high accelerations of >4 $m \cdot s^{-2}$, where accuracy was compromised.

The validity of the assessment of movement through GPS and camera tracking systems is undermined by the application of absolute velocity thresholds, assigned to assess different movement activities (Abt and Lovell, 2009). System manufacturers install default velocity thresholds within the software that permit the calculation of distances covered at various intensities of activity, from walking through to maximal sprinting. However, absolute thresholds affect the objective assessment of the relative work rate of individual players, or comparative analysis with other players or studies, since players possess different levels of fitness and capacities to attain maximal speeds (Abt and Lovell, 2009). Nevertheless, common practice adopts the absolute thresholds, possibly for ease of use, or comparison purposes (Mohr et al., 2003; Barbero-Alvarez et al., 2008; Di Salvo et al., 2010; Gregson et al., 2010; Randers et al., 2010; Carling et al., 2012; Bradley et al., 2013). Furthermore, thresholds are often accompanied by limited or no justification for their selection, and are assigned descriptive terms, such as high speed running, that vary across studies, making comparative analysis more difficult (Weston et al., 2007; Abt and Lovell, 2009; Harley et al., 2010; MacKenzie and Cushion, 2013).

2.4.c Notational analysis

KPIs assessing skilled actions in soccer also require robust, valid and reliable operational definitions, for the scientific study of performance (Hughes and Bartlett, 2002; Mackenzie and Cushion, 2013). However, O'Donaghue (2007) recommends that when performance indicators (KPI) of interest are complex, definitions should be less precise while observers should be thoroughly trained on the system and understand the KPI in questions. Inter-observer disagreement and intra-observer inconsistencies are a threat to valid and reliable collection of data and subsequent analysis (James et al., 2002; James et al., 2007). For this reason, notational analysis studies should report operational definitions and measures of observer reliability, which are often omitted (James, 2006; Williams, 2012; Mackenzie and Cushion, 2013; Carling et al., 2014). The only CP soccer study in notational analysis, examining goal scoring, did not report reliability or validity analysis, nor did it present operational definitions (Yanci, 2014). The lack of clarity on the development of the coding system makes interpretation of and confidence in Yanci's (2016) results difficult to establish.

Presentation of intra-observer reliability indicates the competency of the observer to be consistent and is often cited as percentage agreement from the total number of observations (James et al., 2007). This form of reliability reporting, however, does not account for chance agreements, learning effects or retention of information from previous observations (O'Donaghue, 2007; James et al., 2007). Although in notational analysis there is no consensus on the most appropriate reliability measure, probably due to numerous tests being suitable for different data sets (James et al., 2007; O'Donaghue, 2007), Cohen's kappa is most commonly used in two-coder reliability analysis in notational analysis for categorical data. Cohen's kappa statistic (Cohen, 1960) accounts for potential agreement by chance (calculated in a similar fashion to chi-square), so gives a lower value of agreement, with values >0.8 deemed as almost perfect agreement (Landis and Koch, 1977). Cohen's kappa can be used to evaluate the objectivity of each KPI’s operational definition, so is a useful tool for establishing inter-tester reliability and external validity.

When studies do report reliability, whole system reliability is often reported. Researchers however, must be mindful not to overlook potential issues with accepting this measure alone. Closer examination of individual KPIs in a system can reveal lower levels of inter-observer agreement, which in turn, reduces the reliability, and validity of the system. It is therefore important that reliability analysis evaluates individual KPIs, to avoid masking any inherent problems with their definitions. This is often conducted with further kappa analysis or observers discussing and considering operational definitions while reviewing disagreements in video playback (O'Donaghue, 2007).

2.4.d Summary of measures in performance variables in soccer

The nature of soccer often requires the measurement of performance variables in situ, rather than more controlled environments. Establishing valid and reliable measures for data collection is imperative, in order to ensure confidence that the data is a true reflection of the variability in soccer performance.

2.5 SUMMARY

Despite the overwhelming prevalence of CP within Paralympic sport, there is a distinct lack of research examining CP athletes. Classification of CP is known to be challenging and within CP soccer, differentiation between eligible impairments is currently based on limited quantifiable testing and no normative data, and relies heavily upon classifier experience and expertise. Furthermore, the mixed-classification nature of CP soccer has resulted in the employment of a participation by-law that, to date, has no empirical research to support its effectiveness.

CP soccer is unique in its format and the characteristics of its players. As such, its relationships with AB 11-a-side soccer and futsal are unknown, though the players themselves are distinctly different from their AB counterparts. The following chapters present four original studies that investigate key areas in CP soccer and address the aims of this thesis.

CHAPTER 3 - Study ONE

THE PHYSIOLOGICAL AND ANTHROPOMETRIC PROFILES OF CP SOCCER PLAYERS

3.1 INTRODUCTION

The intermittent nature of soccer ensures that activity changes every few seconds, with high intensity activity occurring every 30 s (Reilly et al., 2000b; Bloomfield et al., 2007). Actions are often 2-10 s in duration and are derived from anaerobic metabolism (Ekblom, 1986; Gaitanos et al., 1993; Bangsbo, 1994). Large periods of the game are often spent standing, walking and jogging at a lower intensity, but match HR_{mean} and VO_{2mean} values are often reported in excess of 85% and 70% respectively (Ekblom, 1986; Bangsbo, 1994; Krustrup et al., 2005). Consequently, soccer possesses a significant aerobic component and VO_{2max} values for elite male players range from 50 to 65 $ml \cdot kg^{-1} \cdot min^{-1}$ (Raastad et al., 1997; Wisloff et al., 1998; Reilly et al., 2000b). The dynamics of soccer means players must possess multiple physical attributes, but it is not imperative to excel in all of them (Reilly et al., 2000b). As such, the assessment of a multitude of physiological parameters is required, to fully understand the profile of players (Svensson and Drust, 2005).

Game-defining moments are strongly associated with anaerobic activity (Reilly, 1996; Krustrup et al., 2005), so activities such as sprinting and jumping are assessed to indirectly evaluate player metabolic energetics (Strudwick et al., 2002; Dawson, 2003; Wisloff et al., 2004; Little and Williams, 2006; Le Gall et al., 2010). Contrasts in test performances are often attributed to playing position and levels of play (Mohr et al., 2003; Krustrup et al., 2005; Rampinini et al., 2007; Di Salvo et al., 2009; Bradley et al., 2010), so testing provides a tool to evaluate player capacity for match-play and evaluate training adaptations and fitness progression (Kollath and Quade, 1993; Reilly et al., 2000b).

As cited in Section *2.2.b.*, limited physiological testing has been conducted on CP soccer players and no profile of CP soccer players has been established; Camara et al. (2013) and Yanci et al. (2016) focused on jumping ability and anaerobic performance, while Andrade et al. (2005) examined isokinetic leg strength, and Reina et al. (2016) focused on movement agility. Findings highlighted that CP players have difficulty in landing and may be more susceptible to injury (Camara et al., 2013). Jump heights and performance in the WAnT were markedly lower than AB players (Yanci et al., 2016), and knee flexors and extensors were weaker in the paretic leg (Andrade et al., 2005). Reina et al. (2016) utilised two tests, the Illinois agility run and the Modified agility test (Sassi et al., 2009), to investigate agility in elite CP players. Findings were two-fold; the tests were found to be reliable and valid for assessing change of direction in CP players, and they discriminated between FT8 players and the other classes (FT5-FT7), thus ameliorating the classification cut-point issues. Kloyiam et al. (2011) examined running economy and YO-YO test performance. With limited samples (n = 14) across four classes however, these authors were unable to be more conclusive than identifying that CP players possess poorer running economy and have more issues with turning than AB controls. Once again, within the CP players, no inter-class differences were noted.

Lab testing often provides 'gold standard' levels of precision and accuracy, but the equipment and time resources required can be burdensome for team sports. Field-testing is an accepted alternative and a common choice for soccer player fitness testing. It brings specificity and ecological validity to testing, but also presents some challenges for validity and reliability, two critical aspects of testing procedures and equipment (Atkinson and Nevill, 1998; Svensson and Drust, 2005). Numerous field tests are available to assess each component of fitness. Aerobic power is commonly assessed using variations of shuttle run tests and timed runs (MSFT, YO-YO, Cooper 12-minute run). YO-YO tests are said to best reflect soccer (Bangsbo, 1993; Krustrup et al., 2003), however the ease of administration of the earlier developed MSFT (Leger et al., 1988; Ramsbottom et al., 1988) has resulted in its more prominent use (Davis, et al., 1992; Strudwick, et al., 2002; Tumilty, 2000).

Sprint, agility and jump tests assess performance variables, with inferences to the physiological capacities that underpin such activities (Svensson and Drust, 2005), and the combination of straight sprints and agility tests provide greater insight into speed capacity (Little and Williams, 2005). Body composition assessment also has an extensive array of techniques and methodologies, as reported and discussed by Ackland et al. (2012) and all have relevance in soccer fitness assessments.

Body composition has so far been overlooked in CP soccer, although Runciman et al. (2015b) assessed the body composition of CP track athletes, and it is commonplace to assess body composition in AB soccer, with the assumption that excess fat reduces movement economy in soceer (Reilly, 1996; Sutton et al., 2009). Elite male players reportedly possess BF% of approximately 8-11%, with no differences between playing positions, apart from the higher BF% recorded in goalkeepers (GKs) (Davis et al., 1992; Arnason et al., 2004; Hencken and White, 2006; Sutton et al., 2009). Skin-fold assessment is a common field test for athletes, but the number and location of anatomical sites varies between methods, as well as the algorithms used to estimate total BF% (Durnin and Womersley, 1974; Jackson et al., 1978; ISAK, 2001). ISAK (2001) consider 8 sites for whole body assessment and suggest the reporting of sum of skin-folds as the outcome variable, with no further processing required to estimate BF% (Gore et al., 2000).

With such extensive research and applied practice devoted to assessing fitness levels of soccer players, and comparatively little information available in CP soccer, the aim of Study ONE is to establish a performance profile of elite CP soccer players. The paucity of evidence is problematic for governance of the sport and objective Paralympic classification of players. Since current CP soccer literature fails to explore impairment class, this study also examines contrasts between the four classes of CP player.

3.2 METHOD

3.2.a Participants - 29 international male soccer players with CP and TBI (Table 3.1) consented to take part in the study. Ethical approval was obtained from the Department of Exercise and Sport Science ethics committee at Manchester Metropolitan University, and the study conformed to the guidelines set out in the Declaration of Helsinki (2000). Participants were preparing for the 2012 Paralympic Games and testing took place during a pre-selection training camp at Lilleshall National Sports Centre, Newport, UK. Data are presented as mean (SD).

Table 3.1 Participants' characteristics

Class	Sample (n)	Age (years)
FT5	5	24 (5)
FT6	6	24 (3)
FT7	12	23 (4)
FT8	6	25 (6)
Combined	29	24 (4)

3.2.b Procedures - A battery of field-based tests were conducted on the first morning of the training camp and participants were asked to refrain from intense exercise in the preceding 72 hours. Abstention from caffeine was enforced at breakfast prior to testing and all players provided a urine sample immediately after waking up, to test hydration status (OsmoCheck, Vitech scientific, Partridge Green, UK (APPENDIX B.1). Osmolarity data indicated no differences between classes or that any player was in a dehydrated state (APPENDIX B.2). Hydration was provided throughout the testing sessions on an *ad libitum* basis. Participants were familiar with the author, as he acted as sport science support for the squad, and they possessed previous experience of the tests and testing conditions. All physiological testing took place indoors, on a non-slip, synthetic hard court surface and following a thorough warm up, conducted by the author.

The battery of field-based performance tests were undertaken, in the following order:

- Sprint tests (5 m, 10 m, flying 20 m performances)
- Modified agility test
- Jump tests (squat, counter-movement and vertical jumps)
- MSFT (20 m shuttle run)

Anthropometric tests of stature and body mass, and Skin-fold assessments were conducted separately, at the team accommodation facility, over a three-day period.

3.2.b.i Anthropometry and subcutaneous fat evaluation - Stature and body mass were recorded (Seca scales, model 869, Seca stadiometer 217; Hamburg, Germany), and an eight-site skin-fold protocol followed, to determine the sum of Skin-fold thickness for each participant (ISAK, 2001) (APPENDIX B.3). Participants were dressed in shorts and the procedures were undertaken by the author, a BASES accredited sport physiologist, with over 15 years of experience in assessing Skin-fold measures in elite sports people. The author's day-to-day technical error of measurement (TEM) for the ISAK Skin-fold eight sites model was assessed, following the guidance of ISAK (2001). Twenty-four volunteers were assessed on two occasions on different days and absolute and relative TEM were established (0.21 mm and 2.06%, respectively). These figures are within the acceptable range for reliability (Gore et al., 2000). Measures of the author's TEM for all eight sites can be found in APPENDIX B.4. A marker pen, Harpenden skin-fold callipers (Baty International, Burgess HIll, UK), a body tape measure (HabDirect, UK) and a chair for the seated assessment of lower limb sites were used to collect the data.

Initially, individuals were marked for the Skin-fold sites (ISAK, 2001). Normal protocol is to assess participants on the right hand side of the body, however due to some participants suffering athetosis, ataxia or spasticity, assessment was made on the least-affected side for each individual. The assessment of each Skin-fold site was undertaken once and values reported by the author to an assistant, for data recording. This process was completed two times and a mean value for each site was calculated. The sum of the means of eight sites culminated in a total sum for each participant, expressed in mm.

3.2.b.ii Sprint and agility performance - Sprint speed was measured over a straight-line course, using photo-cell timing gates (Brower Timing Systems, UT, USA) positioned at 0 m, 5 m, 10 m and 30 m (erected 1.5 m apart; 1 m tall) (Figure 3.1). This enabled the recording of 5 m and 10 m sprint times simultaneously, while the flying 20 m sprint was completed within separate trials. For the 10 m sprint trials, participants were positioned with the toe of their preferred front foot on a start line, - 0.5 m before the 'start' timing gate (0 m). Glaister et al. (2007) indicated that no discernable period of familiarisation is required for straight sprint tests using timing gates.

Participants were then instructed, "When you are ready..." and were permitted to commence the trial at their discretion. Verbal encouragement was given throughout the trial from the author and the coaches, and the participants were instructed to 'run through the final gate, maximally'. After two sub-maximal practice trials (70-90% effort, as instructed), participants completed three maximal trials per test, initially for the 10 m sprint, followed later by the flying 20 m sprint.

The only modification for the flying 20 m sprint trials was the absence of the 0.5 m start line and the 0 m and 5 m timing gates. Participants were instructed to sprint maximally from the start and beyond the 30 m timing gates. Inter-trial recoveries were approximately 3 min in duration, in order for the metabolic recovery of the phosphocreatine energy system. The best performance times were reported for both tests. Mean velocity ($m \cdot s^{-1}$) was calculated for each sprint distance and the best value is reported as V_{max}.

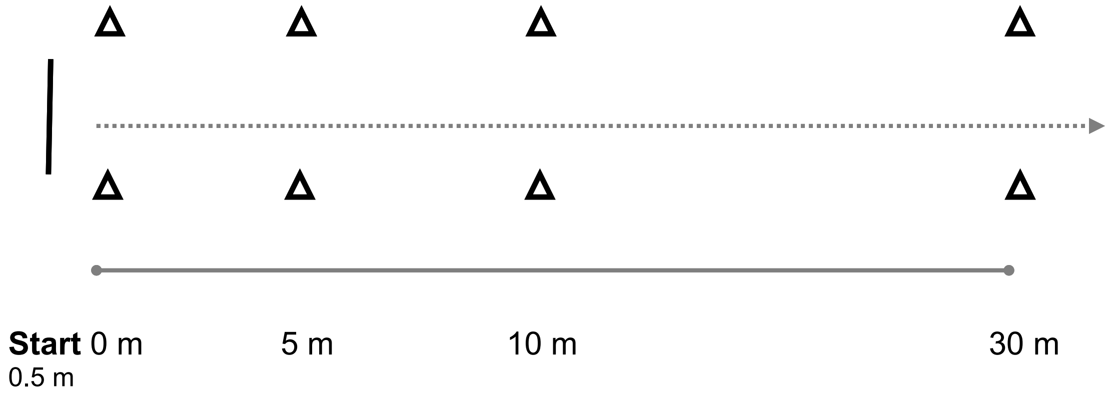

Figure 3.1 Layout of the 10 m sprints and the flying 20 m sprints

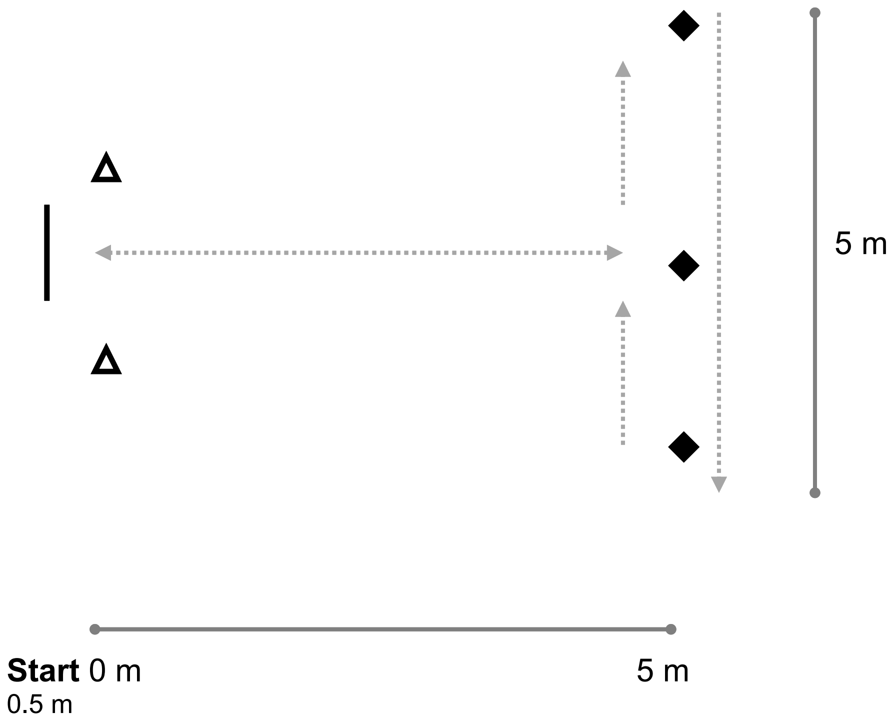

Figure 3.2 Layout of the Modified Agility Test

The Modified agility test (Figure 3.2) utilised a single photo-cell timing gate (Brower Timing Systems, UT, USA), positioned at the start / finish line position (0 m) (erected 1.5 m apart; 1 m tall), while three bollard-style cones (0.5 m tall) were taped to the floor, with the centre of each directly above the designated distance the cone represented. Participants completed four trials, two in each direction. Trials involved 4 turns, where participants were required to touch the top of each cone when turning. The direction of trial one and three commenced with a 90º right turn, trials two and four with a 90º left turn. Only attempts that included a hand touch at each turn were deemed valid. Invalid trials were repeated. Initially, players were given guidance on turning skill; some players had favoured sides due to hemiplegia, and poor selection in turning would adversely affect performance times. Sassi et al. (2009) reported no difference between test-retest scores and inter-class correlation (ICC) >0.90 for adult AB men and women in the Modified agility test.

Participants were positioned on the start line (-0.5 m from starting gate), and given the exact same instructions and encouragement as in the previous sprint tests. After two sub-maximal practice trials (70-90% effort, as instructed), participants completed four maximal trials, with inter-trial recovery of approximately 5 min duration. The best performance times are reported.

3.2.b.iii Jumping performance - Jumping performance was assessed with three jumping modalities: the squat jump, the counter movement jump and the vertical jump. Descriptions of each jump type can be found in APPENDIX B.5. Participants performed three trials of each jump, in a randomised order (e.g. 3 x vertical jump then 3 x counter-movement jump then 3 x squat jump), with all data recorded in cm (Optajump Next, Microgate, Bolzano, Italy). Glatthorn et al. (2011) reported test-retest reliability of the Optajump system as excellent (ICCs 0.982 to 0.989, CV = 2.7%).

The following instructions were consistently provided and once given the cue from the assessor, participants initiated the trial at their own discretion:

- Assume a comfortable open leg stance prior to the test
- Squat depth is to be individually determined
- Maximal effort is required to gain maximal vertical displacement
- Be explosive, drive hard and quickly into the floor
- Inter-trial recovery is 20 s
- "When you are ready..."

Unbalanced landings and landings that fell outside the jump area, designated by the measuring apparatus, were deemed invalid and were repeated. Recovery between each jump modality was approximately 5 min and 30 s between each trial. The best performances are reported and to establish the contribution of body counter-movement and arm propulsion, relative differences were calculated for counter-movement jump v squat jump and vertical jump v counter-movement jump .

3.2.b.iv *Aerobic power* - The MSFT (NCF, Leeds, UK) was used to determine aerobic endurance performance and provide a prediction of aerobic power (VO_{2max}) (Ramsbottom et al., 1988). The test has been widely adopted in the literature for assessing the fitness of soccer players (Davis et al., 1992; Arnason et al., 2004; Hencken and White, 2006; Sutton et al., 2009). Leger et al. (1988) reported a test-retest reliability of 0.95 for male individuals between 20 and 45 years old. The test was well established within the participant group and in consultation with the team's coaches, was selected to aid comparison with previous testing sessions, while ensuring there was no question around skill acquisition to a new test. The test was conducted over a 20 m course, measured using a 50 m field athletics tape measure (Cantabrian, Sheffield, UK) and marked out with coaching discs, to denote lanes for each participant. A CD player and amplifier provided the means to play the MSFT CD at ample volume. All participants wore HR monitors (RS800, Polar, Kempele, Finland), to establish end test HR_{max}. Instructions provided by the assessor were that pacing was key and turning on the line at the bleep was most efficient, while three consecutive missed bleeps would automatically terminate the test.

Verbal encouragement was given throughout the test, with a buddy system in place (non-participating team mate), to encourage their counterpart and to identify players 'at risk' of dropping out, so the assessor could accurately record final performance. The test possesses an increasing numbers of shuttles per level and therefore, the total shuttles completed by each participant are presented and used for inferential statistical analysis.

3.2.c Data analysis - Using SPSS v22.0 (IBM, Chicago, Illinois), one-way ANOVAs were used to analyse the effects of player class (x4) on all performance variables, sum of Skin-fold and pre-test body mass, stature and hydration scores. Subsequently, Bonferroni post-hoc comparisons were used to identify any specific inter-class differences. Games-Howell adjustments to the alpha level were made when homogeneity of variance was violated, as identified by Levene's Test. Games-Howell has been shown to be effective with uneven or small samples with unequal variance (Field, 2013). Pearson's *r* correlation was conducted on jump and sprint data. The alpha level for all tests was set at 0.05 and where significance was found, Cohen’s *d* effect sizes (cited within the text) were calculated to support the ANOVA-based contrast analysis.

3.3 RESULTS

3.3.a Anthropometry

There were no inter-class differences in stature, body mass (Table 3.2) and sum of skin-folds (eight Skin-fold sites', data in APPENDIX B.6).

Table 3.2 Participants' anthropometric data

Class	Stature (m)	Mass (kg)	Sum of skin-folds (mm)
FT5	1.77 (0.04)	73.8 (5.5)	84 (32)
FT6	1.74 (0.07)	61.3 (5.7)	62 (15)
FT7	1.78 (0.08)	70.5 (12.5)	86 (34)
FT8	1.78 (0.06)	72.7 (9.6)	94 (50)
Combined	1.77 (0.07)	69.4 (10.8)	83 (35)

3.3.b Sprint tests and speed agility

Table 3.3 shows that FT8 players were faster than FT5 players over all sprint distances ($d \geq 2.63$), and faster than FT7 players over 10 m and flying 20 m sprints ($d \geq 0.82$). In contrast, the other classes did not differ over any distance. All classes attained V_{max} during the flying 20 m sprint test. FT5 players attained a lower V_{max} than the other three classes ($d \geq 3.87$). The Modified agility test highlighted that both FT8 and FT7 players were faster than FT5 players ($d \geq 1.95$). FT6 players were not different from any other player class in straight sprints or agility tests.

