Time-Motion Analysis and Physiological Profile of Elite New Zealand Touch Players During Competition.

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DEDICATION

I wish to dedicate this thesis to my precious son, Daley Ogden-Kiri. You are my pride and joy and the completion of this thesis would not have been possible without your patience, understanding and love throughout the duration of this thesis. Thank you so much son, love you always.

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgments), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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NOTE TO READER

This thesis is presented as a series of chapters for its submission format. Chapter one and two present an introduction and review of literature, respectively. Chapter three outlines Time-Motion Analysis of elite Touch players during competition, using physical and technical performance data obtained from Touch New Zealand Open National Tournament. Chapter four investigates physiological profiles of elite Touch players. A small amount of introduction and methodological information is repeated during chapters two, three and four to ensure that they are stand-alone studies. Finally, chapter five provides a summary of the results of these studies and discusses the limitations, practical applications and directions for future research.

GLOSSARY

Elite Athlete: an Elite Touch player is an athlete who has successfully demonstrated above average performance and qualifies to compete at a current regional (provincial), national or international level of competition.

Three playing grades: Men's only grade, Women's only grade or mixed gender grade.

Mixed grade: includes female and male Touch players who play in the same team and competition grade. Up to fourteen Touch players in a Mixed team, six of these Touch players (at the elite level three male and three female) are on the field with remaining players used as substitutions. Substituting players can vary in gender or playing positions provided no less than one or more than three males are on the field at any one time.

Physical Game measures: includes all physiological performance variables produced by a Touch player during a competition game. For example, playing time on the field, game time off the field, number of substitutions made, distance travelled, time spent in certain speed zones, average and maximum speed achieved, pre and post game blood lactate concentration measures recorded in a game.

Technical Game measures: includes Touch specific skills utilised by a Touch player during a competition game. For example, all successful and unsuccessful tap balls, roll balls, dummy half pickups, catches, passes, touchdowns, and touches made during a game.

'Insides': is a playing position located mainly around the centre of the field, can be any one of four Touch players on the field, also known as middle or link players.

'Outsides': is a playing position located in the field of play nearest the left and right side lines, can be any one of two Touch players on the field, also known as a winger.

Field of play: is the playing area bounded by the sidelines and touchdown zone lines, both of which are out of bounds (FIT rules, 2003).

Substitution*:* players may substitute at any time in accordance with the interchange procedure. There is no limit to the number of times a player may interchange (FIT rules, 2003).

Dead time: includes all Touch game time stoppages on the field which are not directly involved with offensive or defensive plays. For example, the time it takes to; change possession of ball, set up for a penalty, set up after a touchdown, etc.

Attacking team or player: is the team or player (one of up to six players on the field at any one time), which has possession or is gaining possession of the ball. Their objective is to place the ball over the attacking score line to score a touchdown within five touches (FIT rules, 2003).

Defending team or player: is the team or player (one of up to six players on the field at any one time) without possession of the ball. Their objective is to prevent the attacking team or player from gaining a territorial advantage and a touchdown.

Abstract

Background: Currently, New Zealand elite Touch players are ranked in the top two countries around the world in all three playing grades (Men's, Women's and Mixed). As of January 2010, New Zealand holds the mantle of World Champions in the Mixed (Open, Masters, Under 21) and Men's (Under 21 and Under 18) grades. Determined to obtain this same achievement at future Elite Open World Cup competitions, relevant and specific training programmes need to be implemented. Time-Motion Analysis (TMA) can provide this information by means of qualitative and quantitative measurements of individual performance during a game. There are a limited number studies on the physical demands of elite Touch players during competition and the majority have focused on male and female Touch players who play in a Men's only or Women's only grade. To date, there have been no investigations on the physical and technical demands of New Zealand elite Touch players, or elite Touch players who specialise in playing in a Mixed grade. ***Purpose:*** The aim of the present study was to investigate the physical and technical demands of elite Touch players and determine if any differences exist across the three playing grades and various Touch player groups. ***Methods:*** Twenty male (mean ± SD: age 23.4 ± 3.8 years; height 174.9 ± 6.1 cm; body mass 75.3 ± 8.1 kg) and 18 female (mean ± SD: age 23.9 ± 3.7 years; height 165.9 ± 5.0 cm; body mass 63.9 ± 5.6 kg) elite Touch players participated in this study. Physical and technical game measures, included video footage (playing time, sport specific skill analysis), and GPS data (Time-Motion Analysis) information were obtained during one competition game at the Touch New Zealand (TNZ) Open National Tournament. Blood lactate concentrations were also taken before and after each game, using a portable finger-stick blood lactate concentration meter. Physiological profiles of each Touch player were conducted within two weeks of competing at the TNZ Open National Tournament and included assessment of speed (5-, 10-, 20-, 30-m sprint times) and estimated maximal aerobic power (20 m Multi-stage shuttle run test). ***Results:*** For each playing grade the overall mean time period spent '*on and off the field ratios*' during a game was, male only ~1:1.10, male mixed ~1:1.75, female only ~1:1.40 and female mixed ~1:1.20. Across all grades male mixed players spent significantly ($p < 0.05$) more time sprinting than female only (~50%) Touch players. Maximum speed achieved during a game

ranged from ~22 – 25 km.hr^{-1}, with male only players attaining significantly higher maximum speed than female mixed (~12%) Touch players. Across the three groups, total distance travelled ranged between ~2.8 – 3.1 km, average speed on the field ~9.0 – 10.0 km.hr^{-1}, and post game blood lactate concentrations between ~4 – 7.5 mmol.L^{-1}. However, no significant between-group differences were found for these variables. Male only and male mixed players performed significantly more successful attacking skills during a game, than female mixed (~47%, both) Touch players. Male Touch players who play in a Men's only grade were significantly taller, heavier, faster and achieved greater predicted VO_2max than female Touch players who play in Women's only grade (~7%, ~14%, ~7 – 12%, and ~13%, respectively). Male mixed Touch players were significant taller, heavier and faster than female Touch players who play in a Women's only grade (~5%, ~15%, and ~5 – 9%, respectively) and female mixed Touch players (~5%, ~18%, and ~5 – 9%, respectively). No significant differences ($p > 0.05$) in age, height, body mass, sprint speed and predicted $V0_2$max were found between middle, link and utility playing positions. However, when comparing between gender groups across the three playing positions, male utility Touch players were significantly, heavier and faster than all female positional groups (~16 – 18% and ~7 – 8%, respectively). ***Conclusion:*** It is obvious from the results of the present study that there are several physical and technical game measurement differences and similarities across the three playing grades and with various Touch player positional groups during competition. The results also show that male elite Touch players who play in a Men's only grade are different to female Touch players (on many anthropometric and performance variables). Such data is useful as it provided some indication of the different requirements of the different elite Touch players and grades. These results provide some initial normative anthropometric and physiological data for elite New Zealand Touch players. The project also provides some initial physical and technical game measurement data for elite New Zealand Touch players which can be used as benchmarks for coaches and support staff when planning their athletes training programmes and by sports scientists for further research.

Key Words: physiological, time-motion analysis, video-analysis, game-analysis, global positioning system, notational analysis, blood lactate concentration, elite athlete, Touch.

CHAPTER ONE

Introduction

Introduction

'Touch' is a field team sport commonly known as Touch football, Touch Rugby, and sometimes Six Down (in South Africa). Touch features its own world cup and is predominately played in New Zealand, Australia, and South Africa and is slowly expanding internationally. Touch originated from the sport of Rugby League in the 1960's, with a touch to the body of the opposing player replacing a tackle, therefore limiting the type of contact made during a game. Although the skills of the games are closely allied to Rugby League and Rugby Union, all heavy body contact has been eliminated. For example, there are no tackles, scrums or kicking. The emphasis is on running and agility, with hand passing and catching as core skills.

The game can be played at any age both socially and competitively. A game of Touch is shorter in duration and played on a smaller sized field to Rugby League and Rugby Union. Depending on the association governing over the Touch competition some Touch modules play a 30-minute game divided into two 15-minute halves while competing at the national and international elite level competition games are 40-minute (2 x 20-minute halves) with up to a 5-minute half time break. A Touch playing field is half the size of a Rugby League field, measuring 70 x 50 metres. A team consists of up to 14 players, where up to six are directly involved in game play on the field while the remaining are used as substitutions during the game.