Table 3.3 Field-testing performance data for sprints and speed agility

Class	5 m sprint (s)	10 m sprint (s)	Flying 20 m sprint (s)	Modified agility test (s)	Max velocity ($m \cdot s^{-1}$)
FT5	1.24 (0.07)	2.02 (0.04)	3.07 (0.17)	8.59 (0.52)	6.5 (0.2) [e]
FT6	1.15 (0.09)	1.92 (0.10)	2.80 (0.19)	7.31 (0.99)	7.2 (0.2)
FT7	1.14 (0.08)	1.91 (0.09)	2.75 (0.08)	7.40 (0.69) [d]	7.3 (0.1)
FT8	1.06 (0.08) [a]	1.78 (0.08) [b]	2.68 (0.11) [c]	6.86 (0.86) [d]	7.5 (0.1)
Combined	1.14 (0.09)	1.90 (0.11)	2.80 (0.18)	7.47 (0.92)	7.2 (0.4)

[a] *FT8 different from FT5 ($p = 0.006$)*

[b] *FT8 different from FT7 and FT5 ($p \leq 0.008$)*

[c] *FT8 different from FT7 and FT5 ($p \leq 0.036$)*

[d] *FT8 and FT7 different from FT5 ($p \leq 0.047$)*

[e] *FT5 different from FT6, FT7, FT8 ($p < 0.015$)*

Table 3.4 Field-testing performance data for three jump types

Class	Squat Jump (cm)	Counter-movement Jump (cm)	Vertical Jump (cm)	CMJ vs SJ (%)	VJ vs CMJ (%)
FT5	16.8 (2.7)	19.4 (3.7)	23.5 (3.8)	15.0 (5) [d]	21.8 (8.5) [e]
FT6	22.4 (3.8)	24.2 (4.3)	28.1 (4.9)	7.6 (2.4)	16.5 (2.7)
FT7	24.9 (4.4) [a]	26.7 (4.3)	28.9 (5.0)	7.5 (4.9)	8.3 (2.6)
FT8	29.7 (6.5) [a]	31.9 (7.5) [b]	34.6 (8.3) [c]	7.1 (3.7)	8.5 (3.6)
Combined	24.0 (6.0)	26.0 (6.0)	29.0 (6.4)	8.7 (5.0)	12.4 (7.7)

[a] *FT8 and FT7 different from FT5 ($p \leq 0.017$)*

[b] *FT8 different from FT5 ($p = 0.002$)*

[c] *FT8 different from FT5 ($p = 0.019$)*

[d] *FT5 different from FT8, FT7, FT6 ($p \leq 0.05$)*

[e] *FT5 different from FT7 and FT8 ($p \leq 0.004$)*

3.3.c Jump tests

Table 3.4 shows the jump tests identified that FT8 and FT7 players jumped higher than FT5 players for squat jump ($d \geq 2.15$), but only FT8 players showed superior performance than FT5 for the counter-movement jump and vertical jump. No other inter-class differences emerged. Further analysis highlighted that FT5 players demonstrated the largest increases in jump height when body counter-movements and trunk and arm actions were permitted. These differences were in contrast to all other classes (FT5 v FT8, FT7, FT6 = $d \geq 1.62$).

3.3.d Jump and sprint performance relationships

Pearson's *r* correlation showed a number of significant ($p = 0.01$) correlates between jump and sprint performances (Table 3.5). In particular squat jump and counter-movement jump showed strong associations with 5 m and 10 m sprint times. Flying 20 m sprints showed weaker associations. Vertical jump performance showed weaker associations with sprints than the other two jump types.

Table 3.5 Pearson *r* correlations for jump type - sprint associations

	Squat Jump	Counter-movement Jump	Vertical Jump
5 m sprint	- 0.702	- 0.667	- 0.642
10 m sprint	- 0.712	- 0.682	- 0.650
Flying 20 m sprint	- 0.654	- 0.622	- 0.592

All correlations are significant (p < 0.01)

3.3.e Multi-Stage Fitness Test

Table 3.6 shows there were no differences in the total number of shuttles completed by each class in the MSFT. Final HR values suggest players' effort was maximal to exhaustion.

Table 3.6 Field-testing performance data for MSFT

Class	MSFT shuttles completed (n)	Final running speed attained ($m \cdot s^{-1}$)	HR_{max} ($beats \cdot min^{-1}$)
FT5	88 (6)	3.61	197 (7)
FT6	97 (12)	3.75	198 (3)
FT7	92 (13)	3.61	198 (7)
FT8	101 (18)	3.75	198 (5)
Combined	94 (13)	3.61	198 (6)

3.4 DISCUSSION

The present study is the first to evaluate physiological profiles of elite CP soccer players, using a battery of field tests, and investigate potential class differences. Previous CP soccer studies have focused on single components, such as isokinetic leg strength (Andrade et al., 2005), aerobic fitness and running economy (Kloyiam et al., 2011), speed agility (Reina et al., 2016), and jump performance (Camara et al., 2013; Yanci et al., 2016), but to date, no study has conducted a broader profile of CP soccer players. Previously, limited examination of potential differences between eligible classes had been conducted, with Reina et al. (2016) the only group to explore inter-class contrasts.

In this chapter, results showed that no inter-class differences existed for stature, body mass or sum of Skin-fold. Additionally, aerobic testing showed that no inter-class differences existed for shuttle run performance or predicted VO_{2max}. Differences were evident in tests that require anaerobic performance, greater force generation and coordination (speed and agility). Here, FT8 players were superior to FT5 players in all tests, and to FT7 players in some. FT6 players did not differ from any other class.

Most AB soccer studies have shown no differences in the anthropometric characteristics of players, with the exception of GKs (Davis et al., 1992; Arnason et al., 2004; Hencken and White, 2006; Sutton et al., 2009). Although playing position was not considered here, this study suggests that no inter-class differences exist in CP soccer. Body fat is most influenced by dietary intake and physical activity, and as the players were elite Paralympians with structured training and nutritional support, it is not surprising that no differences were found across the cohort.

Inter-class differences were evident across the range of anaerobic tests that assess activity closely related to game-defining moments (Rampinini et al., 2007; Bradley et al., 2010). FT8 players were quicker than FT5 players (all distances) and FT7 players (10 m and flying 20 m sprint). FT5 players also produced a lower V_{max} than any other class. The Grade 2-3 moderate, diplegic and spastic nature of CP that characterises the FT5 class compromises lower limb strength, and strength is an inherent component of speed (Larsson et al., 1979; Delecluse, 1997; Weyand et al., 2000), thus explaining the FT5 players' lower V_{max}, in comparison to the other classes. The dysfunctional nature of force development in the FT5 class during sprinting is most likely due to limited ROM, heightened co-contraction and spasticity in affected muscles (Poon et al., 2008; Hussain et al., 2014). Beckman et al. (2016) also identified reduced running performance in CP track athletes, demonstrating an even greater relationship between strength characteristics and speed than in AB athletes. FT7 class players are also affected by spastic CP, but in a hemiplegic fashion, so the lower sprint performances for this class are similarly attributable to this factor. Burtner et al. (1998), Goldstein (2001) and Leiber et al. (2004) have all demonstrated that spastic gastrocnemius muscle possesses impaired fibre recruitment, and the velocity dependent nature of spasticity is exacerbated during the demand for rapid fibre recruitment, while Hussain et al. (2014) found weaker gastrocnemius muscle in spastic hemiplegic CP players. Unlike FT5 players' performances, the 5 m sprint did not differ for FT7 players in comparison to FT8, it may be that the distance was too short to identify differences, or that the pronounced unilateral plantarflexion do not impair mechanics, when a heel strike is not an important aspect of acceleration (Reina et al., 2016). The FT6 class did not differ from FT8 in sprint performances, but FT6 encompasses 'mixed-CP' (CPISRA, 2011); spasticity is not a defining feature here, only a minor one, while a mixture of ataxia and athetosis dominate. This class has fewer issues with running and often presents a smooth running gait, unlike FT5 and FT7 classes. Ataxia and athetosis are not deemed to limit running actions as much as spasticity, which could account for the lack of contrasts found between FT8 and FT6 (CPISRA, 2011).

Agility testing in this study employed the Modified agility test (Sassi et al., 2009). This test was notably used by Reina et al. (2016) with CP players and has shown high levels of ICC (Sassi et al., 2009; Reina et al., 2016). In the current study, FT8 and FT7 players were faster than FT5, but not FT6 players. The results compared poorly to results for AB players in the same test (Reina et al., 2016). The ability to change direction, accelerate and decelerate over short distances is characteristic of soccer, so performance of this parameter could be indicative of performance potential in soccer (Stolen et al., 2005). Hemiplegic FT7 players with asymmetrical gait did not appear to be disadvantaged in this test, which involved four turns, possibly using their non-paretic side to good effect for turning. FT6 players also showed no differences compared to other classes. Although stopping and turning is often difficult, the running mechanics can be proficient for FT6 players, affected by 'mixed-CP'. In general, the present study is in agreement with Reina et al. (2016), although they found that FT8 differed from all classes in speed agility. Players in the current study were found to be faster than the CP players examined by Reina et al. (2016). The current study utilised players from one of the higher ranked nations in CP soccer. Higher levels of fitness are discriminating factors in successful teams in AB soccer (Mohr et al., 2003; Krustrup et al., 2005; Bradley et al., 2010), so this may account for the present study reporting performances higher than that of Reina et al. (2016).

Jump performance followed a similar pattern to sprint performance. FT8 players out-jumped FT5 players for all jump types. FT7 players also out-jumped FT5 players, but only for squat jump. As with previous tests, FT6 players did not differ from any class. Jump tests purport to evaluate anaerobic power and are underpinned by strength and coordination (Baker, 1996; Wisloff et al., 2004). Differences between FT8 players and FT5 players are in agreement with several other studies in Paralympic sport, where inter-class differences were found at the extreme ends of the spectrum, while adjacent classes exhibited overlaps in performance capacity (Hutzler et al., 1998; Molik et al., 2010; Morgulec-Adamowicz et al., 2011).

Yanci et al., (2016) studied jump performance, but did not examine inter-class differences, only reporting that CP players were unable to jump as high as AB players. The present study also showed CP players were not as proficient at jumping as AB players (Davis et al., 1992). Yanci et al. (2016) did however identify that CP players showed greater improvements in performance in counter-movement jump in comparison to squat jump than AB players. In the present study, FT5 players in particular, followed a similar pattern from squat jump to counter-movement jump to vertical jump. The likely reason for this is the particularly low initial squat jump in the FT5 players. The key determinant of squat jump performance is lower limb strength, whereas the counter-movement jump assesses leg power under slow-stretch shorten cycle, and vertical jumps permits upper body assistance to jumping (Baker, 1996; Maulder and Cronin, 2005). The present study also identified that a relationship exists between jumps and sprint performance. In particular, strong associations were found ($r > 0.70$) between squat jump and 5 m and 10 m sprints, with weaker associations found between the counter-movement jump, vertical jumps and sprints.

The results of the MSFT showed no inter-class differences. Aerobic fitness is considered an underpinning asset for anaerobic activity in soccer (Ekblom, 1986; Bangsbo, 1994; Balsom et al., 1994; Krustrup et al., 2005), and although CP and TBI do not have direct impact upon VO_2 or cardiopulmonary function, they do impair neuromuscular coordination (Myklebust et al., 1982; Damiano and Abel, 1998; Bax et al., 2005). The predicted VO_{2max} values in this study are markedly lower than those seen in elite AB soccer players (Tumility, 1993; Wisloff et al., 1998; Reilly et al., 2000b). Previous studies have identified that CP affects running economy and gait, and that more severe forms of CP elucidate a greater energy cost for walking and running (Unnithan et al., 1996; Keefer et al., 2004; Bar-O and Rowland 2004), but class impairment differences were not sufficient to discriminate between FT5-FT8 classes in the MSFT.

The severity of impairments characterising FT5, FT6 and FT7 players originate from different forms and topologies of CP, and lead to varying issues with stopping, turning and maintaining a symmetrical gait, all of which adversely affect running economy and elevate relative VO_2. Kloyiam et al. (2011) concluded that CP players have a poorer running economy than AB players and that is likely to be the cause of their underperformance, in comparison to AB controls. The less severe forms of CP associated with FT8 players should permit more economic movement patterns. As such, this class could be expected to operate at running speeds for a lower relative energy cost, possibly demonstrating greater aerobic power than FT5 players, at least. The MSFT did indicate a pattern towards FT8 players attaining greater shuttle run performances, but the nature of field-testing means it was unable to provide sufficient evidence for a more detailed analysis of performance. An alternative explanation could be that inter-class VO_{2max} does not differ and that differences in aerobic fitness are found in the capacity for work, as opposed to maximal power. Bangsbo et al. (1994) found that during the competitive season, elite AB players did not improve their VO_{2max} from that in pre-season. However, as a consequence of soccer training, improvements in lactate threshold did occur and the ability to recover from high intensity exercise was increased, without a concomitant increase in VO_{2max}, only aerobic capacity.

The lack of differences between classes is not unique. Previously, inter-class examination of wheelchair basketball players showed that aerobic testing is less sensitive to inter-class differences than anaerobic testing (Molik et al., 2010; Morgulec-Adamowicz et al., 2011), and although aerobic capacity in CP children has been shown to be impaired it is not impaired to an extent that might be expected from the motor impairments observed (Balemans et al., 2013). Balemans et al. (2013) found no differences across the GMFC spectrum for aerobic testing in children, only within the functional spectrum for anaerobic testing. Similarly, de Lira et al. (2010) found very strong associations between classification of wheelchair athletes and anaerobic test performance, and significant but weaker relationships with aerobic test performance. The results in this study suggest that overlaps of inter-class capability exist, in agreement with previous studies in wheelchair basketball. Hutzler et al. (1998), Molik et al. (2010) and Morgulec-Adamowicz et al. (2011) identified that adjacent classes often have matched performances in physiological testing, while those at the extremes of the classification range show the greatest contrasts.

3.5 CONCLUSION

The results of this study suggest that inter-class differences in CP soccer players are evident in anaerobic based performance assessments. FT8 players are defined in this respect and this aspect of soccer is associated with game-defining moments. Inter-class contrasts here are similar to those found in other studies examining the fitness of wheelchair athletes, where classes at the extreme ends of the impairment spectrum differ, but an overlap in capacity exists in adjacent classes, with regards to anaerobic activity. This is also similar to previous work in CP soccer players for agility activities, although the current study did not concur that FT8 are superior to all other classes; FT6 players, for example, did not differ from any other classes, possibly due to the different type of CP this class exhibits. Furthermore, aerobic testing did not identify any differences between the classes and although impaired running economy has previously been identified, it was not sufficient here to affect running performance and therefore predictions of aerobic power.

Soccer is a multidimensional sport, so the manner in which these performance variables interact will provide additional insight to complement isolated field test performances. The initial contrasts and similarities identified here require further exploration to establish how and in what manner the physical capacities of players manifest themselves in CP soccer match-play.

CHAPTER 4 - Study TWO

TIME-MOTION ANALYSIS OF PARALYMPIC CP SOCCER

4.1 INTRODUCTION

Study ONE identified the key differences and similarities in the physiological capacities and anthropometric characteristics of the four classes of the CP footballer during performance field-testing. No inter-class differences were identified for anthropometric characteristics or aerobic power. FT8 players distinguished themselves from FT5 in anaerobic tests involving jumping, sprinting and agility. However the performance profile of FT6 across the broad range of tests indicates that overlaps in performance exist across the class boundaries. The resultant data provides a foundation to examine whether comparable inter-class contrasts exist in competitive match-play when the demands of the sport are imposed.

Although CP soccer adheres to the FIFA Laws of the Game (FIFA, 2015) it includes specific participation by-laws and game adaptations. Consequently, there are multiple additional constraints placed upon the sport. Game specific constraints include an abbreviated match duration of 60 minutes and modified pitch dimensions within the limits of 70-75 m x 50-55 m with 2 x 5 m goals to accommodate the 7-a-side nature of the game. Additionally, laws within the game are different; throw ins can be one handed and underarm, and significantly there is no application of “Law 11 - offside” (CPISRA, 2013). CP soccer is played with mixed-class competition, where players from different ambulatory classes of CP participate alongside and in direct competition with each other. This aspect is modulated throughout with a participation by-law that, at the time of this study, stated that each team can field a maximum of two FT8 players while it is also mandatory to select a minimum of one FT5 or FT6 player at all times. There are no restrictions for FT7 players (CPISRA, 2013).

These law and rule modifications impose very different environmental, task and player constraints on the game (McGarry et al., 2002). It is therefore likely that the interaction of these three dimensions poses different physiological demands compared to the able-bodied (AB) game of 11-a-side soccer or the 5-a-side game of futsal. Studies in AB soccer have demonstrated such differences due to player number and pitch size manipulations (Owen et al., 2004; Kelly and Drust, 2009; Hill-Haas et al., 2011).

Currently there are no published time-motion analysis studies for disability football, but the research paradigm is now well established in AB soccer (Rampinini et al., 2007; Bradley et al., 2009; Di Salvo et al., 2010; Barnes et al., 2014). Contemporary work has utilised camera based tracking systems or individual player GPS devices to study the physical demands on players. Widespread AB research has investigated various playing levels, sex differences and youth soccer (Castagna et al., 2003; Mohr et al., 2008; Harley et al., 2010). More recently, a focus upon high intensity activity has developed (Di Salvo et al., 2009; Di Salvo et al., 2010).

High intensity activity in match-play is widely regarded as a key discriminating factor of playing level and training status (Mohr et al., 2003; Krustrup et al., 2003; Bradley et al., 2009). More specific focus has examined the temporal patterns of player movement and discriminated the positional demands for players (Di Salvo et al., 2007; Dellal et al., 2010). Subsequently, research and applied practice have informed training plans including team periodisation interventions. The monitoring of players' movements during match-play has also permitted a greater understanding of fatigue and the metabolic and energy demands of soccer (Bangsbo et al., 2006; Carling et al., 2008).

However, the benefits of AB soccer research may not be transferable to CP soccer. CP soccer is unique and the nature of mixed class competition and the capability of each class are of particular interest. Therefore, the aim of Study TWO was to explore the characteristics in elite competitive CP soccer with the use of time-motion analysis. The study examined the work rate of the players with a particular focus on contrasts between the classes.

4.2 METHODS

4.2.a Participants - 40 elite male soccer players with CP (Table 4.1) from four international teams consented to take part in the study. Ethics approval was obtained from the Department of Exercise and Sport Science ethics committee at Manchester Metropolitan University, and conformed to the guidelines set out in the Declaration of Helsinki. All participants were outfield players and the four competing nations were ranked in the top eight 7-a-side soccer teams in the world. Data are presented as mean (SD).

The CPISRA by-laws on the player class participation during match-play resulted in the FT5 and FT6 players commonly featuring as goalkeepers. The focus in this study was on outfield players, so the sampling from FT5 and FT6 players was pooled because the by-laws influence both classes in the same manner, and samples of outfield players from these two classes were very small. Conversely, FT7 and FT8 players tend to be outfield players so no such issue of small samples arose.

Table 4.1 Participants' characteristics

Class	Cohort size (n)	Age (years)	Body mass (kg)	Full match observations (n)
FT5/6	4	24 (8)	77.2 (1.6)	9
FT7	29	21 (6)	67.8 (9.2)	28
FT8	7	25 (10)	71.0 (3.3)	10
Combined	40	22 (7)	69.0 (8.5)	47

4.2.b Procedures - During the eight matches of the 2012 BT Paralympic World Cup (Manchester, UK) all participants wore a body vest fitted global positioning satellite (GPS) 10Hz device (MinimaxX S4, Catapult®, Australia) and a heart rate monitor (Team System, Polar, Finland) prior to taking part in their respective matches. The validity and reliability of these systems have been assessed previously (Johnston et al., 2013; Varley et al., 2012; Akenhead, 2013).

All matches were played in the afternoons on the same grass pitch adhering to CPISRA by-laws for 7-a-side soccer (CPISRA, 2011). Weather conditions throughout the tournament were dry and sunny (~18-22^{o}C, 50% relative humidity). Cloud cover was minimal, clear skies and no obstructions were present that restricted GPS signalling. The tournament followed a mini-league format followed by a Final and a 3rd / 4th position Play Off match. Data were collected throughout each match and only whole match samples were included for analysis (exclusion of data collected from players who were replaced by substitutes or who later entered the field of play as a substitute). All players were fitted with GPS and HR devices prior to the warm up.

The external load parameters recorded were: total distance travelled (m); distance travelled at high intensity (HI) (m), 4.9 – 6.4 m·s^{-1}; distance travelled at very high intensity (VHI) (m), >6.4 m·s^{-1}; frequency of HI and VHI activity, frequency of positive accelerations (ACC) >1.9 m·s^{-2}, and negative accelerations (DEC) >-1.9 m·s^{-2}. Heart rate (HR) data were collected and reported as mean HR, maximum HR attained (HR_{max}), total time spent at <75%, between 75 - 85% and >85% of HR_{max}. HR zones were based upon age-predicted HR_{max}. Data were also 'split' into four quarters (15 min periods) to permit analysis of temporal changes in behaviour.

Velocity thresholds for HI and VHI activity were set to account for the attenuated attainment of maximum velocity (V_{max}) by CP players. Previous studies' (Rampinini et al., 2007; Bradley et al., 2009; Di Salvo et al., 2010; Gregson et al., 2010; Harley et al., 2010; Carling et al., 2012) thresholds and activity terminology vary greatly; therefore previous thresholds, along with V_{max} data derived from Study ONE (flying 20 m test), provided the platform for the thresholds set in this study (see Appendix C.1 for a review of thresholds set in previous soccer studies). VHI activity was established to be 90% of V_{max} achieved by participants in Study ONE while HI activity was 70% of V_{max}. Acceleration thresholds (ACC and DEC) were set to capture what would be considered moderate to high accelerations and decelerations and within the accepted reliability range of the MinimaxX GPS units (Akenhead et al., 2013).

4.2.c Data Analysis - Due to the nature of the competitive match-play environment in which the data were collected, consideration was given to the time being added by match officials for stoppages in play. Quarter and whole-match data were converted from the uncorrected values recorded to *pro rata* values to provide data sets for 15-min quarter- and 60-min whole-match times. This permitted temporal analysis of appropriate variables to be made over equal time periods.

Using SPSS v22.0 (IBM, Chicago, Illinois), two-way ANOVAs were used to analyse the effects of player class (x3) and playing time quarters (x4). Subsequently, post-hoc comparisons were conducted on distance variables, accelerometry variables and time spent in three HR zones. One-way ANOVAs were also used to analyse V_{max} attained, total frequency and distance of HI and VHI activity, ACC and DEC activity and HR_{max} (cited in tables and figures). Greenhouse-Geisser adjustments were applied to account for any sphericity violations found in Mauchly's Test (Field, 2013). The alpha level was set at 0.05 and where significance was found, Cohen's *d* effect sizes (cited within the text) were calculated to support the ANOVA based contrast analysis.

4.3 RESULTS

4.3.a Total distance covered, VHI and HI distance covered

The total distances covered (Table 4.2) by players were different between classes and between match-play quarters. FT7 and FT5/6 total distance covered was 87% and 89%, respectively, of the total distance covered by FT8. FT7 and FT5/6 players did not differ from each other during any of the quarters of match-play. With the exception of the quarter periods either side of half time, distances covered per quarter were different and declined progressively during matches for all classes. Collectively, the three classes showed a 17.5% decline in distance covered from the first to the last quarter. With the exception of FT7 v FT5/6 contrasts, Cohen's *d* highlighted strong effect sizes throughout this aspect of the data (>0.8).

Table 4.2 Mean (SD) distances covered (m)

Class	Distance covered (m) per match quarter (min)				Total Distance (m)
	0-15 [b]	16-30 [c]	31-45	46-60	0-60
FT5/6	1541 (184)	1380 (185)	1410 (130)	1256 (226)	5642 (674)
FT7	1473 (239)	1347 (247)	1351 (235)	1237 (167)	5532 (814)
FT8 [a]	1748 (130)	1608 (172)	1582 (173)	1434 (248)	6343 (551)
Combined	1590 (201)	1456 (208)	1431 (178)	1322 (208)	5846 (672)

[a] *FT8 different from FT7 and FT5/6 in each quarter (p = 0.011 and 0.027)*

[b] *1st quarter different from 2nd quarter, 3rd quarter and 4th quarter for all classes ($p \leq 0.001$)*

[c] *different from final quarter for all classes ($p \leq 0.001$)*

There were no differences between the classes for whole match HI activity (Figure 4.1), however FT8 players covered greater distance at VHI activity than FT7 and FT5/6 (d = 1.26 and d = 1.13).

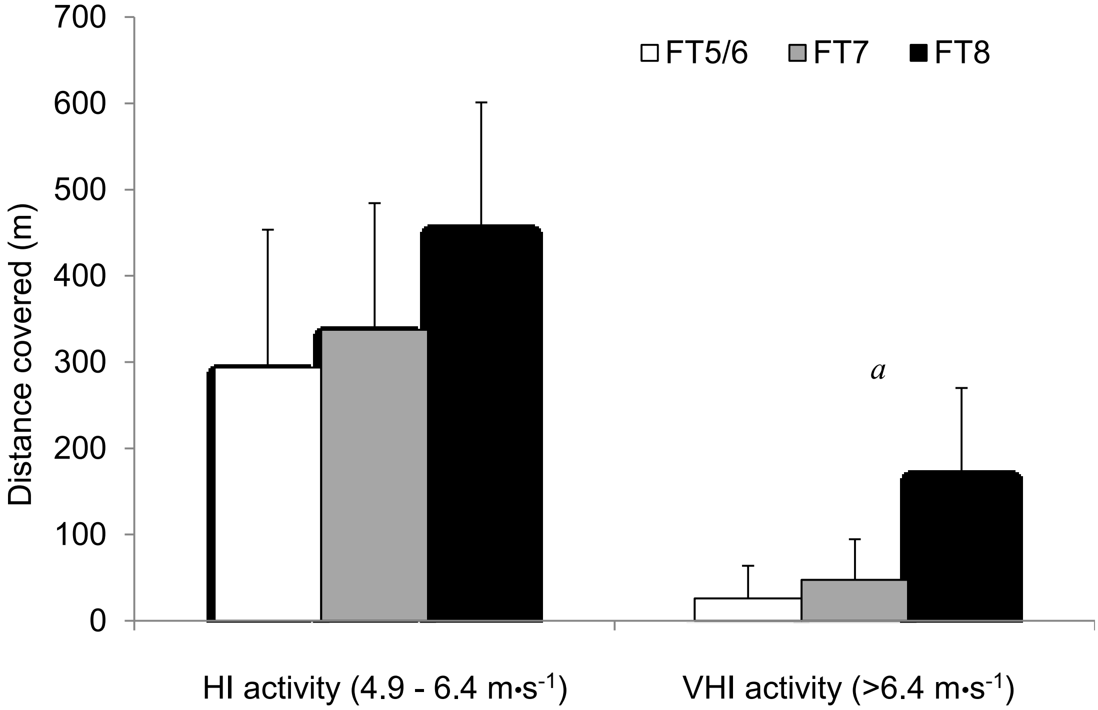

Figure 4.1 Mean distance covered in HI and VHI activity zones

[a] *FT8 different from FT7 & FT5/6 ($p \leq 0.041$)*

4.3.b Percentage contribution, frequency and pattern of VHI and HI to whole match activity

The percentage contribution of VHI activity (Table 4.3) to the total distance covered was significantly greater in FT8 than FT7 and FT5/6 ($d \geq$ 1.23). FT8 players spent a combined 9.9% of total match distance covered at HI or VHI activity, while FT7 and FT5/6 spent 7.1% and 5.7% respectively. FT8 players also engaged more frequently in HI and VHI activity when compared to FT7 and FT5/6 ($d \geq$ 0.82). FT8 players also attained higher V_{max} than FT7 and FT5/6 ($d \geq$ 1.54) while FT7 and FT5/6 did not differ. There were no differences between classes for the mean distance of each bout of HI and VHI activity.

Table 4.3 Maximum velocity, frequency of activity, mean distance per activity and percentage of total distance covered at HI and VHI activity

Class	Maximum Velocity ($m \cdot s^{-1}$)	HI Activity (4.9-6.4 $m \cdot s^{-1}$)			VHI Activity (>6.4 $m \cdot s^{-1}$)		
		Frequency	Distance (m)	% of total	Frequency	Distance (m)	% of total
FT5/6	6.73 (0.44)	23 (10)	14 (2)	5.2 (2.5)	2 (3)	13 (4)	0.5 (0.6)
FT7	6.97 (0.56)	26 (10)	13 (2)	6.1 (2.2)	4 (3)	14 (4)	1.0 (0.8)
FT8	7.74 (0.34)[a]	34 (10)[b]	13 (2)	7.2 (2.4)	12 (5)[b]	14 (4)	2.7 (1.7)[c]
Combined	6.96 (1.13)	27 (10)	13 (2)	6.0 (2.4)	5 (5)	13 (4)	1.1(1.3)

[a] *FT8 different from FT7 and FT5/6 ($p = 0.001$)*

[b] *FT8 different from FT7 and FT5/6 ($p \leq 0.04$)*

[c] *FT8 different from FT7 ($p = 0.008$) and FT5/6 ($p = 0.003$)*

The temporal pattern of the combined HI and VHI activity ($\geq$4.9 m·s^{-1}) (Figure 4.2) shows a decline in the frequency of this activity in FT8 players. FT8 players performed 30%, 15% and 29% less HI and VHI activity in the 2nd, 3rd and 4th quarters. For FT8 players, the 1st quarter was different from the 2nd and 4th quarters (*d* = 1.86).

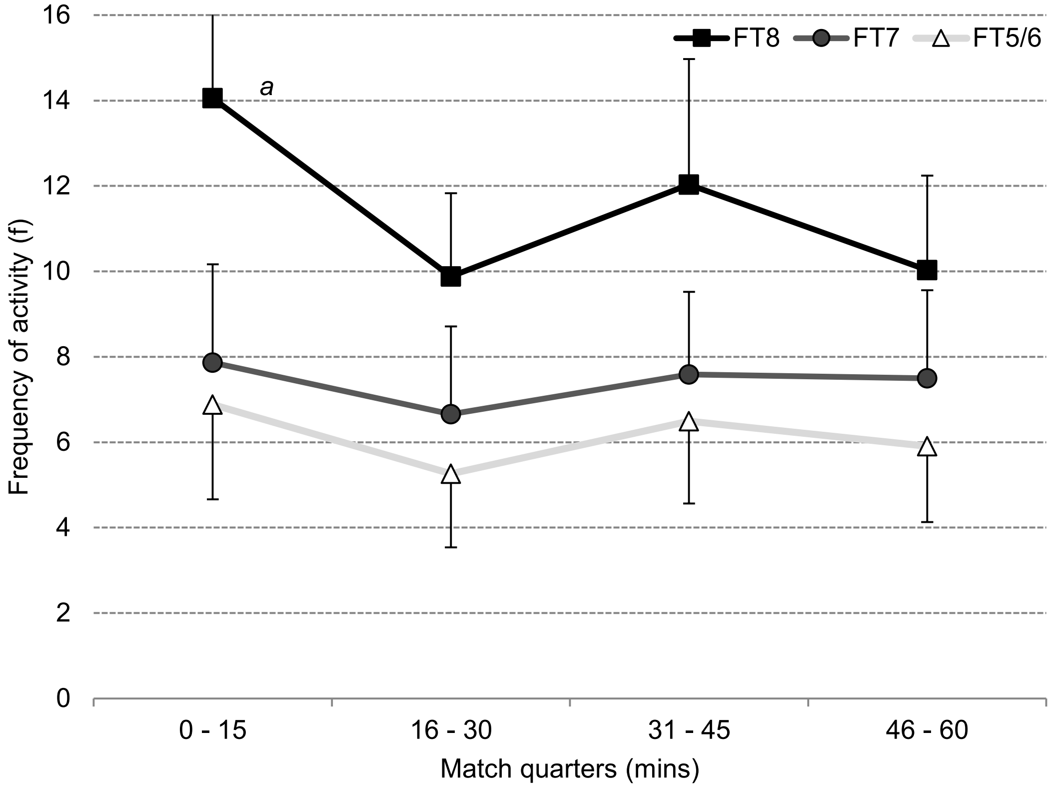

Figure 4.2 Mean frequency of activity (f) of the combined VHI and HI activity per match quarter (>4.9 m·s^{-1})

[a] *FT8 players 1st quarter is different from 2nd and 4th quarters ($p \leq 0.004$)*

The decline in FT7 VHI & HI performance (15%, 4%, 5%) and FT5/6 (24%, 6%, 15%) were not significant. FT8 data shows a ‘recovery’ rebound immediately after half time with improved performance in the 3rd quarter.

4.3.c Frequency and pattern of ACC and DEC during match-play

Table 4.4 shows acceleration data. Player classes did not differ from each other in the frequency of performed ACC but FT8 players performed more DEC than FT5/6 players (d = 5.59). There was a decline in the frequency of ACC and DEC over match quarters (d > 0.52 and d > 0.62) with FT8 players exhibiting the greatest decline from quarter 1 to 4 (d = 0.99 and d = 1.15). When analysing all classes combined, the frequency of ACC declined by 19.6%, 6.6% and 24% per quarter, while mean frequency of DEC declined by 10.7%, 10% and 20%.

Table 4.4 Mean (SD) frequency of ACC and DEC activity in match-play

Class	Accelerations (ACC) >1.9 $m \cdot s^{-2}$					Accelerations (DEC) >-1.9 $m \cdot s^{-2}$				
	0-15	16-30	31-45	46-60	Total	0-15	16-30	31-45	46-60	Total
FT5/6	14 (7)	11 (5)	13 (5)	11 (6)	49 (6)	16 (4)	14 (5)	14 (3)	13 (7)	57 (5)
FT7[b]	17 (6)	14 (6)	16 (6)	13 (5)	60 (6)	19 (6)	18 (6)	18 (6)	16 (4)	71 (6)
FT8[a]	19 (5)	16 (6)	18 (6)	14 (6)	66 (6)	23 (5)	21 (4)	22 (4)	17 (6)	83 (5)

[a] *1st and 3rd Quarter ACC different from 4th ($p \leq 0.043$); DEC different from FT5/6 in 1st, 2nd, 3rd Quarters ($p \leq 0.035$)*

[b] *1st Quarter ACC different from 2nd and 4th ($p \leq 0.048$); 3rd Quarter ACC different from 4th ($p = 0.034$); 1st Quarter DEC different from 4th ($p = 0.036$)*

4.3.d HR response to match-play

No differences were evident across the classes for maximum or mean HR (Table 4.5). However, the cardiovascular response to match-play did result in FT8 players spending 61% of time during match-play at >85% HR_{max}, which was more than both FT7 (39%; d = 3.51) and FT5/6 (31%; d = 4.91). FT7 and FT5/6 players did not differ (Table 4.5). The time spent at >85% HR_{max} during the first half was higher than the second half for all classes (d > 0.85) and there were no differences observed for the time spent at 75-85% HR_{max} zone.

4.3.e Results summary

The frequency of HI and VHI activity declines over the course of the match, with significant decrements observed for the FT8 players, but not in the other classes. A 'recovery' effect was evident in FT8 after a half time break. FT8 players performed a greater number of accelerative activities (ACC and DEC) but also showed the greatest declines in performance over the match time. There were no differences evident between the FT7 and FT5/6 players, and FT5/6 players also showed no signs of a decline in performance over time. FT8 players exhibited a greater HR response to match-play with more time at >85% HR_{max} and time spent at >85% HR_{max} declined in the second half for all classes.

Table 4.5 Mean (SD) time spent (mm:ss) in heart rate zones across match quarters

	<75 % HR_{max} [b]				75-85% HR_{max}				>85% HR_{max} [a]			
Class	0-15	16-30	31-45	46-60	0-15	16-30	31-45	46-60	0-15	16-30	31-45	46-60[c]
FT5/6	3:28 (3:32)	4:31 (4:50)	5:38 (4:06)	8:02 (5:05)	4:27 (2:16)	4:41 (2:41)	4:59 (2:04)	3:54 (2:10)	7:06 (5:02)	5:48 (4:15)	4:23 (3:32)	3:22 (3:47)
FT7	2:22 (3:08)	1:50 (2:55)	3:42 (2:55)	2:40 (3:05)	6:02 (3:34)	6:02 (3:29)	6:50 (2:17)	7:27 (2:31)	6:36 (4:46)	7:08 (4:39)	4:29 (3:28)	4:53 (3:59)
FT8	1:01 (0:31)	1:37 (2:27)	1:59 (3:09)	2:58 (4:05)	3:56 (1:47)	3:59 (1:51)	4:59 (2:46)	4:42 (1:48)	10:21 (1:53)	9:24 (3:14)	8:02 (3:58)	9:01 (3:58)

[a] *1st half time spent at >85% HR_{max} greater than 2nd half ($p \leq 0.015$)*

[b] *2nd half time spent at <75% HR_{max} greater than 1st half ($p \leq 0.021$)*

[c] *FT8 time spent at >85% HR_{max} greater than FT7 and C5/6 ($p = 0.05$)*

4.4 DISCUSSION

This study examined responses of CP players to competitive match-play through time-motion analysis. It is not possible to generalise the findings of studies conducted on AB players in 11-a-side soccer or futsal as CP soccer is inherently different due to the modifications to the environment and task constraints, coupled with the physical impairments associated with CP players. Consequently, this study investigated the demands placed on CP players and more specifically, examined the contrasts between disability classes to provide further insight into the differences and similarities observed in Study ONE.

The main findings were that FT8 players physically outperformed their FT7 and FT5/6 counterparts across most of the variables measured. It was found that FT8 players demonstrated an ability to cover more distance and a greater proportion of this distance was performed at HI and VHI activity levels. This was a consequence of more frequent efforts of HI and VHI activity. FT8 players also performed a greater frequency of ACC and DEC activity than FT5/6. Cardiovascular responses showed that FT8 players spent more time at >85% HR_{max}. Respectively, FT5/6 and FT7 players did not differ from one another in any of these variables. There was a pattern of decline in distance covered and frequency of efforts in HI, VHI, ACC and DEC across match quarters. Significant decline in performance occurred for the FT8 players on distances covered, ACC and DEC activity over four quarters of match-play. From a cardiovascular perspective, time spent at >85% HR_{max} declined (2nd half v 1st half).

There was a marked difference in the total distance covered by FT8 players compared to FT5/6 and FT7. Bradley et al., (2009) suggest that HI activity is a more useful indicator of player performance than total distance alone. Indeed HI and VHI activity have been previously associated with critical phases of play in other forms of soccer (Reilly, 1996). Research in AB soccer would suggest that physical performances at high intensities are strong discriminators of the standards of play and subsequent success (Mohr et al., 2003; Bangsbo et al., 1991) as well as an indicator of fitness levels (Krustrup et al., 2003 and 2005). It can only be hypothesised at this stage that the physical performance of FT8 players is linked to successful team play since no such literature existed in CP soccer prior to this thesis. FT8 players performed 9.9% of all activity at HI or VHI. This will have contained sharp movements, sprints and explosive efforts. The ability to sprint, change direction, accelerate and decelerate quickly over short distances are important movements characteristics of key performance indicators (KPIs) (Bloomfield et al., 2004) such as turnover of possession, pressing, tackling, intercepting, dribbling and supporting team play. In this study, FT8 players demonstrated similar work outputs to that of AB players in 11-a-side soccer (Bradley et al., 2009). Bradley et al., (2009) investigated high intensity running in the English Premier League and the FT8 players in the current study covered similar distances of HI and VHI activity and attained V_{max} that were akin to players in their study. Bradley et al., (2009) showed maximal velocities around 7.64 $m \cdot s^{-1}$ (FT8 = 7.74 $m \cdot s^{-1}$) with high intensity running contributing to 9.0% of total time (FT8 = 9.9%). FT5/6 and FT7 players were not similar to AB professional players in these parameters.

In HI and VHI activity distance covered, the differences observed between FT8 and FT7 and FT5/6 players can be attributed to the frequency of efforts rather than the distance covered per effort. There were no differences between the classes for the mean distance (m) of single bouts of VHI or HI activity however FT8 players executed VHI and HI activity more frequently. This suggests that the task and environmental constraints posed by the pitch dimensions, player numbers and the Laws of the Game (FIFA, 2015) dictate the distance travelled per bout of activity as opposed to the capability of the player. Studies have shown that manipulation of pitch size, player number and rule modifications influence the effective playing area per player, motor behaviours and the physiological demands placed upon players (Owen et al., 2004; Rampinini et al., 2007; Kelly and Drust, 2009; Hill-Haas et al., 2011).

It was highlighted that the V_{max} attained by the FT8 players was greater than the other classes, so it is likely they were able to exceed the VHI minimal threshold more easily and regularly. Work by Hussain et al. (2014) demonstrated in well-trained hemiplegic CP soccer players that the most significant contributor to impaired force development in paretic limbs was muscle activation. The lower distance covered, frequency of HI and VHI activity and V_{max} attained in FT5/FT6 and FT7 players maybe indicative of the severity of the neuromuscular impairments prevalent in these classes of CP. This is further supported by the frequency of accelerations (ACC and DEC) executed by the players and may also be evidence of differences in neuromuscular impairment observed between players' classes.

The data shows that FT7 and FT5/6 players covered similar distances to each other with a similar contribution of HI and VHI activity and similar frequency of ACC and DEC activity. FT7 players tend to present a range of severity of spastic hemiplegia (Grade 2-3). This can sometimes be with only minor lower limb impairment leading to an asymmetrical gait (CPISRA, 2013), while others may have very distinct upper and lower limb spasticity, which affects running economy through affected gait. A range of severity of impairment is also evident in the FT5 and FT6 players. For FT6 players, ataxia, athetosis and dystonia can be evident in diplegic and double hemi-plegic forms (Grade 2-3) that affects coordinative and balance capabilities (CPISRA, 2013) while FT5 players possess spastic diplegia and so have strength issues in both lower limbs leading to reduced sprint ability. The similarities in performances of FT5/6 and FT7 could be due to the severity of impairment overlapping, even though impairment type is different. Severity of impairment is a continuum-based characteristic but requires a cut point for assessment to determine whether classification results in FT5 or FT8, FT6 or FT8 and FT7 or FT8 (Reina, 2014).

The comparisons of data across the quarters show that for total distance there was a steady decline (Table 4.2) in all classes, with an attenuation of this decline in the 3rd quarter after the half time interval. The frequency of VHI, HI, ACC and DEC activity showed a similar pattern but was only significant for FT8 (Figure 4.2 and Table 4.4), while FT7 showed significant decline in ACC and DEC data from the 1st quarter (Table 4.4). It is likely that the interjection of the half-time interval (15 min) permits a physiological recovery via rehydration and energy replenishment. However, there is also time for a reduction in muscle temperature that has been shown to decrease performance (Mohr et al., 2003; Krustrup and Bangsbo, 2001). The aforementioned studies mostly used 5 min sampling intervals, so are likely to be more sensitive and show a greater effect of half-time recovery.

It is likely that dehydration, glycogen depletion and metabolic transition to fat metabolism are not an issue in CP soccer as the matches are only 60 minutes in duration. However factors such as increased core temperature, lactic acid accumulation and muscle ion homeostasis have all been cited as contributory factors to fatigue during a match in AB players (Krustrup et al., 2003; Mohr et al, 2005) and are equally complicit in CP players. The greatest decline in performance occurs in FT8 players. Mohr et al., (2003) observed that high level AB players complete 14-45% less high intensity activity in the final quarter with top players declining by as much as 43% over the course of a game. FT8 players in this study showed similar decrements. Mohr et al., (2003) also showed that lower standard players declined to a lesser extent. This mirrors the pattern here for FT7 and FT5/6 players.

The onset of fatigue exacerbates problems with neuromuscular coordination for individuals with CP (Keefer et al., 2004), so a decline in time-motion variables over the period of a match is not surprising. The greatest decline however occurs in FT8 players. Those players have a greater capacity for muscle activation and could produce greater muscle fatigue. FT8 players also spent more time at >85% HR_{max} especially in the first half. The greater capacity of FT8 players to recruit motor units would stimulate a greater CV response in order to deliver more O_2 and remove more CO_2. FT7 and FT5/6 players probably cannot challenge the CV system equivalently, due to greater neuromuscular impairment that prevents repeated attainment of short HI and VHI activity. Accordingly, FT7 players spent more time around 75-85% HR_{max} while FT5/6 spent increasingly more time at a lower HR. The findings align with findings by Molik et al. (2010) found similar fatigue issues in the least impaired wheelchair basketball players, capable of greater anaerobic work capacity but significant declines in performance over time.

The progressive decline in time spent at >85% HR_{max} during a match reflects the decline in distances covered with the exception of the last quarter where an elevation was observed. Muscular fatigue, normally associated with reduced distance covered is likely to be exacerbated by limitations to muscle function in spastic, ataxic and athetoid CP. Commonly, CP impairments have been shown to alter gait patterns and display a relative increase in energy expenditure (Keefer et al., 2004; Maltaise et al., 2005). More time at >85% HR_{max} in the 4th quarter in comparison to the 3rd quarter may simply reflect the reduced intensity in the 3rd quarter compared to the rest of the match.

It is noticeable that FT5/6 contributed to only 8% of the outfield players, but 50% to the goalkeepers in the tournament. In most cases, teams elect to play their mandatory FT5/6 player as goalkeeper, while FT8 and FT7 players assume the outfield positions. The data suggest that the outfield FT5/FT6 players might be identified by the coaches as capable of competing with FT7 players prior to selection, so the potential impairment issues of diplegia, ataxia and athetoid states are not evident in match-play. FT5/6 and FT7 players also engaged in HI and VHI activity with similar frequency and attained similar V_{max}. This may indicate that the severity of neuromuscular impairments in these outfield players were similar between classes, even though the type of impairment differs.

The study interpretations must be mindful of the dynamics of the games and the influence of specific modified by-laws. FT5/6 players are rarely substituted because one must play at all times and teams often prefer a squad with a second FT5/6 as a goalkeeper, while substitutions of FT7 and FT8 players are more common. The use of substitutes towards the end of a match could lead to perturbations in match-play characteristics as teams attempt to equalise or win the match. Substitutes perform 63% more sprints and 25% more HI runs in the latter stages of matches (Mohr et al., 2003). However with the 7-a-side nature of the sport, inclusion of substitutes' data would dilute the patterns of work rate in the latter stages of matches, so this study focused upon complete game data only.

4.5 CONCLUSIONS

It is generally accepted in AB football that high intensity activities such as high speed running and sprinting are significant discriminators between standards of play and levels of fitness (Mohr et al., 2003; Krustrup et al., 2003). The HI, VHI, ACC and DEC data suggests that in aspects of the game associated with defining moments, FT8 players are able to move faster, more often and over greater distances, making them a physically superior force in matches. In fact, it could be argued that FT8 players in this study performed at similar levels to AB players. Conversely, in this study, FT5/6 are comparable to FT7 players, possibly due to overlaps in impairment severity irrespective of impairment type. Consequently, FT8 players significantly outperformed FT5/6 and FT7 players.

The milder impairments associated with FT8 players led to performances that were superior to FT7 and FT5/6 players. FT7 and FT5/6 players, although affected by different types of CP, exhibit a broad range of severity of impairment, so it is possible for FT5/6 players to match or exceed the physical performances of FT7 players and vice versa. The CPISRA classification system discriminates between types and topologies of CP and assesses the severity of impairment but does not necessarily prevent overlap in capability of FT5–FT7 players. It is only the classification cut-point that on the continuum of impairment severity that seems to influence contrasts in performance between FT8 and the other classes.

The final aspect in classifying a player is an assessment of their capabilities in competitive match-play, i.e. how the player functions within the sport itself. To this end, Study THREE will investigate the key performance indicators (KPI) of individual players during match-play to establish whether the physiological contrasts already observed between classes are borne out in the execution of soccer-specific skills observed within matches.

CHAPTER 5 - Study THREE

TECHNICAL ANALYSIS OF CP SOCCER PLAYERS DURING COMPETITIVE MATCH-PLAY

5.1 INTRODUCTION

Study TWO identified distinct contrasts in work rates between the different classes during match-play. Most notably, FT8 players ran further, and executed more VHI, ACC and DEC activity than their FT7 and FT5/6 counterparts. They demonstrated a greater capacity to maintain HR above 85% HR_{max}, but also declined in performance over the course of matches. Thus inferring greater movement capability but also greater fatigue. Concomitantly, FT7 and FT5/6 outfield players did not differ in any of these variables.

Evidence suggests the dynamic, explosive activities, characterising the superiority of FT8 in Study TWO and Study ONE, are associated with game-defining moments in AB soccer and discriminate between standards of play (Mohr et al., 2003; Krustrup et al., 2003; Rampinini et al., 2009). Technical soccer skills are often linked to more high intensity activity (Reilly, 1996; Stolen et al., 2005; Bangsbo et al., 2006), so it is common for KPIs to be analysed to describe and quantify the impact players make during matches (Hughes and Bartlett, 2002). To date however, there has only been one notational analysis study that has examined CP soccer. Yanci (2015) examined goal scoring in the Spanish CP soccer league but with limited analysis, defining only the basic characteristics of goals scored (open play, set plays, pitch area, 1st or 2nd half). The study did not report technical skills nor the player-class breakdown and hence no data exists regarding these in CP soccer. In addition, the study did not report reliability or outline the operational definitions for KPI.

In AB soccer it is common to assess in-possession and out-of-possession KPIs (Jones et al., 2004; Redwood-Brown et al., 2008; Bradley et al., 2013). Passing, shooting, crossing, dribbling, running with the ball, heading, tackling, intercepting and blocking are terms commonly cited in the literature as KPIs for players (Dellal et al., 2010; Barnes et al., 2014), and are often analysed for frequency and relative success rates (%) (Hughes and Bartlett, 2002; MacKenzie and Cushion, 2013). However, with no definitive glossary of terms, it is imperative that analysis systems include operational definitions and measures of reliability, and external validity for scientific credibility (O'Donoghue, 2007; Sarmento et al., 2014; James et al., 2007). A broad array of KPI definitions, ambiguous reliability and validity are some of the issues that make it difficult to directly apply the current literature to CP soccer (Mackenzie and Cushion, 2013; Carling et al., 2014). Additionally, the manipulation of task and environmental constraints changes the dynamics of a sport and the alterations to pitch-size and player numbers in SSG encourage greater or lesser player interaction with each other and with the ball (Kelly and Drust, 2009; Dellal et al., 2012; Vilar et al., 2014). CP soccer utilises a larger pitch area to player ratio (321 m^2 per player) than futsal (100m^2) (FIFA, 2014) and 11-a-side soccer (79 m^2 to 94 m^2) (Fradua et al., 2012). This may provide players with greater time and space to make decisions during matches. Furthermore, the omission of Law 11 (Offside) is likely to alter the interaction between task, environment and player and therefore influence the observed behaviours (Frencken et al., 2013; Silva et al., 2014). With this in mind, it is pertinent to gain an understanding of the technical characteristics exhibited by players during CP soccer for the advancement of coach understanding, skill development and team training (Lieberman et al., 2002).