The uniqueness about Touch compared to other team sports is that there are an unlimited number of substitutions made during a Touch game and three playing grades within the sport; Men's only, Women's only and a Mixed gender grade. The Mixed gender grade (where both male and female players are on the field at the same time) is particularly popular with social players, and it is widely played in school. However, at the elite level (national or international) Touch players tend to specialise in one of these three grades. New Zealand Touch players are ranked in the top two countries around the world in all three playing grades (www.international-touch.org). As of January 2010, New Zealand holds the mantle of World Champions in the Mixed (Open, Masters, Under 21) and Men's (Under 21 and Under 18) (www.TouchNZ.co.nz).

The nature of the game can be classified as an intermittent sport due to the pattern of frequent short bursts of a high intensity activity interspersed with periods of recovery or lower-intensity exercise. During these periods the athlete is forced to make numerous maximal accelerations with short recovery forward or backwards walk or jogs in between. Such activity requires lactate removal and quick regeneration of phosphocreatine (PCr) stores to allow for sustained performance (Templeton et al., 2001). For these reasons, Touch is considered to be predominantly an anaerobic sport. Despite this, an aerobic base is believed essential in order to allow sufficient recovery from the anaerobic bursts and to assist with recovery over the duration of a game and throughout a tournament, where a player could potentially play up to three 40-minute games in one day. Therefore, to perform at an elite level, a well-developed aerobic capacity would appear to be an essential requirement in order to effectively sustain repeated high-intensity efforts throughout a competitive game lasting 40-minutes.

Time-Motion Analysis (TMA) and physiological profiling studies of elite Touch players have mainly focussed on male Touch players who play in a Men's only grade (Templeton et al., 2001) and female Touch players who play in a Women's only grade (O'Connor, 1997; O'Connor, 2002). A more recent study by Coffey (2007) which used GPS tracking devices to perform a TMA of 82 elite Open Touch players during competition did not actually document the gender or playing grade of participants. To date there have been no investigations into the physiological demands of elite Touch players from New Zealand and across the three playing grades. Furthermore, Touch specific skill levels and how these may differ across the three playing grades have not been investigated in the sport of Touch. These gaps in the literature provide an opportunity to investigate the physical and technical demands of elite Touch players.

Thesis Purpose

The general purpose of this thesis was to investigate the physical and technical demands of elite Touch players and determine if any differences exist across the three playing grades and various Touch player groups. A variety of performance analysis methods were employed during the investigation, including the use of portable GPS units, video cameras, portable lactate Pro

analyser and a set of developed definitions of Touch specific skills to assess the technical outcomes of elite Touch players during a competition game.

Thesis Aim

The aim of this project is to increase understanding of the physical and technical demands of elite Touch players, particularly from the three playing grades (Men's, Women's and Mixed) and various Touch player groups. Specifically, the objectives of this thesis were:

1. To quantify the physical and technical demands of elite Touch players during competition, and determine if differences exist across the three playing grades and gender groups.
2. To outline physiological profiles of elite Touch players, and determine if differences exist across the three playing grades, various playing positions (middle, link, utility) and gender groups.

Thesis Significance

Studies on the physical demands of Touch players during competition are limited. Combining accurate and reliable TMA with video-analysis, blood lactate concentrations and physiological profiling data would provide a more comprehensive picture of the demands of Touch than previously achieved. Relative activity time and distance and physiological indices have never previously been monitored concurrently or fully distinguished between various playing grades and genders. It would seem apparent that the sport of Touch would benefit from a much more recent and comprehensive analysis of the physiological demands of the sport. The current study has significance for coaches, sport scientists and physical conditioners who are continuously striving to improve performance of their athletes. Sport specific training strategies that are ideal for an elite Rugby player or marathon runner may not be suitable for an elite Touch player. This

research will provide information to assist with the development of further research for more sport specific assessments and training programmes.

Thesis Limitations and Delimitations

The information provided within this study although useful has some limitations and delimitations. Firstly from a methodological perspective the participant characteristics will be considered. A homogeneous group of athletes was used in this thesis (elite Touch players of regional and national level, aged 18 – 35 years). The findings may not necessarily apply to Touch players outside the age range (under 18 or over 35 years old), those of other standards (social or club level Touch players), or those who compete in different sporting pursuits. Also only 38 athletes (20 male and 18 female) participated in these studies. More participants would improve the statistical power of the findings, particularly for comparisons across the three playing grades. However, 28 of the elite Touch players who participated in the study were some of the best Touch players in the country at the time of testing as they were selected to represent New Zealand at the Touch World Cup in the following year.