The importance of undertaking technical analysis in CP soccer is further reinforced, as the final component of classification involves assessment of players, who are 'under review', during competitive matches (Reina, 2014). With no objective data available, classification currently relies upon the experience and expertise of the assessor and could be prone to subjectivity (Reina, 2014). The 'cut-point' assessment decision (Reina, 2014) between FT8 and the other classes is critical to a player and their team, as by-laws restrict FT8 players' while promoting FT5 and FT6 participation. Quantifying player activity in matches will assist in reaching final classification decisions through the use of more evidence-based assessment and simultaneously satisfy the IPC's ambitions for greater clarity in classification (Tweedy and Vanlandewijck, 2011; Reina, 2014; IPC, 2015).

Consequently, the aim of Study THREE was to examine the technical skills of CP players during competitive match-play and subsequently to examine any inter-class contrasts.

5.2 METHOD

5.2.a Sampling and Participants – All 20 matches of the 7-a-side soccer tournament at the 2012 Summer Paralympic Games were analysed. The sample included all outfield players (n = 80) from the eight competing nations across the four classes of impairment at the event. Match footage was provided by the Paralympic broadcaster and was publically broadcast live on a variety of media platforms. Ethical approval for the study was obtained from the ethics committee of Manchester Metropolitan University, and conformed to the guidelines set out in the Declaration of Helsinki (2000).

All matches were played at the Riverbank Arena, London, on a water-based artificial turf pitch. Pitch dimensions were 55 m x 70 m therefore the pitch area to player ratio provides 321 m^2 of space per player. Matches took place during daylight hours in the month of August (Temp: 18^{o}C (4.6); RH: 61% (19)). Table 5.1 shows information regarding the sample of players across the CPISRA classes. Individual player class data was available from the official IPC Team and Match Reports. Data are presented as mean (SD).

Table 5.1 Participants and tournament minutes played (outfield players)

Class	Players (n)	Age (years)	Number of Matches played
FT5	5	24 (4)	22.0
FT6	4	26 (5)	10
FT7	48	28 (7)	145
FT8	23	24 (5)	72
Combined	80	26 (5)	241

5.2.b.i Procedures – development of a notational coding system; a notational coding system was developed for use with Studiocode® (v9.5.1, Sportscode) notational analysis software for Apple MacIntosh and validated with inter and intra-observer agreement to assess a series of KPIs that permitted the objective observation and analysis of individual player involvement in general play.

Operational definitions permit the establishment of reliability of the observer and external validity of the coding system (Hughes and Franks, 1997). KPIs were established to evaluate in-possession and out-of-possession skills. Most of the KPIs are common terms within AB literature although variation in terminology is conspicuous (MacKenzie and Cushion, 2013). The more specific KPI terms of 'low-risk' and 'high-risk' pass in this study were employed in order to evaluate passes that may be penetrative in nature but also risk the loss of possession for the team in question. James et al., (2002) used similar KPIs but did not provide operational definitions. An explanation of all KPIs is presented in Table 5.2.

Table 5.2: KPIs and observer operational definitions

KPI	Operational definition	Successful / Unsuccessful
Low-risk pass	*Passing the ball to a team mate using feet, on the ground, without it penetrating between or behind opponents*	Received by a team-mate, retained possession
		Regained by the opposition or ball out of play
High-risk pass	*Passing the ball to a team mate with a ball flight in the air or penetrating closely between or behind opponents or using volley, head or chest pass*	Received by a team-mate, retained possession
		Regained by the opposition or ball out of play
Shot	*An attempt on the opponent's goal to score with any body part or technique*	Attempt is on-target, no further interference in the ball flight would have led to a goal scored
		Attempt is off-target, no further interference in the ball flight would have led to a goal kick.
Dribble	*An attempt to travel with the ball past an opponent maintaining individual possession of the ball*	Moving past an opponent and maintaining possession
		Conceding possession or the ball going out of play
Tackle	*A successful attempt to take the ball directly from an opponent*	Successful in dispossessing the opponent
Intercep-tion	*The successful cutting out of an opponent's pass*	Successful in dispossessing the opponent

5.2.b.ii Procedures – establishing reliability of the coding system; the analysis system underwent checks for reliability and external validity with intra-observer reliability and inter-observer agreement analysis. The author conducted a test-retest analysis 14 days apart on a single match for intra-observer reliability (k^1) and inter-observer agreement (k^2) to establish external validity. For inter-observer agreement a post-graduate performance analysis student was trained on the system prior to participating in the inter-observer agreement analysis.

The analysis included 560 separate events over all KPIs and resulted in a kappa co-efficient for intra- and inter-observer reliability of $k^1 = 0.89$ and $k^2 = 0.88$ respectively. Furthermore, scrutiny of specific KPI observer differences concluded that discrepancies were not the consequence of issues with any individual KPI and so the whole system was accepted as possessing very strong reliability and validity.

5.2.b.iii Procedures – match observations; the NA process comprised of observing each match in its entirety on two occasions from the point of view of one team then the other. All matches (including the reliability testing) were observed at 50% of real time speed to facilitate accurate observations.

5.2.c *Data management and data reporting* – The information gathered (Table 5.2) on each KPI permitted the calculation of success rates (%) for each class. Additionally, KPIs were normalised to derive 'occurrence per match' values for each class of player. This was achieved using the minutes played in each match by each class.

Several one – way ANOVAs were performed (SPSS v22.0) for inter-class contrasts with Bonferroni correction for post-hoc pairwise comparisons to reduce the chances of Type I errors when using multiple comparisons on a single data set. Alpha was set at 0.05. Any violations to the homogeneity of variance of the data were detected by Levene’s test and an adjustment to the alpha level was made with post-hoc analysis using Games-Howell, as this has been shown to be effective with uneven or small samples with unequal variance (Field, 2013). KPI inter-class contrasts were supported with the calculation of mean differences using Cohen's *d* effect sizes and accompanying qualitative descriptors (Cohen, 1988).

5.3 RESULTS

5.3.a In-possession KPI

Table 5.3 shows relative success rates (%) for each in-possession related KPI. There were no inter-class differences evident in either low-risk pass % or high-risk pass %. FT8 and FT7 players possessed a greater shot success rate than FT6 ($d \geq .82$). No inter-class differences were evident for dribble success %.

Table 5.3 Mean percentage success rates (SD) for each KPI for a typical player of each class

Class	Low-risk pass	High-risk pass	Shot	Dribble
FT5	88.9 (13.6)	48.3 (22.0)	20.8 (25.0)	27.6 (21.4)
FT6	90.5 (14.8)	47.0 (30.0)	11.2 (20.0)[a]	32.6 (43.5)
FT7	92.8 (5.0)	60.1 (11.5)	34.0 (14.8)	50.1 (12.6)
FT8	94.4 (4.7)	57.0 (8.8)	35.8 (11.6)	52.3 (14.8)

[a] *FT8 and FT7 different from FT6 (p = 0.018 and p = 0.034 respectively)*

KPIs were also analysed as 'occurrences per match'. Figure 5.1 illustrates that a typical FT8 or FT7 player executed a greater number of low-risk passes and successful low-risk passes ($d \geq 1.11$) than FT5 players per match. These figures show that FT5 players performed 40% fewer successful low-risk passes per match than FT7 and FT8 players.

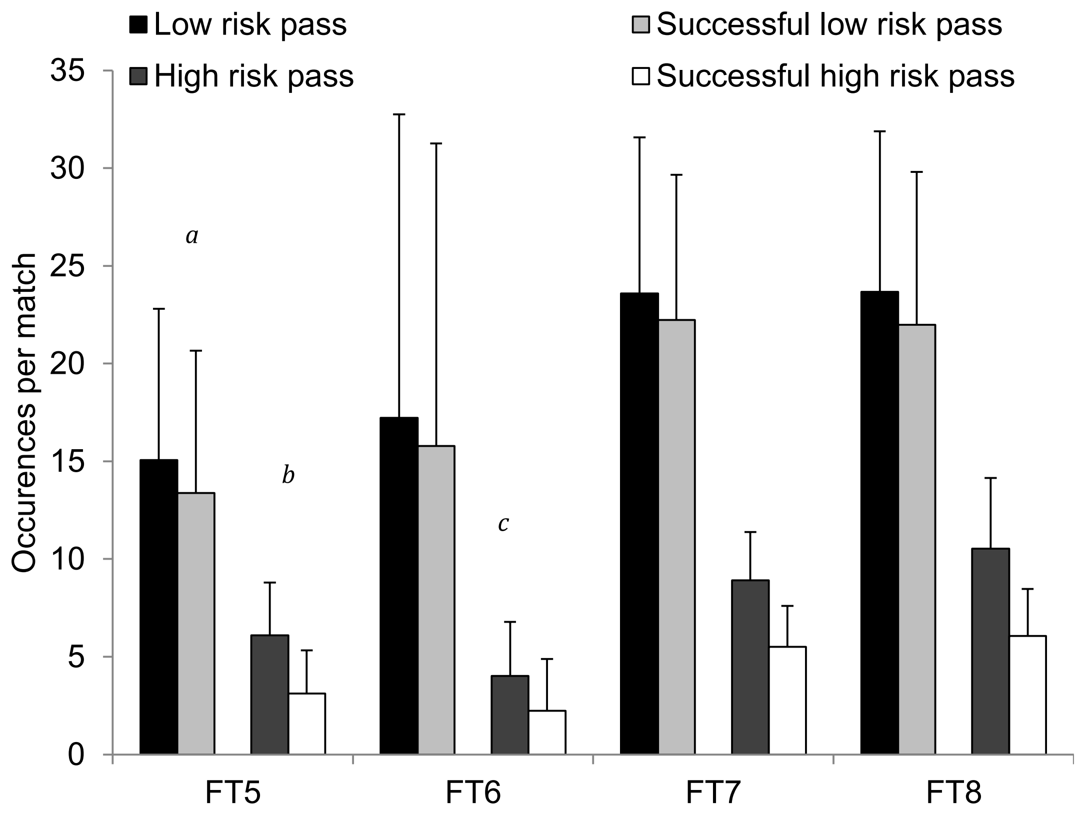

Figure 5.1 Mean (SD) low and high-risk pass occurrences per match for a typical player of each class

[a] *FT5 different from FT7 and FT8 for low-risk passes and pass success ($p \leq 0.039$)*

[b] *FT5 different from FT7 and FT8 for high-risk passes and pass success ($p \leq 0.05$)*

[c] *FT6 different from FT7 and FT8 for high-risk passes and pass success ($p \leq 0.003$)*

Similarly, FT8 and FT7 players executed more high-risk passes and more successful high-risk passes than FT6 and FT5 players ($d \geq 1.16$). These figures show that FT5 and FT6 players typically performed 44 – 63% fewer successful high-risk passes than FT7 and FT8 players per match.

FT8 players executed more shots than FT7 and FT5 players with large effect sizes evident against all classes ($d \geq 0.99$) while FT7 players executed more shots than FT5 ($d = 2.19$). FT8 and FT7 players also executed more shots on target (successful shots) than their FT5 and FT6 counterparts ($d \geq 1.26$) (Figure 5.2).

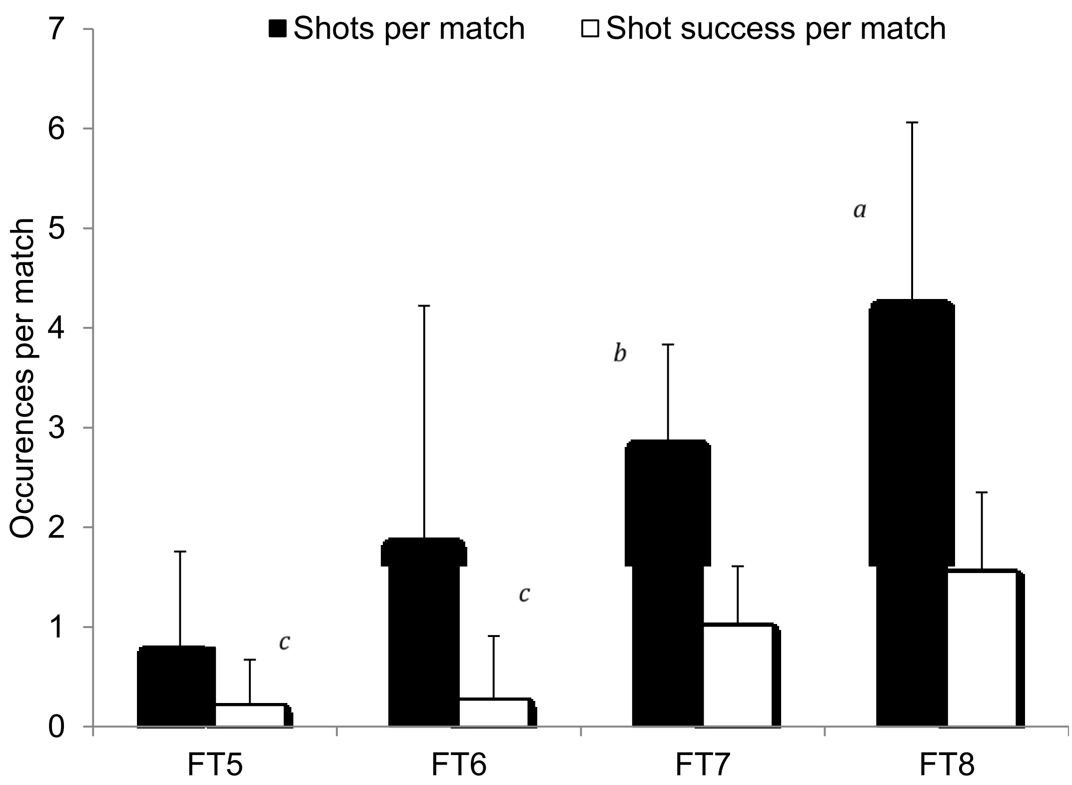

Figure 5.2 Mean (SD) shot occurrences per match for a typical player of each class

[a] *FT8 different from FT5, FT6 and FT7 for shots per match (p ≤ 0.043)*

[b] *FT7 different from FT5 for shots per match (p ≤ 0.0001)*

[c] *FT5 and FT6 different from FT7 and FT8 for successful shots per match (p ≤ 0.023)*

FT5 and FT6 players executed a shot on target approximately every four matches while FT7 and FT8 were successful in this KPI at least once every match. FT5 and FT6 players executed 80% fewer shots on target than FT7 and FT8 players. In addition, FT7 players executed 35% fewer successful shots than FT8.

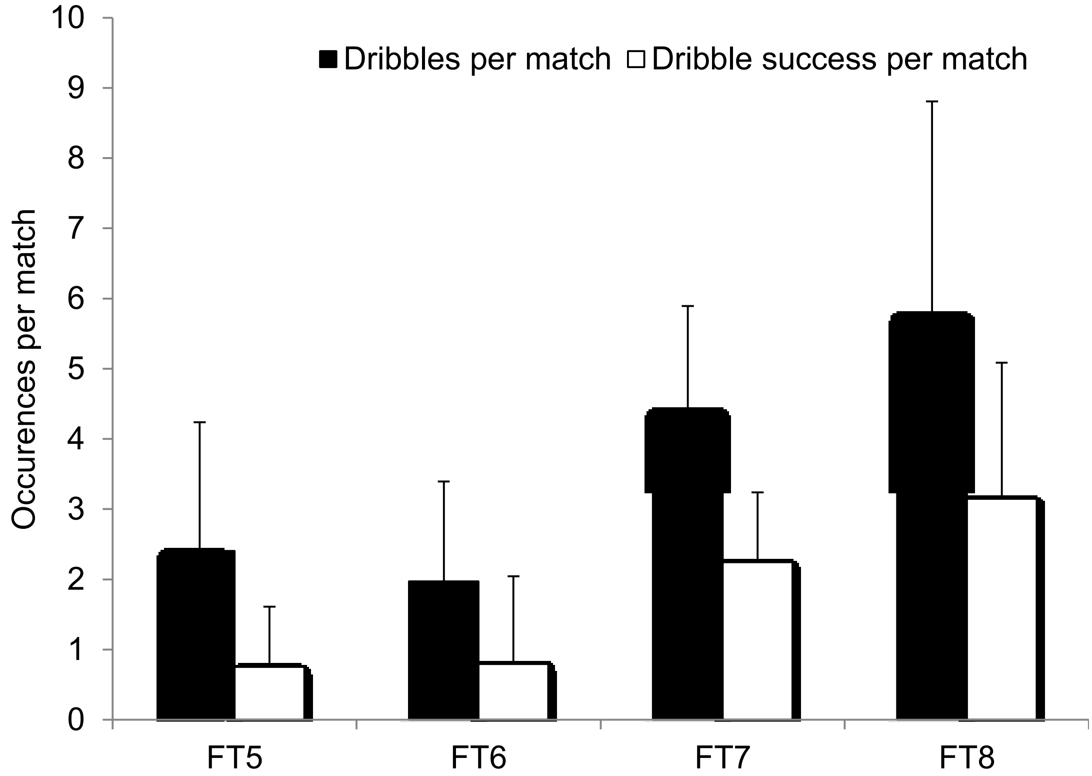

Figure 5.3 Mean (SD) dribble occurrences per match for a typical player of each class

[a] *FT5 and FT6 different from FT7 and FT8 for dribbles and successful dribbles (p ≤ 0.037)*

FT8 and FT7 players executed a higher number of dribbles and more successful dribbles than FT6 and FT5 players ($d \geq 1.28$) (Figure 5.3). Therefore FT7 and FT8 players typically executed at least two successful dribbles every match.

5.3.b Out-of-possession KPI

With regard to the out-of-possession related KPIs, there were no differences evident between the classes for tackles or interceptions (Figure 5.4).

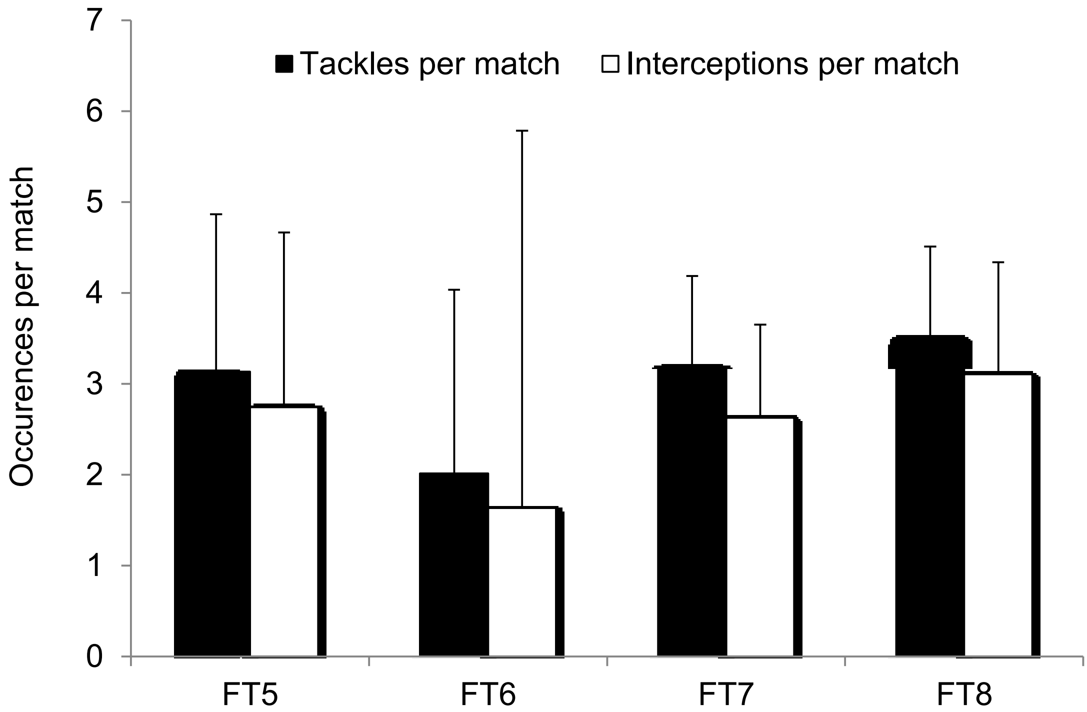

Figure 5.4 Mean (SD) tackles and interceptions per match for a typical player of each class

5.3.c Results summary

FT8 and FT7 players executed more passes and more successful passes per match than FT5 or FT6 players. FT8 and FT7 also executed more shots, shots on target, dribbles and successful dribbles than FT5 and FT6 players. FT8 and FT7 players do not differ in any aspect of the attacking individual KPIs except for the execution of shots, where FT8 executed more. For out-of-possession related KPIs, no differences existed between the classes for tackles or interceptions.

5.4 DISCUSSION

This study offers an insight into player involvement and relative success in match-play. The main findings of the study were that there were no differences between the classes with regard to success rates (%) for each KPI (the only exception being lower shot success for FT6). When considering KPI actions per match, FT8 and FT7 players performed a greater number of actions than FT5 and FT6. However, there were no inter-class differences for tackles or interceptions. Overall, FT8 and FT7 players have greater involvement in ball possession and execute a greater number of success actions than FT5 and FT6 players.

The success rates of KPIs (%) in this study suggest that player class does not affect the relative level of performance of technical skills. FT5 and FT6 players are diplegic impaired, possibly suffering with ataxia, athetosis or spasticity while FT7 are hemiplegic, suffering spasticity in upper and lower limbs. Players with milder symptoms of all forms of CP are ultimately classified as FT8 (Reina, 2014). The impairment variations observed in the population inevitably lead to unique movement issues and in turn, unique issues with executing technical skills. Previous AB studies have identified contrasts between different standards of soccer for the success rates of skills such as passing, dribbling and shooting (Rampinini et al., 2009; Andersson et al., 2010). Similar contrasts have been identified with differences observed in the physical capability of players at different standards of soccer (Bangsbo et al., 1991; Mohr et al., 2003; Mohammed et al., 2014), yet the data in this study shows no inter-class differences for KPI success rates. Therefore, it seems the inter-class functional differences observed earlier in this thesis have not led to differences in the success rates of technical KPIs in matches. The successful execution of KPIs by classes associated with greater severity of impairment must be attributed to other factors.

Although this type of study cannot measure decision-making by players during the matches, it is an element of skill that may provide possible explanation for the similarities in KPI success rates across classes. Before executing any technical skill, a performer must first make a decision. Decision making in sport is based upon the processing of information from three sources; the task, the environment and the performer (Araujo et al., 2006). The decision to pass, dribble or shoot considers the interaction of all three dynamic sources of information and a correct decision will result in a successful outcome such as the team maintaining possession of the ball or possibly a shot at goal (McGarry et al., 2002; Grehaigne et al., 1997). Participants in this study were all elite players from the top eight ranked nations in CP soccer, consequently they possess a combination of awareness of their own physical and technical capabilities and are likely to possess sound game understanding (Williams, 2000). Technical skill level may vary between players, not least due to impairment and subsequent functional issues, but the level of understanding acquired through playing experience serves to inform each player of what their skill level affords them to execute effectively and what it does not in a given situation (Vaeyans et al., 2007; Grehaigne et al., 1997). It could be possible that these elite players from across the class spectrum possess similar capacity to selectively attend to, recognise, analyse and interpret visual information (Abernethy, 1987; Reilly et al., 2000a). For instance, a player in possession of the ball will select an action based upon what that moment in time affords him. For a FT5 player with impaired leg strength this maybe a short 10 m pass, but for a more capable FT8, he may choose a long-range pass. Both players successfully complete the desired action. What was afforded to the FT8 was not afforded to the FT5 and so his choice is different but the outcome is the same.

In the current study, pass success rates (combined low and high-risk passes) of the whole cohort ranged from 78.0% (FT5) to 85.3% (FT7). These data show high performance levels when compared to previous studies in AB soccer. Bradley et al. (2011 and 2013), Carling and Dupont (2011) and Dellal et al. (2010 and 2012) report passing success rates in a lower range from 68.2% to 78.8%. It is possible that differences in the playing area to player ratio may account for this. The individual playing area available in CP soccer is 321 m^2 per outfield player, when accounting for the off-side law the individual playing area for 11-a-side AB soccer is much less and can range from 79 m^2 to 94 m^2 (Fradua et al., 2012). The playing area per player available in CP soccer is also greater than futsal (100 m^2) (FIFA, 2014). The larger playing area available to CP players affords more time and space to make decisions and execute skills. Offensive team shape will occupy a larger effective playing space and so increase the distances between ball carriers and defenders (Grehaigne et al., 1997; Davids et al., 2013). This will allow execution of passes with a greater likelihood of success, as seen in other SSG studies (Vilar et al., 2014; Travassos et al., 2011).

While success rates (%) provide useful insight, the frequency of involvement by a player is also pertinent to a greater understanding of player performance (Hughes and Bartlett, 2002). The typical occurrence of each KPI per match provides useful information given that class participation is strictly managed by CPISRA by-laws. Player class involvement in match-play may provide another dimension with which to examine potential class contrasts.

This study showed that a typical FT8 or FT7 player executed more in-possession KPIs than FT6 or FT5. FT8 and FT7 players executed more passes and more successful passes per match than FT5 and FT6 players. Contrasts regarding high-risk pass execution were most revealing. High-risk passes are penetrative and most damaging to the opposition as they are most likely to lead to perturbations in play and attempts on goal. Conversely, they are also most likely to lead to a loss of possession. Partridge et al. (1993) observed that in relation to collegiate sides, senior teams execute more risky passes in an attempt to create more scoring opportunities. However, similar to FT8 and FT7 in this study, James et al. (2002) concluded that it is the more skillful players within teams who play more 'risky' passes rather than it being a whole team strategy. The data for shots and dribbles further highlighted FT8 and FT7 players' dominance over their counterparts in the FT5 and FT6 classes and suggests that FT8 and FT7 players maybe more critical to the overall attacking success of the team.

High-risk passing, shooting and dribbling have also been associated with high intensity activity by players (Reilly, 1996; Bangsbo et al., 2006; Rampinini et al., 2009). They require quick executions and explosive movements to accelerate, change direction or strike the ball with power. The preceding two studies in this thesis have examined a number of parameters associated with physiological characteristics where FT8 players have been identified as superior to other classes in many ways, while FT7 players have also shown superiority over FT5 and FT6. A more detailed discussion on potential associations between specific physiological and technical aspects of CP soccer will follow in Chapter 7; however, there seems to be a strong case for a similar association here as in AB soccer.

Surprisingly, inter-class contrasts were not evident for out-of-possession KPIs. Tackles and interceptions by all classes showed players engaged in two to four tackles per match and two to four interceptions per match. Defensive actions require players to first make decisions based on the relative distances from their opponents and the ball, evaluating the speed of movement of both and then executing an action of tackling or intercepting (Travassos et al., 2011; Vilar et al., 2014). It would seem reasonable to suggest that physical capability would contribute to the frequency that out-of-possession KPIs were executed. However, the data illustrated large variance in these KPIs and suggests these vary greatly from match to match. This is a characteristic that has been observed previously (Bush et al., 2015) where the state of the match and the standard of the opponent are co-variables influencing defensive tactics (Rampinini et al., 2007; Lago-Penas and Dellal, 2010) and therefore may have contributed to an absence of inter-class contrasts in this study.

5.5 CONCLUSION

The combination of success rate % and ‘occurrences per match’ as methods to report KPI observations has led to a number of interesting contrasts. With the exception of FT6 players’ shot success rate, players did not differ in their ability to execute successful KPIs. Unlike physical movements, the decision-making aspect of skill execution is unencumbered by impairment and so players across the class spectrum are capable of making similarly successful decisions. Interestingly, the KPI success rate in this population was higher than previously seen in AB soccer and futsal but previous research supports the conclusion that the CP soccer pitch area to player ratio provides a greater amount of time and space to make decisions and execute appropriate skills. Although, equity in skill level across classes seems to be inferred here, differences between classes did materialise when data were normalised for time played and analyses focused on KPI occurrences per match. An FT8 or FT7 player typically executed more in-possession KPIs per match than FT6 and FT5 players, with FT8 players also outperforming FT7 for shot execution per match. These findings suggest that inter-class differences exist with regard to the level of involvement of players in matches and the physical capabilities that have been observed in Studies ONE and TWO may have a bearing on match-play.

The study of individual technical skill is a tool to assess player involvement, (Hughes and Bartlett, 2002; MacKenzie and Cushion, 2013), but further understanding is required to examine the impact on whole team play. Furthermore, it remains to be established whether the participation by-laws foster the equity in competition demanded in Paralympic sport. In order to explore these areas, Chapter 6 presents Study FOUR, an analysis of successful play leading to goals in CP soccer. The study evaluates CP soccer team play and more specifically the relative and absolute impact of each class of player on goal scoring patterns of play.

CHAPTER 6 - Study FOUR

TACTICAL ANALYSIS OF GOAL SCORING IN CP SOCCER

6.1 INTRODUCTION

Study THREE identified that the success rates of technical key performance indicators (KPIs) were generally higher than that found in AB soccer while no differences were found between the impairment classes. This suggests that the greater pitch size to player ratio in cerebral palsy (CP) soccer permitted more time and space for decision-making and the proficiency of skill execution was comparable across classes. However, FT8 and FT7 players executed significantly more in-possession KPIs per match than FT6 and FT5 players. There were no differences between the classes for out-of-possession KPIs per match. Individual KPIs provide insight into the general involvement of the players during match-play, but the efficacy of players' involvement as a function of team play cannot be determined solely from this form of analysis (James et al., 2002; Hughes and Bartlett, 2002: MacKenzie and Cushion, 2013).

Goal scoring and associated patterns of play leading to goals has long been a focus of attention in notational analysis research and is seen as integral to the study of successful play (Abt et al., 2002). Although goal scoring is the primary objective in soccer it is a rare event. Bishovets et al. (1993) suggested that the effectiveness of a team depends on their attacking rather than defensive ability so detailed knowledge of the antecedents of goal scoring is a valuable commodity. This knowledge may be used to implement effective strategies in training and matches (Lago and Martin, 2007).

Goal scoring pattern research is commonplace within soccer (Yiannakos and Armatas, 2006; Andersson et al., 2010; Wright et al., 2011; La Presa et al., 2013; Sarmento et al., 2016). Key match-play characteristics associated with goal scoring have been identified as ball possession, types of assist, regain of possession, areas of threat and temporal patterning (James et al., 2002; Jones et al., 2004; Ridgewell, 2011; Bradley et al., 2013; Sarmento et al., 2016). However, Yanci (2015) is the sole study that has applied such an investigation to CP soccer.

Chapter 2 described the task, environmental and performer constraints associated with CP soccer are notably different from futsal and 11-a-side.

While some aspects of goal scoring are likely to be similar, it is also likely that the patterns of play leading to goals could differ from those in AB soccer and hence it is worthwhile investigating the potential characteristics unique to CP soccer (Frencken et al., 2013; Silva et al., 2014; Vilar et al., 2014).

Much attention has been focused on the number of passes leading to a goal and the importance of possession on goal scoring (Reep and Benjamin, 1968; Reilly and Thomas, 1976; Hughes and Franks, 2005; Yiannakos and Armatas, 2006). Generally, shorter passing sequences are more associated with goal scoring (<4 passes) but are also more frequent in matches and a relationship exists between total frequency of short sequences and goals scored from them (Hughes and Franks, 2005). Studies in 11-a-side soccer (Yiannakos and Armatas, 2006) and futsal (Sarmento et al., 2016) have identified that most goals are scored from within (44%) or directly in front (20%) of the penalty area. The discrete breakdown of goal origin shows that goals from open play account for 65-72% of all goals scored (Yiannakos and Armatas, 2006; Wright et al., 2011; Mitrotasios and Armatas, 2014). Extensive examination of goal scoring in the English Premier League identified that the characteristics associated with regain of the ball (often termed 'turnovers') account for 63% of all goals (Wright et al., 2011). In particular, the origins of assists and regains were important antecedents to the success of the subsequent attack, with 44% of goals originating in the central attacking areas of the pitch (Armatas et al., 2005; Wright et al., 2011).

Although the aforementioned variables provide detailed insight into goal scoring behaviour, CP soccer is yet to be explored to any significant extent. Yanci (2015) provided some, but limited information regarding CP soccer. This study on goal scoring in the Spanish CP soccer league conducted limited analysis of the aforementioned KPIs. It is suggested that notational analysis studies can suffer from situation specific limitations (MacKenzie and Cushion, 2013) and the usefulness of the information provided by Yanci (2015) may illustrate this point. Spanish CP soccer league may provide particularly weak application to international standard CP soccer tournaments, as CP soccer is a developing sport and considerable differences exist between the top international teams and the Spanish national team (Ranked 18th from 24 nations: IFCPF (2016) www.ifcpf.com/ranking), so the standard of the domestic league is unlikely to reflect top-level play. Nevertheless, Yanci (2015) found that 94.4% of goals were scored from open play with 61.3% scored from inside the penalty area. More goals were scored in the first half, while there was no bias in terms of footedness of the scorer. Significantly, Yanci (2015) did not report aspects of KPI operational definitions or any reliability checks for his analysis system, a common oversight in PA research (Hughes et al., 2002; Williams, 2012; MacKenzie and Cushion, 2013). Additionally the study failed to analyse several important aspects of goal scoring. Key details regarding pass sequences, turnovers or assist passes were absent. Pitch areas of action were ignored and the breakdown of the involvement of the class of players was overlooked.

CP soccer, similar to wheelchair basketball and wheelchair rugby, functions with direct mixed-class competition. To achieve the aim of equity and fairness in competition, these sports must complement the Paralympic classification of athletes with specific rules to manage the inter-class differences that exist during competition. Consequently, wheelchair basketball and rugby operate with a rule that limits teams to a maximum total of player class points permitted on the court at any given time (IWRF, no date; IWBF, 2014). At the time of this study, the participation by-law restricted teams to fielding a maximum of two FT8 players, while imposing the mandatory selection of one FT5 or FT6 player (CPISRA 2013). This ruling may affect the involvement of specific player classes during match-play as the time available to each player on the pitch is not equal. Although other research in other SSGs and futsal, have not analysed specific players or positional involvement in matches, the analysis of player class is imperative for a full understanding of the dynamics of team play.

More extensive analysis in general aspects of goal scoring and more specifically player class involvement, would provide coaches and support staff, as well as those within the governing body, with more objective data upon which to inform both coaching practice and the classification assessment in CP soccer. It was therefore the aim of Study FOUR to examine the patterns of play leading to goals in order to describe successful behaviours in CP soccer.

Furthermore, specific analysis of player class involvement in these patterns was conducted. This in turn, assists in evaluating the effect of the participation by-law in managing equity and fairness in a mixed-class Paralympic sport.

6.2 METHOD

6.2.a Sampling and Participants

The analysis for this study was derived from the same matches and tournament as Study THREE (see section 5.2.a). Ethics approval was obtained for all data collection for both studies within a single ethics application. In this study goalkeeper actions were also included within the analysis. Table 6.1 shows details of all participants. Data are presented as mean (SD).

Table 6.1 Participants and tournament minutes played

Class	Total sample (n)	GK sample (n)	Age (years)	Outfield time (min)	GK time (min)
FT5	9	4	24 (4)	1321	980
FT6	8	4	26 (5)	581	300
FT7	56	8	28 (7)	8682	1240
FT8	23	0	24 (5)	4296	0
Combined	96	16	26 (5)	14880	2520

6.2.b.i Procedures – development of a notational coding system; a notational coding system was developed for use with Focus X2 (version 1.5) notational analysis software for Windows XP on PC, and validated to assess a series of key performance indicators (KPIs) that permitted the quantitative observation and analysis of patterns of play leading to a goal.

As with Study THREE, the development of operational definitions facilitated the assessment of reliability of observer analysis and external validity of the coding system (Hughes and Franks, 1997). KPIs were established to evaluate actions that lead to goals being scored. KPIs were deemed characteristics of single actions leading to a goal. The three KPIs identified were goals scored, assisting pass and regain of possession. In each case, the zone of the pitch in which the event took place and the class of the player involved (Figure 6.1) was recorded. The pitch was divided into previously recognised areas for tactical observations around key zones of the penalty area, central pitch and wing areas (James et al., 2002; Wright et al., 2011; Mitrotasios and Armatas, 2014). Hockey pitch markings aided the demarcation between areas during analysis Additionally, goals were categorised as either from open play or a set play, and the number of passes in possession leading to the goal were recorded.

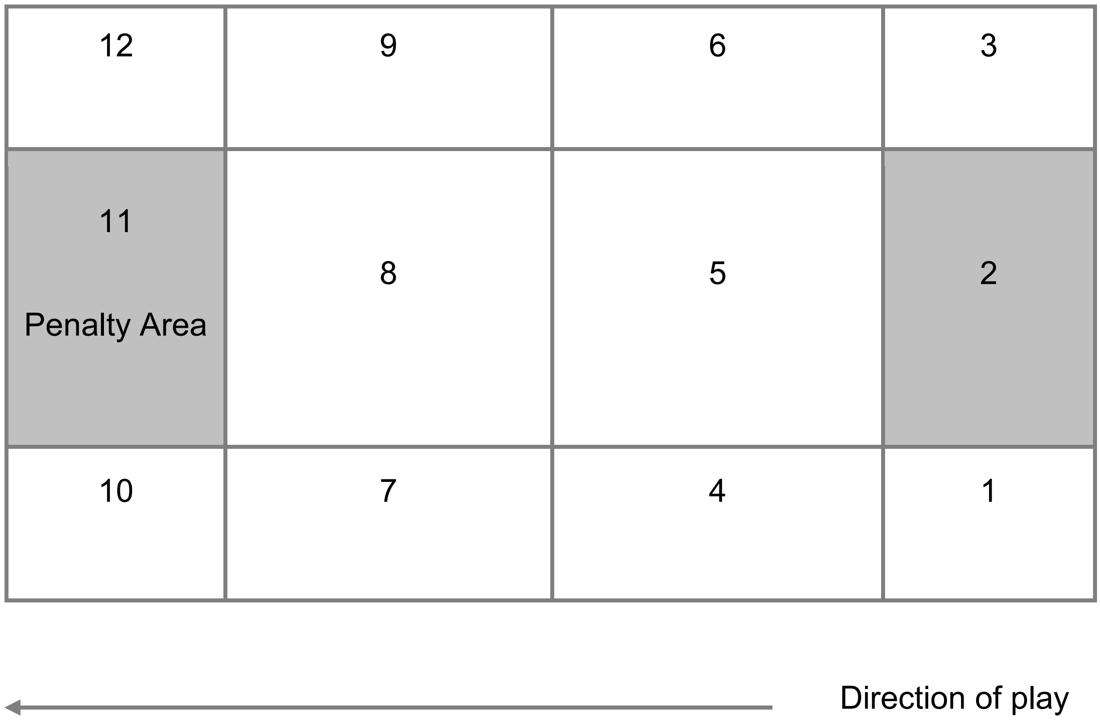

Figure 6.1 Designated pitch zones for analysis of patterns of play leading to a goal

Table 6.2 outlines the operational definitions devised to establish reliable observation of appropriate goal scoring KPIs. Details of the information gathered for each KPI is also presented.

Table 6.2 KPI operational definitions for the assessment of patterns of successful match-play leading to a goal

KPI	Operational Definition	Information gathered
Goal	*The final contact with the ball before it crosses the goal line.*	Class of the scoring player
		Zone of the pitch from which the *goal* was scored
		Origin of the goal; Directly from a set play (≤2 passes) Indirectly from a set play (≥3 passes) Scored in open play
		Type of set play
Assist	*The final 'pass' (of any type) prior to a goal being scored*	Class of the assisting player
		Zone of the pitch from which the *assist* originated
Regain	*The regain of possession from the opposition directly leading to a goal*	Class of the regaining player
		Zone of the pitch from which the *regain* occurred
Passing Sequence	*From the point of ball regain to scoring the goal*	Number of passes in the possession Sequence of passes (n)

6.2.b.ii Procedures – establishing reliability of the coding system; the analysis system underwent checks for reliability and external validity with intra-observer reliability (k^1) and inter-observer agreement (k^2) analysis employing Cohen's kappa statistic (Viera and Garrett, 2005; James et al., 2007). The author conducted reliability test-retest analysis 14 days on 16 goals from the tournament. For inter-observer agreement a post-graduate performance analysis student was trained on the system prior to participating in the inter-observer agreement analysis.

Analysis involved observation of 128 separate goal scoring 'events' over the four KPIs and the associated variables (i.e. pitch zone, player class involvement). The kappa co-efficient for intra- and inter-observer reliability was k^1 = 0.93 and k^2 = 0.90 respectively. Furthermore, scrutiny of specific KPI observer differences concluded that discrepancies were not the consequence of issues with any individual KPI and so the whole system was accepted as possessing very strong reliability and validity.

6.2.b.iii Procedures – match observations; the NA process involved observing each goal at 50% of real time speed (including the reliability testing). Each goal was reviewed from the point at which the scoring team regained the ball prior to the goal being scored. Multiple observations of this relatively short (most occasions were less than 10 s), but variable time frame permitted accurate observation of the KPIs and collection of the relevant information outlined in Table 6.2.

6.2.c Data management and data reporting – the KPIs and relevant information leading to a goal (Table 6.2) were analysed for the percentage contribution (%) to the number of goals scored in the whole tournament. All goals scored, assists and regains KPI were attributed to each of the four player classes (FT5, FT6, FT7, FT8), and KPI ratios were calculated based on the outfield minutes played per class, to create normalised figures of ‘matches per KPI’. Goalkeeper minutes were discounted to prevent skewed ratios. Data were also analysed to identify any potential characteristics of successful possessions (duration (s) and number of passes (n)).

Statistical analysis included (SPSS v22.0) chi-square for goodness of fit on data pertaining to: zone of the pitch for goals, assists and regains; class time played; goals scored; assists and regains executed. Alpha was set at 0.05.

6.3 RESULTS

6.3.a Analysis of patterns of play leading to a goal

The total number of goals scored in the tournament was 105 goals. Two games involved periods of extra time and there was one own goal. Table 6.3 provides a breakdown of goals scored. More than two thirds of all goals were scored from a regain of possession during open play, while goals scored indirectly from throw ins (scored with more than a two pass possession) were the most frequent set play goals. In total, corner kicks accounted for only four goals in the tournament.

Table 6.3 Origins of goals (open and set plays)

Origin of the goal	Goals	% Total goals
Regain in open play	72	68.6 %
Direct corner kick	1	1.0 %
Direct free kick	7	6.7 %
Direct throw in	2	2.0 %
Direct goal kick	0	0 %
Penalty	2	2.0 %
Indirect corner kick	3	2.9 %
Indirect free kick	2	2.0 %
Indirect throw in	11	10.4 %
Indirect goal kick	5	4.8 %

Table 6.4 illustrates the relationship between passing sequence and goals scored. Over 70% of all goals were scored from a passing sequence of three passes or fewer and only 8% of goals involved a sequence of eight or more passes. Overall, there was a diminishing return of goals scored as the passing sequence increased.

Table 6.4 Goals scored as a function of the length of the passing sequence leading to a goal

Passing sequence (n)	Goals scored (%)
0	18.1
1	22.0
2	15.2
3	15.2
4	6.7
5	4.8
6	4.8
7	5.7
8	1.9
9	1.0
10	1.9
11	1.0
>12	1.9

Figure 6.2 shows a breakdown of all pitch zones within which goals, assists and regains leading to a goal originated. The central attacking zones of the pitch (zone 11 and zone 8) were the most common action zones leading to a goal. Most goals were scored from within the penalty area (zone 11), while zone 8 was the most common origin for assists and regains of possession. This zone was immediately adjacent to, and directly in front of the penalty area. In the attacking half of the pitch, the wide zones (zones 7, 9, 10, 12) accounted for far fewer goals (5.7%), assists (18.3%) and regains in possession (22%).

Zone 12 G = 1.9 A = 4.9 R = 0	**Zone 9** G = 1.9 A = 6.1 R = 15.3	**Zone 6** G = 0 A = 0 R = 4.2	**Zone 3** G = 0 A = 0 R = 2.8
Penalty Area G = 74.3 A = 29.3 R = 12.5	**Zone 8** G = 20 A = 47.6 R = 29.2	**Zone 5** G = 0 A = 1.2 R = 16.7	**Zone 2** G = 0 A = 2.4 R = 5.6
Zone 10 G = 1.9 A = 4.9 R = 0	**Zone 7** G = 0 A = 2.4 R = 6.9	**Zone 4** G = 0 A = 5.7 R = 1.2	**Zone 1** G = 0 A = 0 R = 1.4

G = Goals A = Assists R = Regains

← Direction of play

Figure 6.2 Origins of goals scored, assists and regains leading to a goal (%)

Chi-square analysis revealed differences in pitch zones for goal scoring (χ^2 = 268.5, p < 0.001), assists (χ^2 = 234.8, p < 0.001) and regains (χ^2 = 71.0, p < 0.001)

6.3.b Player class involvement in goals scoring and time played in matches

The involvement of each player class was also of interest in this study, Table 6.5 shows the relative contribution (%) of each class to the total minutes played, and the KPIs executed during successful patterns of play. The representation of FT5 and FT6 is most apparent in the role of GK. 44% of all FT5 players and 50% of all FT6 players represented in the tournament operated as GKs. FT7 players were represented (50%) but no FT8 players were designated as GKs. FT8 players only played outfield. However, chi-square analysis revealed that FT8 players scored a disproportionately high amount of goals in relation to their time played (15 goals more than expected), whereas FT7 players scored eight fewer than would have been expected from their outfield appearance time. Similarly, FT5 players underscored (by seven goals compared to expected values), while FT6 players scored a proportional amount of goals in relation to the minutes played during the tournament.

FT8 and FT7 players contributed to over two thirds of all assists both figures being higher than expected based pro-rata on time played (four each, respectively). FT6 players performed as expected, while FT5 players did not produce a single assist in the tournament. With regard to regains of possession, FT7 players contributed the most, but this was commensurate to their time played, whereas FT8 players made eight more regains leading to a goal than their time played would suggest. FT6 players' regains were relatively low, while FT5 players did not make a regain leading to a goal.

Table 6.5 Player class contribution to study sample size, minutes played and goal associated KPIs

Class	Outfield player sample (%)	Outfield minutes played (%)	GK player sample (%)	GK minutes played (%)	Goals scored (%)[a]	Assists (%)[b]	Regains (%)[c]
FT5	6.3	8.9	25	38.9	1.9	0	0
FT6	5	3.9	25	11.9	3.8	3.6	1.4
FT7	60	58.4	50	49.2	50.5	63.1	57.8
FT8	28.8	28.9	0	0	42.9	33.3	40.9
Total	100	100	100	100	99.05*	100	100

[a] *Disproportionate amount of goals relative to minutes played (χ^2 = 27.7, $p < 0.001$)*

[b] *Disproportionate amount of assists relative to minutes played (χ^2 = 7.9, $p < 0.0493$)*

[c] *Disproportionate amount of regains relative to minutes played (χ^2 = 10.4, $p < 0.058$)*

** one own goal in the tournament accounts for total < 100%*

Figure 6.3 illustrates scoring frequency by class. In this study, a typical FT8 player scored a goal every 1.6 matches while a typical FT7 player scored a goal every 2.7 games. An FT6 player scored every 2.4 matches while an FT5 player scored every 11.0 matches.

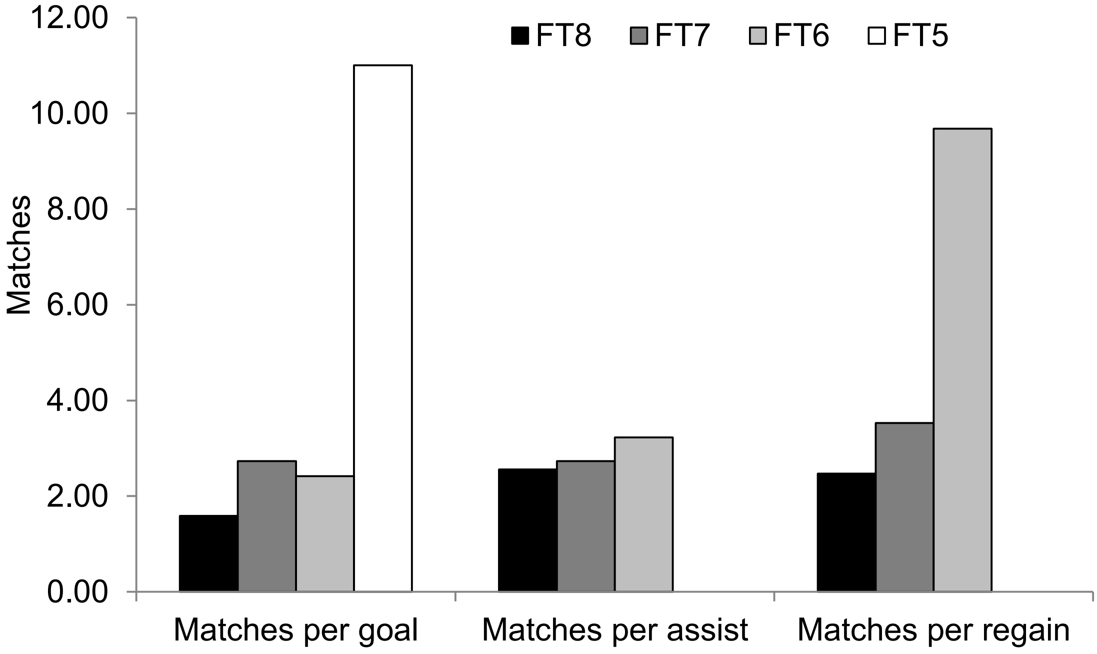

Figure 6.3 Matches played to score a goal, execute an assist or regain possession leading to a goal being scored

Figure 6.2 also illustrates assists and regains that led to goals being scored. FT8 players' performances equated to an assist every 2.6 matches. FT7 players executed an assist every 2.7 matches while FT6 players contributed at a rate of one assist every 3.2 matches. Additionally, FT8 players contributed a regain leading to a goal every 2.5 matches, while FT7 and FT6 contributed a regain every 3.5 and 9.9 matches, respectively.

6.3.c Results summary

The patterns of play leading to goals involved goals mostly scored from open play (68.6%), with possesions of shorter passing sequences most commonly leading to goals. The most common pitch zones for goals, assists and regains were the central zones of the attacking half. The wide zones were not as involved in goal scoring. Interesting issues emerge from the analysis of class involvement in goal scoring. Player class involvement was an important feature of the analysis and it showed that FT7 players scored the most goals in the tournament. This class also executed the most assists and regains that led to goals. However, FT7 players scored fewer goals than would have been expected, given their proportion of outfield minutes played. Conversely, FT8 players scored more goals, and produced more assists and regains than would be expected from their proportion of minutes played, and consequently were more prolific than their counterparts when performance data were normailsed. FT5 and FT6 players contributed fewer actions leading to goals, but it should be noted that most FT5 and FT6 players are assigned the position of GK.

6.4 DISCUSSION

The aim of this study was to analyse patterns of play that lead to goals in CP soccer. Goal scoring related KPIs were observed with regard to scoring zones, assists, regains and general possession characteristics. Once again, player class involvement was of particular interest.

The main tactical findings were that most goals, assists and regains occurred during open play and in the central zones of the field. Shorter passing sequences were also more common precursors to goals. The FT5 and FT6 players played a disproportionately high amount of minutes as GKs, while FT7 and FT8 dominated outfield minutes played. In absolute terms, FT7 players scored the most goals, and executed the most assists and regains that led to goals. Significantly, FT8 players executed a disproportionately high number of assists and regains, despite restrictions placed upon their playing time, as well as scoring more goals than expected. In contrast the other classes were involved in goal scoring patterns less often than their time played would suggest.

With over 68% of goals originating from open play and 94% of goals scored from within or directly outside the penalty area (Figure 6.3), the present study resonates with the findings of Yanci (2015). Furthermore, the current study made significant progress with the introduction of pitch zones, the analysis of regains and assists to establish an understanding of the areas of importance when possession is regained and how goals originate from attacking play. This form of detailed analysis is in keeping with extensive work in AB soccer (James et al., 2002; Yiannakos and Armatas, 2006; Wright et al., 2011). Less goals were scored in open play in this analysis compared to Spanish League soccer (Yanci, 2015), however differences in operational definitions may account for this disparity. Yanci (2015) did not present any information regarding operational definitions or report any reliability checks. This is an illustration of the discrepancies that emerge due to unstandardised KPIs in PA and highlights the need for reliability and external validity checks for notational systems (James et al., 2007; MacKenzie and Cushion, 2013). The current study showed high levels of inter- and intra-observer agreement, and the nature of the goal analysis facilitated multiple reviews of video footage, to establish confidence in the observations made.

The current study concurs with previous work focusing on goal scoring patterns in 11-a-side soccer and futsal (Olsen, 1988; Yiannakos and Armatas, 2006; Wright et al., 2011; La Presa et al., 2013; Sarmento et al., 2016). Goals are scored from predominantly the central positions and within the penalty area (Mitrotasios and Armatas, 2014). The proximity to the goal and the angle available for shooting has long been suggested to influence the probability of shot success (Reep and Benjamin, 1968; Pollard et al., 2004) and this seems no different in CP soccer.

Nevertheless, the precursors to goals are of great interest to coaches for tactical understanding (Lago and Martin, 2007), and it would be expected that the preceding patterns of play correlate to success in soccer (Grehaigne et al., 1997; Hughes et al., 1998). Passes that led to goals, and regains of possession were of particular interest in this study, and the central zones of the pitch were significant for assists and regains by scoring teams. This is often found in 11-a-side soccer (James et al., 2002; Wright et al., 2011; Mitrotasios and Armatas, 2014) and futsal studies (Sarmento et al., 2016; La Presa et al., 2013; Alvarez et al., 2014), but the impact of wing play here is notably minor in comparison to 11-a-side (Wright et al., 2011; Mitrotasios and Armatas, 2014, Yiannakos and Armatas, 2006). This study indicates that similar to futsal, goals from crosses are infrequent, and suggests that passes and supporting runs behind the opposing defenders are more effective than dribbles and crosses from wide zones (Sarmento et al., 2016; Tenga et al., 2010).

In the matches analysed within this study, shorter passing sequences (<4 passes) were most commonly associated with goals scored. This concurs with AB soccer literature (Hughes and Franks, 2005; Wright et al., 2011; Mitrotasios et al., 2014). Short passing sequences occur more often in soccer (Hughes and Franks, 2005) but it seems the perturbations caused by turnovers in possession, and the dynamics of a team's shape during the transition from in- to out-of-possession is influential (Tenga et al., 2010).

Tenga et al. (2010) found that imbalances in opponents' defense were a significant factor in facilitating scoring opportunities. Data showed that whether possessions were long or short was not as significant as whether teams encountered unbalanced defences Unbalanced defences provide small time windows of opportunity to score and so short sequences tend to be successful.

The total number of players and the minutes played by players from each class mirrors the distribution of a 7-a-side team conforming to the mandatory and minimum requirements of CPISRA. The CPISRA by-law states that one FT5 or FT6 player must play at all times, while a maximum of two FT8 players are permitted at any time (CPISRA, 2013).

Although some flexibility is possible in the selection of different player classes, the data shows that teams selected as few FT5 and FT6 players as possible, predominantly using them in goal. 47% of all FT5 and FT6 players in the tournament were GKs (accounting for 50% of all GKs). No team selected a FT8 player as a GK. This distribution suggests teams favour FT8 and FT7 players in outfield positions, even though the FT7 class differs from FT5 or FT6 by type of impairment and not severity. It may also indicate a reluctance of coaches to select FT5 and FT6 as outfield players and therefore restrict their participation opportunities even though the participation by-law makes the inclusion of an FT5 or FT6 player are mandatory.

The rationale for the participation by-law in CP soccer is to facilitate fairness for mixed-class competition, but it does so by promoting and restricting specific classes. This is unique to CP soccer; wheelchair basketball and wheelchair rugby operate with a by-law that permits participation of any class of player, but instead restricts the total sum of the player class points in a team at any one time. In this manner, multiple combinations of classes may be selected, while seemingly no specific class is unduly affected by the ruling (IWBF, 2014; IWRF, no date).

The ruling regarding class participation in CP soccer makes examination of class involvement in successful play crucial. In absolute terms, FT7 players scored the most goals and executed the most assists and regains in the tournament, but they also played the most outfield minutes (over 58%

of total outfield minutes). However, chi-square analyses of FT7 players' KPIs identified that they were lower than would be expected, based upon the amount of outfield time played. This pattern was mirrored by FT5 and FT6 players, however FT8 players outperformed the expected frequencies of all KPIs associated with goal scoring, despite being the focus of a participation by-law that restricts their playing time. In the context of a match, a typical FT8 scored a goal every 1.6 matches, and assisted and regained possession leading to goals more frequently than any other class at a rate of 2.6 and 2.5 matches per action, respectively. It seems that the participation by-law does not prevent FT8 class dominance or promote opportunities for FT5 or FT6 to contribute with equity. The by-law does however, restrict eligible individuals who are classified FT5, FT6 or FT8 for Paralympic participation.

6.5 CONCLUSION

Observations of the 2012 Paralympic Games showed that central attacking play was the most common pattern of play that led to goals. More specifically, turnover of possession, followed by a short sequence of passes was the most common pattern of goal scoring, as it exploits unbalanced defenses. This sequence is akin to that observed in 11-a-side soccer. However, unlike 11-a-side, there is little evidence to suggest that crossing the ball from wide zones is an effective strategy to score goals in CP soccer or that scoring from set plays is as important. From a class involvement perspective, team selection seems to favour FT7 and FT8 outfield players, while FT5 and FT6 players make appearances mostly as GKs. FT7 players scored most often, but also played most outfield minutes. Interestingly, FT8 players scored disproportionately more goals, executed more assists and regains than expected from their time played and so created actions leading to goals more frequently than other classes, despite their participation being restricted by the participation by-law that aims to establish an even playing field for all classes.

CHAPTER 7

DISCUSSION

7.0 DISCUSSION

This research study was undertaken to establish the performance characteristics of Paralympic 7-a-side soccer and soccer players with CP and TBI. Research investigating this form of soccer and players engaged in it is scant, and in comparison to both AB soccer and other Paralympic sports, CP soccer has been largely overlooked. Particular challenges face Paralympic classification, with regard to CP and TBI, due to the complexity and range of associated impairment types and severities (Rosenbaum et al., 2006; Reina, 2014; Beckman et al., 2016). Consequently, the evidence-base for coaching, classification and governance in this sport is conspicuous by its absence.

The aims of this thesis were to establish profiles of CP soccer and CP soccer players, identify any contrasts across the four eligible Paralympic classes and provide evidence-based information relevant to practitioners working in CP soccer.

7.1 MAIN FINDINGS

Study ONE resulted in the first ever profile of elite CP players achieved by conducting a battery of field tests. Eligibility for Paralympic sport requires impairment to restrict the functioning of an individual to below what is expected of AB athletes (CPISRA, 2011; IFCPF, 2015; Beckman et al., 2016). Unsurprisingly, CP players exhibited lower performance values than observed in AB players (Tumilty, 1993; Raastad et al., 1997; Wisloff et al., 1998; Reilly et al., 2000b; Reina et al., 2016). A key finding was that inter-class contrasts were identified in anaerobic based field tests. This mirrored previous studies where anaerobic testing identified distinctions between classes (Molik et al., 2010; Morgulec-Adamowicz et al., 2011; DeGroot et al., 2012).

Study ONE demonstrated that the least impaired class (FT8) outperformed the most impaired class (FT5) in sprints, jumps and speed agility tests, and outperformed the FT7 class in 10 m and flying 20 m sprints. Furthermore, spastic hemiplegic FT7 players displayed better performances (SJ and speed agility) than spastic diplegic FT5 players, although no other distinctions were evident. These differences are likely due to the impairment affecting strength in both lower limbs of FT5 individuals. FT6 players (affected by ataxic and athetoid CP) did not differ from other classes, exhibiting anaerobic performances that overlapped with adjacent classes. FT6 do not have pronounced strength impairment, instead they possess impaired coordinative ability. The study concurs with a number of previous studies in CP, observing that impaired strength is detrimental to running performance (Jung et al., 2013; Moreau et al. 2013; Williams et al., 2013; Beckman et al., 2016), and that adjacent classes can overlap in physical capability (Vanlandewijck et al., 2004; Molik et al., 2010; Morgulec-Adamowicz et al., 2011).

With no observable differences in aerobic fitness, it was concluded that muscle recruitment and force development are key discriminators between classes and reflects previous observations in non-sporting populations (Balemans et al., 2013; de Lira et al., 2010) and paralympic populations (Morgulec-Adamowicz et al., 2011).

FT8 players covered greater distances than all other classes during competitive matches (STUDY TWO), spending significantly more time above 85% HR_{max}. Anaerobic activity was once again prominent in the differences observed with VHI activity and frequency of sprints discriminatory variables for FT8 and the other classes.

FT8 players demonstrated greater V_{max} (Study TWO) and faster sprint times (Study ONE). Repeated sprint ability was not assessed, but FT8 players' more frequent VHI activity suggests greater aerobic capacity, in order to aid resynthesis of phosphocreatine and lactate to pyruvate for repeated bouts of anaerobic work (Balsom et al., 1994; Bangsbo 1994; Mohr et al., 2003) however STUDY ONE did not identify differences.

The patterns of VHI and ACC and DEC activity over the time course of the matches show that, like AB players, CP players are vulnerable to fatigue (Mohr et al., 2005; Krustrup et al., 2005), with the most physically capable players (FT8) suffering to the greatest extent (Mohr et al., 2003). In the present study, VHI, ACC and DEC activity of FT8 players declined to the greatest extent, mirroring the findings of Molik et al. (2010), who reported in wheelchair basketball players. The general decline in physical performance is likely to be indicative of increased core temperature, lactic acid accumulation and muscle ion homeostasis (Krustrup et al., 2003; Mohr et al., 2005), while the more pronounced decline in FT8 players' performance may be a function of their greater VHI efforts leading to changes in gait, with fatigue, and an increasing cost of anaerobic activity (Keefer et al., 2004; Maltaise et al., 2005).

High intensity activity in AB soccer has been associated with aspects of match-play involving proximity to the ball and game-defining moments, and discriminates between levels of play (Reilly, 1996; Mohr et al., 2005; Rampinini et al., 2007). Study THREE demonstrated that FT8 or FT7 players engaged in the technical skills of passing, shooting and dribbling more frequently than FT5 or FT6 players. Rampinini et al. (2007) has shown that skill success rates do not decline with reduced anaerobic capacity; rather it is the frequency of engagement with match-play that suffers. Findings from Studies ONE and TWO would suggest that the anaerobic superiority displayed by FT8 players in particular, and in some instances FT7 players, could be contributory factors to the frequency with which technical skills are executed by these classes seen in STUDY THREE.

Interestingly, the success rates (%) of technical KPIs were higher for all classes in Study THREE than those observed in AB soccer (Bradley et al., 2013; Carling and Dupont, 2011; Dellal et al., 2012). Furthermore, the findings concur with Rampinini et al. (2007), that anaerobic capacity is not a factor in technical KPI success rates, as no inter-class differences were evident here. The larger pitch size-to-player ratio in CP soccer could contribute to the higher technical KPI success rates observed, as this permits more time and space to make decisions and execute skills with greater certainty (Grehaigne et al., 1997; Davids et al., 2013). Although no inter-class differences existed in KPI success rates, FT8 and FT7 were shown to complete a greater number of high-risk passes, which are more penetrative and more likely to lead to goal scoring opportunities (Tenga et al., 2010). It is possible that their greater coordinative and strength capabilities facilitate the execution of more challenging passes.

The greater anaerobic capabilities of FT8, and to a lesser extent FT7, are likely to influence the more frequent engagement in KPI during matches. However the data does not account for the CPISRA participation by-laws designed to complement classification and prevent inequality in mixed-class competition. The by-laws restrict participation of FT8 players and promote participation of FT5 and FT6 players. STUDY FOUR focused upon this aspect of CP soccer and investigated the patterns of play leading to goals.

Analysis showed that CP soccer, is in many ways, similar to 11-a-side soccer and futsal. Goals scored from central positions were most common, while passing sequences of four passes or less were characteristic of successful play (Hughes and Franks, 2005; Wright et al., 2011; Mitrotasios and Armatas, 2014). Unlike 11-a-side soccer however, goals rarely originate from wide positions (Wright et al., 2011) crossing of the ball and set plays for goals are infrequent (Mitrotasios and Armatas, 2014) and regains in possession occur ostensibly in the attacking half of the field.

The evaluation of class involvement in goal scoring (Study FOUR) showed that FT8 players contributed more goals, assists and regains leading to goals than would be expected from their time played in matches. Conversely, FT5 and FT6 players, despite the positive discrimination for participation, failed to contribute the expected proportion of similar goal related actions that their time played would predict. This study also showed that FT5 and FT6 players were disproportionately used as GKs, while no GKs were of the FT8 class. The mandatory participation of FT5 and FT6 seems only to increase their participation by playing as GKs while retaining outfield positions for FT7 and FT8 players.

The passing, shooting and dribbling prowess of FT7 and FT8 players is integral to goal scoring and successful play in CP soccer. However, FT8 players distinguished themselves as the only class that outperformed their expected game involvement, as a function of time played. The anaerobic capacity that FT8 players possess is strongly associated with these actions, so it seems that FT8 players pose a challenge for mixed-class competition as the current by-law and classification system is unable to prevent their dominance.

In summary, the findings of these studies suggest that the FT8 class dominates the sport of CP soccer, through superior anaerobic capabilities. Despite the best intentions of classification and the CPISRA / IFCPF participation by-law, these differences are not neutralised during match-play.

7.2 IMPLICATIONS OF FINDINGS

7.2.a Implications for coaching

Until now, there has been a paucity of specific information that coaches could turn to for support in CP soccer. This research provides unique and objective information that may assist with physical training, can be used to assist talent identification and direct and inform tactical coaching.

Findings indicate that anaerobic activity, underpinned by neuromuscular capability, is key to player involvement in match-play. CP affects muscle activation, muscle size, co-contraction and coordination (Wiley and Damiano, 1998; Damiano and Abel, 1998; Hussain et al., 2014), but research has shown that individuals with CP respond positively to strength training (Ross et al., 2001; Anderson et al., 2003; Millet et al., 2002; Nordmark et al., 1997; Engsberg et al., 2000; Zhao et al., 2011). In this research, stronger, faster players (FT8 class) were more involved in match-play and it would be advisable for coaches to focus physical preparation on strength, power and increased ROM training to enhance neuromuscular capability. Conversely, the development of aerobic power does not seem as important to success in CP soccer. CP does not directly affect the CV system, although running economy is likely to be improved through strength training and improved coordination (Paavolainen et al., 1999; Unger et al., 2006; Unnithan et al. 2007; Scholtes et al., 2008). This would facilitate lower relative VO_2 during aerobic activity and may enhance recovery between intermittent exercise bouts, to aid repeated sprint ability.

Developing normative data for each of the classes, with a focus on strength, agility and sport specific activities, would support talent identification. It is suggested that coaches employ field-testing as part of their squad selection process; the identification of individuals possessing favourable anaerobic capacity would be particularly beneficial. Sport-specific testing is underpinned by multiple contributing factors (Reilly et al., 2000a; Williams, 2000; Mason et al., 2010), and the broad spectrum of impairments associated with CP would suggest that individuals might exhibit impairments eligible for the more favourable classes of FT5-FT7, while still being able to perform sport specific activities proficiently. With structured training, the potential developments in strength and coordination of players in the FT5-FT7 classes would be extremely beneficial to teams.

Teams commonly score goals by capitalising on regained possession in central attacking areas and scoring from passing sequences of less than four passes. It is suggested that coaches consider offensive tactics that promote quick attacks, to capitalise on the unbalanced defences that are often encountered when possession is regained (Hughes et al., 1998; Tenga et al., 2010; James et al., 2012). Successful exploitation of match perturbations inevitably leads to the short passing sequences and shots on goal identified in this research. Conversely, coaches are also advised to develop defensive tactics that quickly neutralise a loss of possession, to avoid vulnerability to quick counter attacks. Goal scoring from wide areas is infrequent and it would be advisable to defend compactly and centrally, in a manner that directs opposition attacks to wide areas of the pitch.

7.2.b Implication for classification

Paralympic classification aims to promote participation by controlling the impact that impairment has on the outcome of competition (Tweedy and Vanlandewijck, 2011). Currently, the CPISRA / IFCPF classification system operates with ambiguous definitions and unclear, inconsistent descriptors across the classes (Reina, 2014). With three classes defined by different types or topologies of impairment, the cut-point between the FT8 class and other classes is key to controlling the impact classification has on the outcome of competition. However, classifying an individual as FT8 significantly reduces opportunities for participation and has implications for team selection, while the misplacement of an individual into FT5-FT7 would provide a significant, unfair advantage to a team.

Quantifiable measures of impairment would enhance assessment objectivity and it is suggested that the governing body develops valid and reliable field-tests to aid the classification process, since this is currently absent from classification in CP soccer (IPC, 2007; Tweedy et al., 2014;

Beckman et al., 2016). Findings from this research advocate a focus on assessing strength and anaerobic components of fitness.

To complete classification, players are observed in competitive matches (CPISRA, 2011). Prior to this thesis, there was no information on the expected level of involvement of each class, success rates of technical components, or the impact of movement actions. Assessors therefore, were seemingly not aware that all classes perform technical KPIs with equal success rates, or that FT7 and FT8 players are involved in more in-possession actions. Although assessors observe players' movement patterns, they also evaluate the impact upon specific actions in the sport, such as ball control, kicking and dribbling skills. The findings of the KPI analyses may be useful for contextualising what would be expected from each class by providing a more objective template for assessors to use.

It is difficult to envisage how classifiers can objectively evaluate match performances, when multiple factors contribute to technical involvement, decision-making and success rates in soccer (Grehaigne et al., 1997; Williams, 2000; McGarry et al., 2002). Players make decisions on which action to undertake by assimilating information from the task, the environment and their own affordances, as shown in Study THREE, and subsequently execute skills very successfully (Grehaigne et al., 1997; Vaeyans et al., 2007). This shows that players evaluate problems in similar ways, irrespective of their impairment. Furthermore, the inherent match-to-match variability in play and players' relative involvement introduces an additional uncontrollable variable that may affect classifiers' perceptions of a player's capabilities. Previous authors have also cited issues with classification assessment in competition (DeGroot et al., 2012; Strohkendl, 2001). Strohkendl (2001) stated that classification should be a purely physical, impairment-based judgement and that in-competition assessment should not be considered, but instead replaced with valid, reliable field-testing. Furthermore, Beckman and Tweedy (2009) recommend that testing is resistant to training effects, can assist in evaluating trained status and identify false representation, none of which are possible during in-competition assessment.

It is the opinion of the current author that it is impossible to objectively ascertain the functional impact of impairment during match-play, due to the multitude of factors underpinning technical skills and player performance. The evaluation of physical capacity in novel or sport-specific functional physical tests should be the favoured method of assessment. These tests can be objective, controlled and are not compromised by the confounding variables that are present during match-play.

7.2.c Implications for the participation by-law

The CPISRA / IFCPF participation by-law is designed to complement the classification of impairments, as CP soccer operates as a mixed-classification sport (CPISRA, 2011). However, FT5 and FT6 players were predominantly selected as GKs, strategically limiting their use as outfield players. Furthermore, FT8 players did not feature as GKs, but are the only class with limited participation. In this respect, the by-law restricts eligible players at each end of the class spectrum. Since the commencment of this thesis, the CPISRA placed further restrictions (IFCPF 2015), by reducing teams to fielding only one FT8 player. In short, it may seem advantageous to be classed as an FT8 player, with greater match involvement and superior physical capability, but this reduces the likelihood of participating or even being selected for a team. Similarly, the consequence of the performance discrepancies found between FT5 and FT8 players significantly reduces the opportunity for FT5 players to compete as outfield players, as coaches strive to develop the strongest possible team.

Not all mixed-classification team sports operate in this fashion; Wheelchair basketball (IWBF, 2014) and Wheelchair Rugby (IWRF, no date) operate alternative systems. Selected from eight half-point classes, Wheelchair basketball permits a maximum of 14 points for the five court players. In Wheelchair rugby, four players (from seven half-point classes) can total a maximum of 8 points. Neither system singles out a class for promotion or restriction and team selection is subsequently more flexible.

As Paralympic sports develop, sufficiently strong fields of competitors across nations emerge and narrower bands of competition are feasible. Multiple events can then exist for different classes as seen in Paralympic track and field and swimming (www.rio2016.com/en/paralympics). Currently, only one 7-a-side soccer event is available for those with CP and TBI, but the IFCPF may have to consider the point at which the sport is sufficiently developed to warrant separating the classes.

The current CP soccer by-law does not satisfy the aim of creating equity for all classes in terms of fair competition or opportunities to participate. It may be pertinent for the IFCPF to consider restructuring the by-law, to avoid discriminating individual classes and facilitate more flexible selection criteria. Alternatively, the IFCPF may consider creating an entirely separate event for the FT8 class, thus eradicating any contrasts between FT8 and the other classes.

7.3 LIMITATIONS AND CONSIDERATIONS

Conducting research in an applied environment posed the challenge of balancing the needs of the governing body, teams and coaches, with the establishment of sound scientific practice to collect valid and reliable data. Access to this population, offered by the aforementioned gatekeepers, seems unparalleled when reviewing CP soccer literature. However, some compromises were made in order to work effectively in this environment.

Field-testing revealed no differences between classes for aerobic power. Although this concurs with previous studies, it is acknowledged that alternative field-tests may be more sensitive to potential class contrasts, and the use of lab-based testing would undoubtedly have provided greater insight into cardio-respiratory fitness with the ability to derive lactate thresholds, evaluate running economy as well as directly assess VO_{2max}. However, field-testing is the preferred method of testing team sport players and is in keeping with Paralympic classification protocol of favouring field-based assessments.

Time-motion analysis using GPS devices is widespread, yet the use of individual velocity thresholds and common terminology is not established in the literature. It is possible that individualised intensity and HR zones may have provided further insight into the match demands experienced by each class. This was not possible due to having insufficient pre-tournament access to the participants from the four national teams in question, which prevented the ascertainment of individualised thresholds. However this research did adjust the thresholds systematically to account for the impaired running capability of the participants.

It is possible that the development of a more complex analysis of patterns of play, turnovers and common perturbations may have furnished a more detailed understanding of CP soccer’s technical and tactical characteristics. Nonetheless, this research significantly contributes to the understanding of the dynamics of CP soccer and player class involvement especially since no data exists, either for comparison or baseline.

As is often the case, future research will address some of these points, but it is also important to address some key issues highlighted by the findings in this thesis. Section 7.4 will outline proposed future directions.

7.4 FUTURE DIRECTIONS IN RESEARCH

7.4.a Validation of impairment and functional tests for classification

In CP soccer's current format, exploration of the underpinning physical attributes that influence functional performance is important. This research avenue should seek to enrich and enhance the classification process, with objective measures of pertinent physical attributes that are affected by eligible impairments.

As with previous work in other sports (Vanlandewijck et al., 2004; Vanlandewijck et al., 2011; Beckman et al., 2014; Connick et al., 2015; Beckman et al., 2016), studies that ascertain contributory components to functional activity would develop the objectivity currently absent from CP soccer classification. Validation of supplementary tests of strength that could be associated with functional, sport specific anaerobic tests related to running, jumping, agility and changing direction would be particularly useful.

7.4.b Comparative examination of the CP soccer participation by-law

The participation by-law states that a team may only field one FT8 player at any time (IFCPF, 2015). This rule amendment arose after data collection for this thesis was conducted, so it would be pertinent to conduct similar NA research on the 2016 Paralympic Games 7-a-side soccer competition. This would permit a comparative analysis with the current studies and establish whether the by-law change has neutralised the influence of FT8 players.

7.4.c Pilot scheme of a restructuring to the participation by-law

The participation by-law places further restrictions on FT8 players, in order to complement classification and counteract FT8 player superiority, however the by-law was not founded upon published evidence. The IPC's goal of fair and equitable competition not only aims to create interest in Paralympic sport and validate competition, but also to increase participation among eligible individuals. The CP soccer by-law restricts participation of FT8 players, and currently only one FT8 can play at any time, the attractiveness for players classified in the mildest impairment class is further diminished while there is even greater incentive for teams to possess as few of their players classified in the least impaired class.

It is recommended that future research seek to pilot new participation by-laws that may better serve the IPC philosophy, fostering equity in competition, but concomitantly encouraging participation. It is the opinion of this author that the exploration of by-laws akin to those operating in wheelchair basketball (IWBF, no date) and wheelchair rugby (IWRF, 2014) should be explored.

CHAPTER 8

CONCLUSION

8.0 CONCLUSION

The aim of this thesis was to identify the performance characteristics of Paralympic CP soccer and soccer players with CP and TBI. Specifically, the aims were to: describe CP players in terms of physiological capabilities; explore the physiological match demands; and analyse the technical and tactical characteristics of match-play. Furthermore, a central theme was Paralympic classification, including whether contrasts exist between the four eligible classes of impairment across the areas of soccer profiled.

In aspects of physical performance, CP soccer players exhibited inferior performances compared to those of AB players in previous studies. The data support key eligibility criteria for Paralympic sport: impairment must limit function of an individual to the extent it prevents equitable participation in AB sport. Interestingly, when considering technical skills such as passing, shooting and dribbling, CP players generally exhibited higher success rates than those previously observed in elite AB soccer. Tactical analysis of the sport showed that successful play leading to goals mirrored AB soccer in terms of passing sequence length and location of shots for goals. However, CP players scored a higher percentage of goals from open play, with far fewer goals originating from wide areas of the pitch.

The findings lead to the conclusion that CP soccer functions differently from other forms of soccer, with law modifications likely to be influential in the differences observed during match play. Consequently, when preparing teams, coaches should consider the emergent physical, technical and tactical aspects of CP soccer revealed here and be cautious when relying upon information gathered from AB soccer studies only.

An examination of inter-class differences showed that FT8 players, the least impaired class, were superior in most aspects of physical performance, but this was most apparent in anaerobic based activities where strength is a key determinant of performance. Similar to AB players, FT8 players showed vulnerability to fatigue during matches, but this was not characteristic of the other classes. In most cases, the physiological characteristics and performances of FT5, FT6 and FT7 classes did not differ in either field-testing or match-play. As classification for FT5-FT7 classes is determined by type and topology of CP rather than impairment severity, it follows that these three classes could demonstrate overlaps in performance. Technical and tactical analysis revealed that the skill level of players, defined by KPI success rates, did not differ, but the frequency with which FT8 players executed KPIs was greater. It is therefore likely that the inherent anaerobic components of KPIs contribute to the observed inter-class differences.

The findings lead to the conclusion that the cut-point between FT8 and the other classes is key to objectively classifying athletes. Field-testing data suggests that validated anaerobic and strength-based performance tests may assist in the crucial classification process, while observing players during matches is not conducive to objectivity in classification.

The CP soccer participation by-law was considered in relation to goals scored and associated technical actions. Despite the by-law's objective of neutralising FT8 players' dominance in match-play, it was found that this class scored more goals and contributed more assists and regains of possession than was expected of their relative time played. Conversely, compulsory participation of one FT5 or FT6 player per team did not enhance their involvement in these aspects of matches.

The findings lead to the conclusion that the CP soccer participation by-law is not fit for purpose. The by-law fails to establish equity in mixed-class competition, while restricting participation opportunities for the least and most impaired classes. In both instances, this conflicts rather than supports the IPC's philosophy of providing equitable competition and participation opportunities for eligible individuals.

Overall, this thesis presents an evidence-based profile of CP soccer; a Paralympic sport that has been somewhat overlooked from a research perspective. It is hoped that the findings and subsequent discussion presented here will serve to inform a methodical, evidence-based development of coaching, classification and governance of CP soccer in the future.

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APPENDICES

APPENDIX A.1

Table A.1 IPC Eligible impairments for Paralympic participation

Impairment	Explanation
Impaired muscle power	Reduced force generated by muscles or muscle groups, may occur in one limb or the lower half of the body, as caused, for example, by spinal cord injuries, Spina Bifida or Poliomyelitis.
Impaired passive range of movement	Range of movement in one or more joints is reduced permanently. Joints that can move beyond the average range of motion, joint instability, and acute conditions, such as arthritis, are not considered eligible impairments.
Limb deficiency	Total or partial absence of bones or joints, from birth or as a consequence of trauma (e.g. car accident or amputation) or illness (e.g. bone cancer).
Leg length difference	Bone shortening in one leg from birth or trauma.
Short stature	Reduced standing height due to abnormal dimensions of bones of upper and lower limbs or trunk, for example due to achondroplasia or growth hormone dysfunction.
Hypertonia	Abnormal increase in muscle tension and a reduced ability of a muscle to stretch, which can result from injury, illness or a health condition such as cerebral palsy.
Ataxia	Lack of co-ordination of muscle movements due to a neurological condition, such as cerebral palsy, brain injury or multiple sclerosis.
Athetosis	Generally characterised by unbalanced, uncontrolled movements and a difficulty in maintaining a symmetrical posture, due to cerebral palsy, brain injury, multiple sclerosis or other conditions.
Visual impairment	Vision is impacted by either an impairment of the eye structure, optical nerve/ pathways or the part of the brain controlling vision (visual cortex).
Intellectual Impairment	A limitation in intellectual functioning and adaptive behaviour as expressed in conceptual, social and practical adaptive skills, which originates before the age of 18.

APPENDIX A.2

CPISRA (2011) Descriptions of eligible classes for 7-a-side football

Class 5 (FT5): Diplegic / Asymmetric Diplegic / Double hemiplegic / Dystonic

- Moderate involvement
- This individual may require the use of assistive devices in walking but not necessarily when standing or throwing
- A shift of centre of gravity may lead to loss of balance
- An asymmetric diplegic or double hemiplegic Athlete with involvement on both sides with lower limbs more affected than upper extremities
- Athletes with dystonia where the lower limbs are more affected than upper extremities

Lower Extremities: Spasticity Grade 2-3. Involvement of both legs that may require assistive devices for walking. A Class 5 Athlete may have sufficient function to run on the track. Balance: Usually has normal static balance but exhibits problems in dynamic balance e.g. attempting to pivot or stop and start.

Upper Extremities: This is an area where variation occurs. Some minimal to moderate limitation in range of motion and/or coordination can often be seen during sport movement, but functional strength is within normal limits.

Football (FT 5): During sport, exertion will increase tone and decrease function. The Athletes will have difficulty in turning, pivoting and stopping, usually running only short distances due to involvement in both lower limbs. Stride length is reduced and/or decreased with exertion. Trapping may be difficult. Follow through movements may be impaired due to limitations in range of movement. Foot extension may be limited affecting passing. Balance during a throw-in may be impaired.

Class 6 (FT6): Athetoid, Ataxic or Mixed CEREBRAL PALSY

- *Moderate involvement in all four limbs*
- *The Athlete ambulates without assistive devices*
- *Athetosis or ataxia is typically the most prevalent factor but some athletes can have problems with athetosis or ataxia mixed with spasticity*
- *Athletes with dystonic athetosis in all four limbs belong in this classification unless the impairment is minimal.*
- Class 6 Athletes have more control problems in their upper limbs than Class 5 Athletes, although Class 6 Athletes usually have better function in their lower limbs particularly when running or performing in a closed chain sport like cycling.

Lower Extremities: Function can vary considerably depending on the sports skill involved, from poor, laboured, slow walking to a running gait, which often shows better mechanics. There can be a marked contrast between the walking athetoid with uncoordinated gait and the smooth even paced coordinated running/cycling action. Athletes with ataxia will have a wide based stance and gait. Spasticity can occasionally be seen in Class 6 Athletes and should not be a reason for placement in Class 5. When running the Athlete may have "flight" (both feet off the ground at the same time) Balance: Athletes who are athetoid may have good dynamic balance compared with static balance. Both athletes with athetosis and ataxia, in particular, will have problems with balance and with starting, stopping, and turning when running. They will also have varying degrees of difficulty with balance while hopping and jumping. The Athlete has delayed saving/protective reactionswhen falling or losing balance.

Upper Extremities: The Athlete with a mixed picture may have problems with limitation of range of movement. Athletes who are athetoid or ataxic have poor upper limb coordination and timing – delayed reactions with catching and throwing and increased involuntary movements on activity. Grasp and release can be significantly affected when throwing.

Football (FT 6): The Athlete will have trouble stopping and changing direction quickly with and without the ball. Coordination and timing problems will be seen when tracking,trapping and kicking the ball. The Athlete may have difficulty dribbling orcontrolling the ball when running. Explosive movements and vertical jumps are difficult to perform. Acceleration hesitation and increased impact of momentum on deceleration are typically noted. Accuracy when planting the non-passing foot may be inconsistent; passing accuracy may fluctuate because of difficulty with balance on the stance leg and/or stability of the kicking ankle joint.

Class 7 (FT7): Hemiplegic

- Spasticity Grade 2- 3 in one half of the body (on the frontal plane)
- Walk/run with a limp due to spasticity in the lower limb
- Good functional ability in the other side of the body

Lower Extremities: Hemiplegia Spasticity Grade 2 - 3. Non affected side has better development and good follow through movement in walking and running. The Athlete has difficulty walking on his heel on the impaired side and has significant difficulty with hopping and balancing and side stepping on the impaired leg or side.

Upper Extremities: Function is limited on the affected side. There is good functional control on the unaffected side. The affected arm and shoulder will have increased spasticity and decreased range of motion. There are many spasticity patterns in the arm that may fit into this class.

Football (FT7): The Athlete who walks with a noticeable limp may appear to have a smoother stride when running but may not have a consistent heel strike. The Athlete has difficulty pivoting and balancing on the impaired side. The Athlete's affected arm muscles will have an increase in tone when running and may appear bent when walking. There are many patterns in the lower limb and upper limb demonstrating spasticity in the hemiplegic side. Training does not change these patterns it only changes the quality of movement of functional ability. However, the Athlete experiences a visible restriction caused by spasticity during fast movement and an increase in tone with exertion. The

Athlete demonstrates a limitation in knee pick up in sprinting and also has an asymmetrical stride length. Step length is decreased on the impaired side in relation to the unaffected side. Running may appear to be nearly symmetrical however, due to the spasticity and limitations on the impaired side, there will be a difference in step length and stance time. Hip placement on the affected side is frequently variable affecting both passing and shooting power. Loose ankles may be observed intermittently during play. Pulling toes up on the more affected side while exerting and placing the ball in the arch or towards the back of the impaired foot is frequently observed. In some Athletes with an acquired brain injury, the dominant side may be the impaired side. Therefore the Athlete may kick the ball with the dominant side. If the Athlete is unable to balance or has insufficient support on the impaired side, they may choose to stand on the less affected side and kick with the impaired leg.

Class 8 (FT8): all forms of CP and TBI

- Diplegic / Asymmetric Diplegic / Double hemiplegic / Dystonic
- Hemiplegic Spasticity Grade 1 to 2
- Monoplegic with spasticity in major joint
- Athetosis, Ataxia or Mixed Cerebral Palsy

This Athlete may appear to have near normal function when running but the Athlete must demonstrate a limitation in function to Classifiers based on evidence of spasticity (increased tone), ataxia, athetosis or dystonic movements while performing on the field of play or in training. The Athlete may walk with a slight limp but runs more fluidly. The Athlete must have an evident impairment of function observed during classification and on the field of play. The Athlete must have one of the following:

5.8.1 Mild Diplegia / Asymmetric Diplegia / Double hemiplegia / Dystonic Hemiplegia /Monoplegia/

Clear evidence must include spasticity grade 1 - 2 in affected limbs. A difference needs to be demonstrated between active ranges of motion vs. passive. In addition, a clear difference between fast passive ranges of motion against slow passive range of motion needs to be demonstrated.

Plus

- Leg length difference or difference of muscle bulk of more than 2 cm
- Upper motor neuron reflex pattern must be demonstrated. This may include:

Positive uni or bilateral babinski; Clear uni or bilateral clonus 4 beats or more; Noticeably brisk reflexes or clear difference in reflexes left vs.Right; Wartenberg's sign; Disdiadokokenesis; Dyssynergie and dysmetria

Lower extremities: Foot dorsi flexion and toe - heel gait when walking backwards the heel will not go down completely on the affected side. The Athlete pivots to both sides on the field of play although there is a difference in the pivoting to the affected side due to spasticity.Upper extremities: The affected arm and shoulder contributes to propulsion. Monoplegia: Must involve a major joint – hip/shoulder joints that have limitations in range of motion left versus right or active versus passive. Players with arm monoplegia, which does not include the shoulder girdle, are not eligible for Football 7-a-side.

5.8.2 Athetosis / Ataxia

The Athlete must have clear signs of cerebellar dysfunction. Ataxia, balance problems and uncoordination must be evident both on examination during evaluation and the field of play. The impairment must have a demonstrable impact on sport performance as seen by the Classification Panel such as difficulty stopping, starting, turning, balance and explosive movements.(FT 8) Athletes with minimal involvement may appear to have near normal function when running but the Athlete must demonstrate a limitation in function to Classifiers based on evidence of spasticity (increased tone), athetosis, ataxia or mixed involvement. Variable contractions in opposing muscle groups may cause tremors or fine oscillating joint movements. Athletes frequently have increased difficultygenerating force against gravity than their non-disabled counterparts creating difficulty in mastering elite football skills. Crossing and finishing can be somewhat impaired in athetoid or ataxic athletes and is only intermittently visible. When attacking in and around the box, the player's impulse impairment creates a slight but significant hesitation when compared to non-disabled elite players. In some Athletes with an acquired brain injury, the dominant side may be the impaired side. Therefore the Athlete may kick the ball with the dominant side. If the Athlete is unable to balance or has insufficient support on impaired side, they may choose to stand on the less affected side and kick with the impaired leg.

APPENDIX B.1

Table B.1: Hydration data for participants in Study ONE

Class	Hydration Status ($mOsmols.kgH_20^{-1}$)
FT5	550
FT5	420
FT5	520
FT5	500
FT5	410
FT6	210
FT6	350
FT6	450
FT6	360
FT6	450
FT6	220
FT7	540
FT7	440
FT7	350
FT7	400
FT7	300
FT7	250
FT7	430
FT7	180
FT7	260
FT7	260
FT7	540
FT7	520
FT8	400
FT8	560
FT8	590
FT8	470
FT8	480
FT8	300

No differences between groups for absolute hydration scores. No player indicates warnings of dehydration prior to physiological testing

APPENDIX B.2

Table B.2 Ratings for hydration (Osmocheck, Vitech Scientific, UK.)

Rating	mOsmol/kg H_2O
Very Good	<200
Good	200-600
Warning	600-1000
Danger	>1000

APPENDIX B.3

International Standards for Anthropometric Assessment (International Society for the Advancement of Kinanthropometry, 2001)

- *Triceps*

Subject position: The subject assumes a relaxed standing position with the left arm hanging by the side. The right arm should be relaxed with the shoulder joint slightly externally rotated and elbow extended by the side of the body.

Method: The fold is parallel to the long axis of the arm.

- *Subscapular*

Subject position: The subject assumes a relaxed standing position with the arms hanging by the sides.

Method: The line of the skinfold is determined by the natural fold lines of the skin.

- *Bicep*

Subject position: The subject assumes a relaxed standing position with the left arm hanging by the side. The right arm should be relaxed with the shoulder joint slightly externally rotated and elbow extended by the side of the body.

Method: This skinfold is parallel to the long axis of the arm.

- Iliac crest

Subject position: The subject assumes a relaxed standing position with the left arm hanging by the side. The right arm should be either abducted or placed across the trunk.

Method: The line of the skinfold generally runs slightly downward posterior-anterior, as determined by the natural fold lines of the skin.

- *Supraspinale*

Subject position: The subject assumes a relaxed standing position with the arms hanging by the sides.

Method: The fold runs medially downward at about a 45° angle as determined by the natural fold of the

skin.

- Abdominal

Subject position: The subject assumes a relaxed standing position with the arms hanging by the sides.

Method: This is a vertical fold. It is particularly important at this site that the measurer is sure the initial grasp is firm and broad since oftenthe underlying musculature is poorly developed. This may result in an underestimation of the thickness of the subcutaneous layer of tissue.

- Front thigh®

Subject position: The subject assumes a seated position at the front edge of the box with the torso erect and the arms hanging by the sides. The knee of the right leg is usually bent at a right angle. In some subjects, this skinfold may be easier to take with the knee extended.

Method: If the fold is difficult to raise the subject is asked to assist by lifting

with both hands the underside of the thigh to relieve the tension of

the skin

- Medial calf

Subject position: The subject assumes a relaxed standing position with the arms hanging by the sides and the right foot placed on the box. The right knee is bent at about 90°.

Method: The subject's right foot is placed on a box with the calf relaxed. The fold is parallel to the long axis of the leg.

APPENDIX B.4

Table B.4 Technical error measurement (TEM) using skin fold assessments of 24 individuals, as calculated under ISAK guidelines (2001)

Skin-fold site	Absolute TEM (mm)	Relative TEM (%)
Biceps	0.19	2.87
Triceps	0.42	3.10
Subscapular	0.28	2.78
Iliac Crest	0.46	3.10
Supraspinale	0.23	2.90
Abdonimal	0.69	4.99
Front Thigh	0.34	3.09
Medial Calf	0.17	2.25
Mean	0.35	3.13

TEM calculated as follows (Perini et al., 2005):

$$\text{Absolute TEM} = \sqrt{\frac{\Sigma\, di^2}{2n}}$$

Where: $\Sigma\, di^2$ = *sum of the differences squared*

n = *number of volunteers*

i = *number of deviations*

$$\text{Relative TEM} = \frac{\text{TEM}}{\text{VAV}} \times 100$$

Where: VAV = variable average value

APPENDIX B.5

Jump Testing Descriptors

For all jumps

- Participants are instructed to position themselves between the OptaJump Sensor bars with the feet position shoulder width apart.

Squat Jump (SJ)

- Hands are positioned onto the hips and must remain in this position throughout the jump.
- The participant then squats into a comfortable position as close to 90º knee bend as possible and as close to the feet being flat on the floor as possible.
- This position must be held for a minimum of 2 s .
- Squat jump must commence with an upward movement only.
- Dipping of the trunk or deeper squatting at the ankle, knee and hip will invalidate the trial.

Countermovement Jump (CMJ)

- Hands are positioned the same as the SJ.
- The jump commences with a downward squatting action as close to 90º knee bend as possible and as close to the feet being flat on the floor as possible.
- Extension of the ankles, knees, hips and trunk will follow immediately and quickly. There is no pause during the full action.

Vertical Jump (VJ)

- Hands are positioned freely by the participant's sides.
- The jump commences with a downward squatting action as close to 90º knee bend as possible and as close to the feet being flat on the floor as possible.
- Extension of the ankles, knees, hips and trunk will follow immediately and quickly. There is no pause during the full action.
- The use of the arms and upper body are permitted to assist the participant.

APPENDIX C.1

TABLE C.1: Activity threshold velocities used in time-motion studies to describe player movement activity and intensity

Study	Activity	$km \cdot h^{-1}$	$m \cdot s^{-1}$
Mohr et al., 2003	Sprinting	30	8.33
Di Salvo et al., 2010	Sprinting	25.2	7.00
Gregson et al., 2010	Sprinting	25.2	7.00
Di Mascio et al., 2013	Sprinting	25.2	7.00
Bradley et al., 2009 & 2013	Sprinting	25.1	6.97
Alvarez et al., 2008	Sprinting	25.1	6.97
Carling et al., 2012	Sprint	25	6.94
Study TWO	Very High Intensity (VHI)	23.4	6.50
Harley et al., 2010	Sprinting	23.1	6.41
Prozone	-	23	6.39
Randers et al., 2010	Sprinting (futsal)	22	6.11
Carling et al., 2012	High Intensity Actions	19.8	5.50
Gregson et al., 2010	High Speed Running	19.8	5.5
Di Mascio et al., 2013	High Speed Running	19.8	5.5
Bradley et al., 2009 & 2013	High Speed Running	19.8	5.5
Prozone	-	19	5.28
Oliveira et al., 2014	Sprint (futsal)	18.4	5.11
Harley et al., 2010	High Speed Runs	18.15	5.04
Alvarez et al., 2008	High Speed Running (futsal)	18.1	5.03
Mohr et al., 2003	High Speed Running	18	5.00
Study TWO	High Intensity (HI)	17.6	4.89
Randers et al., 2010	High (futsal)	16	4.44
Oliveira et al., 2014	High Intensity	15.5	4.31

APPENDIX D.1

Presentations derived from this thesis

Boyd, C., Barnes, C., Marsh, L., Williams, A.G. (2013). Time-motion analysis of football for athletes with cerebral palsy: *special reference to classification. Paralympic High Performance Conference*, St Georges' Park, Burton, UK, May 2013.

Boyd, C. (2014). Movements and actions in football: for athletes with CP. *FA Masterclass Conference on Disability Football*, St Georges' Park, Burton, UK, May 2014.

Boyd, C. (2015). The impact of mixed classification competition on key performance indicators (KPIs) in 7 aside football. *Paralympic High Performance Conference,* St Georges' Park, Burton, UK, March 2015.

Peer-reviewed publications derived from this thesis (STUDY 2) (see APPENDIX D.2)

Boyd, C., Barnes, C., Eaves, S.J., Morse, C., Roach, N., Williams, A.G. (2016) A time-motion analysis of paralympic football for athletes with cerebral palsy. *International Journal of Sport Science and Coaching*, 11, pp. 552-558.

APPENDIX D.2

Title
A time-motion analysis of paralympic football for athletes with cerebral palsy

Original Investigation

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Preferred reading head
A time-motion analysis of CP football

Abstract word count = 158

Text only word count = 3334

Number of figures and tables; Figures = 2; Tables = 4.

ABSTRACT
To investigate the soccer match-play work of players with Cerebral Palsy (CP), 40 elite players were monitored for cardiovascular and locomotive demands of tournament match-play. Using GPS and HR monitors, total distance travelled, distance travelled at high intensity (HI) and very high intensity (VHI)(m); frequency of HI and VHI activity; heart rate (HR). Disability classes C5/6, C7, C8 were compared. The results showed C8 players covered the greatest distance. Frequency, contribution and maximum speed of HI and VHI activity was greater in C8. There was a progressive decline in distances covered in all classes across match quarters. C8 spent more time above 85% HRmax. No differences were observed between C5/6 and C7 classes. In conclusion, C8 players most notably perform best in VHI activity associated with game-defining moments. C5/6 and C7 players performed equitably. This study is the first to provide an insight for practitioners and coaches interested in the work rates in soccer for athletes with CP.

KEYWORDS**:** Paralympic, soccer, GPS, workload, time-motion.

INTRODUCTION

Football for athletes with cerebral palsy (CP) is a format of Association Football played under the Laws of the Game with a number of notable modifications [1]. The game is 60 minutes in duration while the pitch dimensions are also abridged to 70-75 m x 50-55 m with 2 m x 5 m goals. It is essentially a small-sided game, with only 7 players per team and no offside law [2]. Consequently, the application of work rate analysis from the able-bodied (AB) game is of limited use here. Other modifications to the laws to accommodate player impairment, mean that the game functions very differently to AB football.

As with all Paralympic sports, football also involves the classification of players based upon the degree and form of physical impairment they possess due to CP. The classification system permits the inclusion of a spectrum of CP induced impairments and other acquired brain injury (ABI) such as cerebral strokes or head injuries, which commonly lead to neuromuscular dysfunction. The Cerebral Palsy International Sports and Recreation Association (CPISRA) are responsible for the ratification of events and classification of athletes with CP in accordance with International Paralympic Committee (IPC) standards. An IPC Position Stand stated that a classification system should be ‘selective’ and not performance-related and athletes are classified by types of impairment and not severity [3]. To this end, CPISRA conduct a combination of clinical and field-based tests in the classification assessment and establish each player’s final class.

Players in the ambulatory classes (Classes C5 - C8) are eligible to compete but restrictions are placed upon the distribution of classes permitted on the field of play at any given time. As C8 players are often least affected by impairment, teams may field a maximum of two C8 players at any time*. C5 (commonly diplegic CP) and C6 players (commonly ataxic or athetoid CP) tend to be most affected and teams must field a minimum of one C5 or C6 player at all times. C7 players (commonly hemiplegic) are without playing restrictions. Three substitutions are permitted during game play but the classification rule remains throughout games.

Currently there are no published time-motion analysis studies for disability football but the research paradigm is now well established in the able-bodied (AB) game [4, 5, 6]. Most contemporary work has utilised camera based tracking systems or individual player GPS devices to study the physical demands of players with a focus upon high intensity activity [6, 7], as this is widely regarded as a key discriminating factor of playing level and training status [8,9]. The widespread use of this technology has informed the training methods, periodisation and monitoring of player exposure to match-play at elite level [10], but the benefits of such information may not be applicable to modified football for players with a disability. The widespread development of elite level Paralympic sports requires a scientific approach to preparation and to this end, quantifiable match data is essential for continued progress.

Our study applied the time-motion analysis research paradigm to the Paralympic domain and explored the fundamental aspects of time-motion analysis in football for athletes with CP. The aim was to establish landmark competitive time-motion analysis data and examine the relative levels of work done by players across the classification spectrum, with a view to informing football-specific conditioning in the future.

METHODS

Participants- 40 elite male footballers with CP (Table 1) from four nations consented to take part in the study. Ethical approval was obtained from the local ethics committee of Manchester Metropolitan University, and conformed to the guidelines set out in the Declaration of Helsinki. All participants were outfield players and the four competing teams were ranked in the top eight 7-a-side football teams in the world.

Due to playing restrictions on class distribution (a C5 or a C6 must be present on the field of play) and the smaller outfield player sample size of these classes (C5 and C6 players commonly feature as goalkeepers) data from C5 and C6 players were pooled. Conversely, C7 and C8 players tend to be outfield players and so no such sampling issues were of concern.

<<<<INSERT TABLE 1: participant characteristics>>>>>>>

Measurements - During the eight matches of the 2012 BT Paralympic World Cup (Manchester, UK) all participants wore a body vest fitted global positioning satellite (GPS) 10Hz device (MinimaxX S4, Catapult, Australia) and a heart rate monitor (Team System, Polar, Finland) fitted prior to taking part in their respective matches. The GPS device was recently validated for high levels of reliability and low levels of measurement error [11, 12].

All matches were played in the afternoon on a grass pitch adhering to CPISRA modified rules for 7-a-side football [2]. Data were collected throughout each game and only whole game samples were included for analysis (excluding data collected from players who were replaced by substitutes or who later entered the field of play as a substitute).

The calculation of quantified threshold speeds for high intensity activity (HI) and very high intensity activity (VHI) was based upon the adjustment for age of Prozone® thresholds [5] for age in youth football [13]. We deemed it necessary to adjust our activity thresholds for players with CP who are incapable of attaining a peak velocity V_{peak} akin to senior elite AB players. Although absolute threshold speeds may have inherent shortcomings, Prozone® thresholds are commonly used to determine wearable GPS technology threshold speeds. In order to adjust appropriately, during earlier pilot field-testing we attained flying 20 m sprint times from a cohort of elite players with CP across the spectrum of classes (C5 – C8) (n=39). Subsequently, we were able to establish a mean (SD) V_{peak} of 7.31 (0.14) m/s. Relative to elite AB players (8.3 m/s) [13] the CP players V_{peak} was 88%. Applying this ratio to the Prozone® thresholds of 7.0 m/s and 5.5 m/s, adjustments to the thresholds for HI and VHI were derived for this study. All players within the study were capable of attaining the full range of threshold speeds.

The GPS-related parameters recorded included: total distance travelled (m); distance travelled at HI (m), 4.9 – 6.4 m/s and VHI (m), > 6.4 m/s; frequency of HI and VHI activity. Heart Rate (HR) data were collected and reported as mean HR, maximum HR, time spent <75%, between 75 – 85% and > 85% of maximum HR (MHR).

Data and Statistical Analysis- Due to the nature of the competitive match-play environment in which the data were collected, we considered the time being added by match officials for stoppages in play. Quarter and whole-match data were converted from the uncorrected values recorded to *pro rata* values to provide data sets for 15-minute quarter- and 60-min whole-match times. This permitted comparisons to be made over equal time periods.

Using SPSS v19.0 (IBM, Chicago, Illinois), two-way ANOVAs were used to analyse the main effects of classification (x3) and playing time quarters (x4). Subsequently, post-hoc pair-wise comparisons were conducted on distance variables and heart rate. Greenhouse-Geisser alpha level adjustments were applied to account for sphericity violations found in Mauchly's Test. One-way ANOVAs were used to analyse maximum velocity, frequency and distance of HI and VHI activity and maximum heart rate. Alpha was set at 0.05.

RESULTS

The total distances covered (Table 2) by players during match-play were different between classifications and between match-play quarters. C8 players covered 811m more than C7 ($p = 0.011$) and 701m more than C5/6 ($p = 0.027$). With the exception of the quarter periods either side of half-time, distances covered per quarter were different and declined progressively throughout the matches for all classes in each quarter ($p \leq 0.001$). Collectively, the three classes showed a 17.5% decline in distance covered from the first (1587m) to the last quarter (1309m) as a consequence of 60 minutes of match-play. It is notable that C7 players and C5/6 players did not cover different distances at any point during match-play.

>>>>INSERT TABLE 2<<<<<<

There were no differences between the classes (C8 v C7 v C5/6) for HI activity (Figure 1). However C8 covered more ground at VHI activity than C7 and C5/6 ($p \leq 0.041$) while the other two classes did not differ (Figure 1).

>>>>>>INSERT FIGURE 1<<<<<<<<<<<

In Table 3 the percentage contribution of VHI activity to the total distance covered was greater in C8 than C7 ($p = 0.008$) and C5/6 ($p = 0.003$). C8 players' VHI activity contributed to 2.2% of the overall distance covered in comparison to a significantly lower contribution for C7 ($p = 0.008$) and C5/6 ($p = 0.003$). No differences were observed across the classes for the percentage contribution of HI activity to the total distance covered.

>>>>>>>INSERT TABLE 3<<<<<<<

C8 players engaged more frequently in HI and VHI activity than C7 and C5/6 ($p \leq 0.04$) completing on average 35 HI and 9 VHI activity bouts per game. The distances covered during each HI and VHI activity bout were not different across the classes and so when a player engaged in HI or VHI activity they covered approximately 12-15 m. Once again C5/6 players demonstrated an ability to match the performance levels of their C7 counterparts with no differences being observed between these groups. Another discriminating feature between classes was the maximum velocity attained. C8 players attained higher maximal velocities than C7 and C5/6 ($p = 0.001$) while C7 and C5/6 attained similar maximal velocities. The maximum velocities attained by all players exceeded the threshold values set for HI and VHI activity.

>>>>>>>INSERT TABLE 4<<<<<<<<

No differences were evident across the classes for maximum or mean HR. The mean HR during the 3rd quarter (immediately after half time) was lower than during the other three quarters ($p \leq 0.031$, Table 4).

>>>>>>>INSERT FIGURE 2<<<<<<<<

C8 players spent 61% of time during match-play above 85% MHR, which was more than both C7 (39%) and C5/6 (31%) ($p = 0.05$), C7 and C5/6 did not differ (Figure 2). The time spent above 85% MHR during the first half was higher than the second half ($p \leq 0.021$). There were no differences observed for time spent at 75-85% MHR. The time spent below 75% MHR was higher during the second half than during the first half ($p \leq 0.015$), corresponding with the gradual decline in time spent above 85% MHR across the quarters.

DISCUSSION

In this study we investigated time-motion performance variables in CP football - a form of football that has thus far been overlooked. The main findings were that C8 players physically outperformed C7 and C5/6 players in various categories of distance covered.

We found that C8 players demonstrated an ability to cover more ground at higher intensities that are associated with the critical phases of play in matches [14]. Research in elite AB football would suggest that physical performances are strong discriminators of level of play and subsequent success [8, 9] and so we would hypothesise that the performance C8 players is linked to successful team play. With the most minimal impairments, often through post-natal brain trauma or injury, C8 players can often seem uninhibited with near normal gait patterns and mechanical efficiency [2]. The onset of fatigue exacerbates problems with neuromuscular coordination [15] and so a decline in distance covered over the period of the game is not surprising, but our data show that the decline in distance covered from the first quarter to the last was approximately 17.5% in all classes – thus supporting a sustained class distinction throughout a match. HI activity has been observed to decline by 20% in the English Premier League from the 1st to the 2nd half but a decline in total distance covered (is less pronounced than seen in the current study [5]. The relative contribution of VHI activity to total distance was higher in C8 than C7 and C5/6, which suggests that these players make a greater contribution to successful team play.

However, our findings did show that C7 and C5/6 players covered similar distances with similar contribution of HI and VHI activity. C7 players tend to present a range of severity of spastic hemiplegia, sometimes with only minor lower limb impairment leading to an asymmetrical gait [2]. When running, asymmetry often disappears and so the impairment seems to have less effect at speed. Our study however, does show that C7 players could not attain the maximal speeds of the C8 players while C5/6, who are commonly affected by diplegic, athetoid or ataxic CP attained similar maximum speeds to their C7 counterparts. This finding suggests the level of impairment associated with C8 is quite distinct from the other classes, while the level of impairment is more comparable between C7 and C5/6.

The dominance of C8 players is further evidenced by their maximum velocity attained and frequency of HI and VHI activity, both were greater than the other classes. The ability to sprint, change direction and accelerate quickly over short distances are important movements for key performance indicators (KPIs) [16] such as turnover of possessions, pressing, tackling, intercepting, dribbling and supporting team play. It seems therefore, that the value of the C8 class to the team is substantial. Interestingly, the distance travelled per HI and VHI bout did not differ between the classes and so we can infer that direct involvement in specific game activities probably determined the mean distance per bout of HI and VHI. The lower distance covered and the frequency and time spent at VHI in C5-7 maybe indicative of the neuromuscular impairments associated with CP. Muscular weakness has been associated with impaired gross motor function and gait in individuals with CP and it is possible that the weakness associated with spastic CP accounts for the reduced level of VHI activity in the lower classifications [17]. Other related factors that may explain the variance could be range of motion and coordination issues. This level of impairment may also explain the ability for C8 players to attain greater time above 85%MHR. However, the relative neuromuscular function in each CP class remains unreported and difficult to ascertain.

It is noticeable that only 8% of outfield players were C5/6 while they contributed 50% of the goalkeepers in the tournament. In most cases, teams elect to play their mandatory C5/6 player as goalkeeper, while C8 and C7 players assume the outfield positions. Our data suggest that outfield C5/C6 players might have been identified as capable of physically competing with C7 players prior to selection, so impairment issues of diplegia, ataxia and athetoid states does not materialise in match-play. C5/6 and C7 players also engaged in HI and VHI activity with similar frequency and attained similar maximal velocities. This could indicate that the severity of neuromuscular impairments were similar between classes even though the type of impairment differs. Additionally, the players selected may show a greater aptitude for ball control and skill elements of the game due to coordinative and range of motion capabilities.

C8 players spent more time above 85% MHR with greater time spent above 85% MHR in the first half. The movement capability of C8 players may be capable of stimulating a greater CV response and thus service the need for oxygen delivery during such activities. C7 and C5/6 may not have been able to challenge the CV system sufficiently with C7 spending more time in the 75% - 85% HR range while C5/6 spent increasingly more time in the lower HR range. The greater neuromuscular impairments of C7 and C5/6 may prevent the repeated attainment of the short HI and VHI activity and as such limit CV response.

The progressive decline in time spent above 85% MHR during a match mirrors the decline in distance covered with the exception of the last quarter where an elevation of time spent above 85% MHR was observed. The local muscular fatigue associated with reduced distance covered is likely to be exacerbated by the limitations of muscle function in spastic, ataxic and athetoid CP. Commonly, CP impairments have been shown to alter gait patterns and display a relative increase in energy expenditure [15].

There is much debate regarding operational definitions of movement activities [10] with inter-study variations commonplace. Walking, jogging, running, striding and sprinting have been used to categorise locomotion [18]. More recently, the terms ‘high intensity’ (HI) and ‘very high intensity’ (VHI) have been introduced [5, 10]. These semantics complicate meta-analyses of multiple study findings in AB literature. The use of absolute [5, 19] thresholds remains the most common method. Recently a study [5] on the English Premier League used defined zones based upon the Prozone® thresholds widely employed by professional clubs, based upon empirical data [20]. We made adjustments to thresholds for HI and VHI activity from ProZone® thresholds for senior AB players to accommodate the impairments of CP players and permit the threshold zones to be sensitive to the participants' capabilities. We believe the future utility of individualised velocity thresholds in this research paradigm may be of great benefit to gain a clearer insight into player activity levels in all studies of time-motion analysis using GPS devices.

Where we must be cautious in our interpretations is in the consideration of the dynamics of the games and specific modified rules of the CP game. C5/6 players are rarely substituted because one must play at all times and teams often prefer a squad with a second C5/6 as a goalkeeper, while substitutions of C7 and C8 players are more common. The use of substitutes towards the end of a match is likely to lead to increased effort from those players who started the match as competing teams look to equalise or win. However with the 7 a-side nature of the sport, the inclusion of substitutes' data would dilute the patterns of work rate in the latter stages of the matches and so we decided for this initial study to focus upon whole game data only. Previous work has noted greater high intensity activity by substitutes than starting players in the latter stages of matches and this may cloud patterns emerging from 60 minutes of competitive match-play [8]. Further work that may analyse the contribution of substitutes would add further insight to this area.

CONCLUSION

It is generally accepted in AB football that high intensity activities such as high speed running and sprinting are significant discriminators between levels of play and levels of fitness in soccer [8, 9]. The HI and VHI data for C8 players suggests that they are able to sustain and repeat levels of activity associated with the critical moments of match-play. The role of disability classification intends to be selective by type of impairment rather than by performance [3]. However, where inter-classification competition is a component of the sport, impairment differences may influence team performance. The challenge for classification while establishing impairment parity is not to penalise those athletes that through their own endeavours develop themselves into superior athletes [3]. Further investigation into the spectrum of impairment that exists within classes would be beneficial.

In terms of classification criteria, this study may be of use in the final assessment of classification, namely match-play observation. Currently, this is a purely qualitative process and to our knowledge has no evidence base to assist in the process. In particular, our study raises questions regarding the severity of impairments within each class and the manner in which C8 dominance can be accounted for. [See footnote]

The relative differences between classes should therefore inform coaches and sport scientists when preparing their athletes for competitive match-play. Our data suggests that it is possible to identify players in the classes C5/6 who can physically match the performances of class C7. Understanding the classes' capacity for work may assist coaches evaluations on relative levels of performance and could better inform the selection of players in line with the rules regarding classification while still employing effective tactics for the team.

The findings in this study are an initial insight into the demands of soccer for athletes with CP and ABI but would benefit from complementary research in the discipline of match analysis. It remains to be seen whether the physiological contrasts seen here are borne out in tactical, technical and strategic aspects of successful match-play, but it is rational at this point to suggest that physiological dominance of C8 players is likely to contribute to match-play success.

In summary, in aspects of the game where defining moments are seen it seems that C8 players are able to move faster, more often and over greater distances making them the physical dominant force in match-play. Conversely, C5/6 are comparable to C7 players in all aspects examined here. The nature of impairments within classes needs further examination if the rules imposed upon class participation in matches are to promote equality in competition.

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Table 1 Participants' characteristics

Class	Cohort Size (n)	Age (years (SD))	Body Mass (kg (SD))	Number of observations
C8	7	25 (10)	71.0 (3.3)	10
C7	29	21 (6)	67.8 (9.2)	28
C5/6	4	24 (8)	77.2 (1.6)	9
Combined	40	22 (7)	69 (8.5)	47

Table 2 Total distances covered per quarter of match-play for each class

Class	Match Quarters (min)				Whole Match
	0 - 5 [b]	16 - 30 [c]	31 - 45	46 - 60	0 - 60
8 [a]	1748 (130)	1608 (172)	1582 (173)	1434 (248)	6343 (551)
7	1473 (239)	1347 (247)	1351 (235)	1237 (167)	5532 (814)
5/6	1541 (218)	1380 (240)	1410 (130)	1256 (226)	5642 (674)
Combined	1587 (184)	1445 (202)	1448 (185)	1309 (318)	5839 (668)

[a] *different from C7 and C5/6 in each quarter ($p = .011$ and $.027$ respectively)*
[b] *different from 16-30 min, 31-45 min and 46-60 min for all classes ($p \leq .001$)*
[c] *different from 46-60 min for all classes ($p \leq .001$)*

Table 3 Maximum velocity, frequency, mean distance per activity and percentage of total distance covered of HI and VHI runs for each class

Class	Maximum Velocity (m/s)	HI Activity (4.9 - 6.4 m/s)			VHI Activity (> 6.4 m/s)		
		Frequency	Distance (m)	%	Frequency	Distance (m)	%
8	7.74 (0.34)[a]	35 (8)[b]	12 (2)	6.8 (2.4)	9 (6)[b]	15 (4)	2.2 (1.7)[c]
7	6.97 (0.56)	25 (10)	13 (2)	5.8 (2.2)	4 (3)	12 (4)	0.9 (0.8)
5/6	6.73 (0.44)	23 (11)	13 (2)	5.3 (2.5)	4 (2)	12 (4)	0.8 (0.6)
Combined	7.15 (0.45)	31 (10)	13 (2)	6.0 (2.4)	6 (4)	13 (4)	1.4 (1.0)

[a] *different from C7 and C5/6 ($p = .001$)*
[b] *different from C7 and C5/6 ($p \leq .04$ respectively)*
[c] *different from C7 and C5/6 ($p = .008$ and $p = .003$ respectively)*

Table 4 Match-play maximum and mean HR attained for each class

Class	Maximum HR	Mean HR per match quarter			
		0 - 15	16 - 30	31 - 45[a]	46 - 60
8	200 (6)	170 (5)	171 (7)	168 (7)	169 (10)
7	194 (11)	164 (14)	166 (13)	159 (14)	160 (13)
5/6	196 (18)	161 (20)	157 (19)	153 (19)	158 (18)
Combined	197 (12)	165 (13)	165 (13)	160 (13)	162 (14)

[a] *different from ($p \leq .031$)*

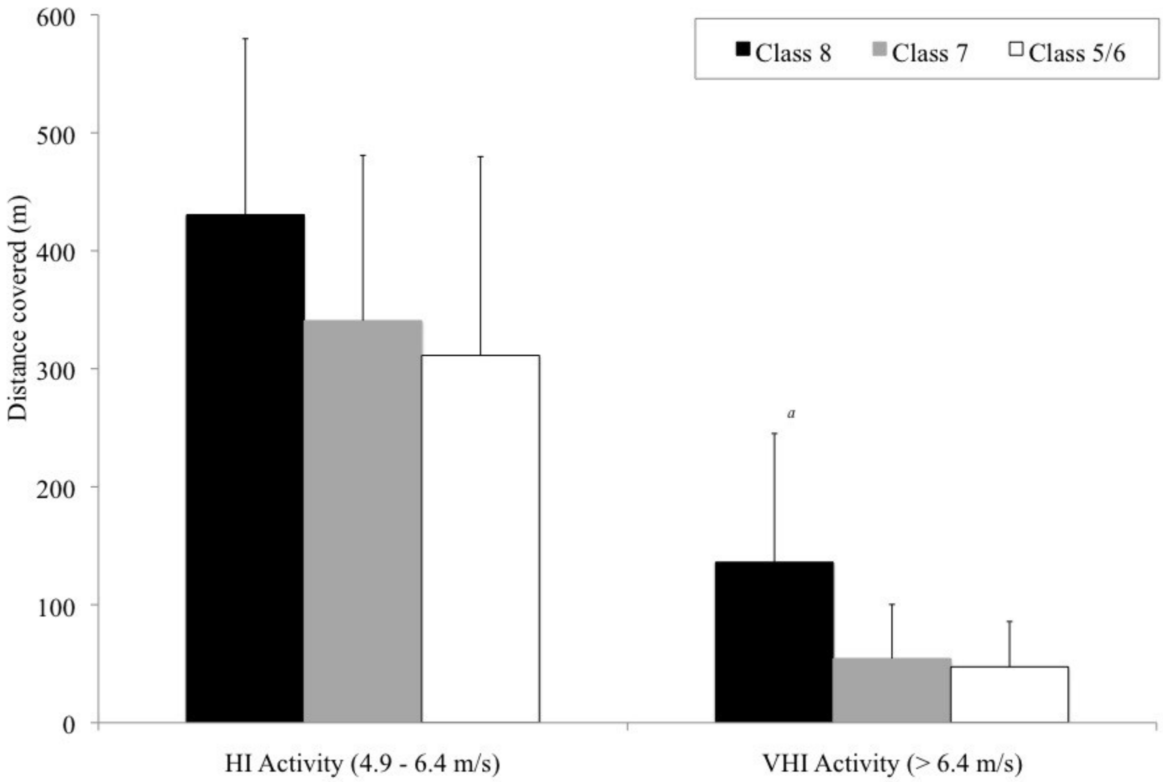

Figure 1 Distances covered at HI and VHI for each class
[a] C8 different from C7 and C5/6 p $\leq$ .041

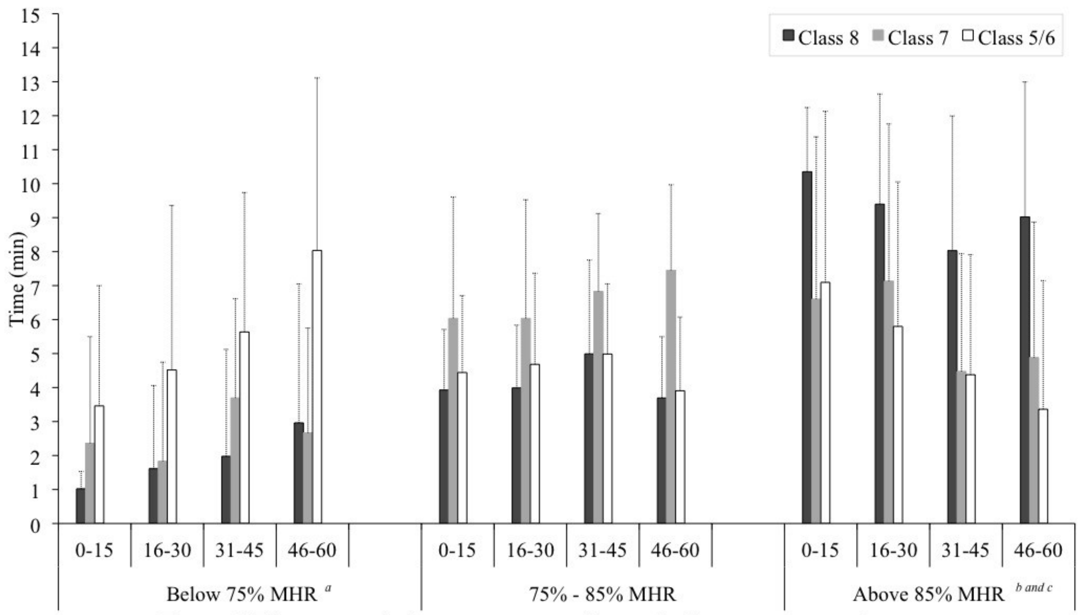

Figure 2 Time spent in heart rate zones for each class across match quarters
[a] 2nd half greater than 1st half p $\leq$ .015, [b] 1st half greater than 2nd half p $\leq$ .021,
[c] C8 greater than C7 and C5/6 p = .05

APPENDIX E

List of abbreviations

AB - able-bodied

ACC - positive accelerations

DEC - negative accelerations

BASES - British Association of Sport and Exercise Sciences

CDC - Centre for Disease Control

CP - cerebral palsy

CPISRA - Cerebral Palsy International Sport and Recreation Association

FIFA - Federation of International Football Associations

GPS - global positioning satellite

IFCPF - International federation for Cerebral Palsy Football

IOC - International Olympic Committee

IPC - International Paralympic Committee

ISAK - International Standards Anthropometry and Kinanthropomtetry

KPI - key performance indicators

WHO - World Health Organization

TBI - traumatic brain injury

IWBF - International Wheelchair Basketball Federation

IWRF - International Wheelchair Rugby Federation

ROM - range of motion

WAnt - Wingate anaerobic test

MSFT - multi-stage fitness test

TEM - technical error of measurement

HI - high intensity activity

VHI - very high intensity activity