TMA and video analysis data were collected from only one competition game for each athlete during the Touch New Zealand Open National Tournament. Performance measures may differ in other games, at other venues and at other national or international fixtures (depending on level of opposition, coaching tactics and player selections, etc.).

Fitness testing data were collected within 1-2 weeks of competing in the TNZ Open National Tournament at various venues around New Zealand. Performance measures may differ on a different day and in other locations. Also, speed trials were performed individually which is not a true competitive environment. It may be that data collected in the same competition environment would better represent the important variables for fitness testing elite Touch players.

CHAPTER TWO

A Review of the Literature

Time-Motion Analysis and Physiological Profiles of Elite NZ Touch Players: Methodological Considerations in Time-Motion Analysis - Video Analysis and GPS.

Background

The primary objective of this review attempts to investigate methodological considerations in 'Time-Motion Analysis', particularly for the sport of 'Touch', to assist in further research developments for more sport specific assessments and training programmes. Information from a variety of sources including manufacturers and their products in the sports analysis industry have been examined to provide an overview of analysis tools with a focus on video analysis and GPS athlete tracking devices.

Significance of the review

By incorporating a systematic approach such as TMA of sport performance, not only can analytical techniques be developed and thus form a real basis for making change, but new and innovative strategies may also emerge in the quest for excellence. Without systematic observation strategies coupled with analysis; it becomes difficult to design training sessions that are sport specific (Upton, 2004). How well we prepare athletes depends on how well we understand the demands and needs of the sport. For example, work: rest ratios, type of movements, intensity, etc.

In January 2005, New Zealand became the world champions at youth level in the sport of Touch. Determined to obtain this same achievement at future Elite Open World Cup, relevant and specific training programmes need to be implemented. TMA can provide this information by means of qualitative and quantitative measurements of individual performance during a game. For example; evaluating movement patterns of each player, the distance covered by each player and the time spent on any particular 'event' (e.g. movement activity) i.e. walking and sprinting, "time played" on field (work) and off field (rest), etc. Touch NZ is committed to maintaining their world standing and has commissioned a TMA of their sport. This review provides the basis upon which their TMA will be founded.

Terms used in this review

Notational Analysis: Recording of events for the purpose of collating statistical details of performance. For example, study of movements during play, technical and tactical evaluation as well as statistical collection (Reilly & Gilbourne, 2003).

Time-Motion Analysis ("TMA"): Notational analysis of match-play through use of a timing device used to assess the physical and physiological demands of sport (Bloomfield et al., 2005).

Video Analysis: Analytical method used to understand which sports skills and human movement are performed, thus to provide the basis for qualitative and quantitative approaches to motion analysis (Lees, 2002).

Global Positioning System ("GPS"): A navigation system that uses operational satellites in orbit around earth to measure and log one position each second (Larsson, 2003).

Aims and hypotheses

The aim of this literature review is to investigate methodological considerations in 'Time-Motion Analysis', particularly for the sport of 'Touch', to assist with the development of further research into more sport specific assessments and training programmes. Finding suitable methods and equipment that are easy to use, non evasive, have little effect on a player's performance and provides relevant information to analyse performance during a competition Touch game are essential. It is hypothesised that video analysis and a Global Positioning System would be a suitable method to use for the sport of Touch as both methods would provide relevant information on the physiological demands of an elite Touch player during competition.

Methodology

A systematic, comprehensive review of literature was conducted, utilising the following methodology:

Databases searched: Sport Discus (OVID); Taylor and Francis Journals; Science Direct; ProQuest Science Journals (ProQuest); OVID databases; Journals@OVID (OVID); Expanded Academic ASAP (Gale); ENGnetBASE

Keywords: time-motion analysis AND GPS; time-motion analysis AND video analysis; GPS AND video analysis; GPS AND sports OR team sports; video analysis AND sports OR team sports; Performance Analysis AND sports OR team sports; Match OR Game analysis AND sports OR team sports

Online sources: Google scholar (http://scholar.google.com/); Sportstec (http://www.sportstec.com/); GPSport SPI 10 (http://www.gpsports.com/)

Keywords: time-motion analysis AND GPS; time-motion analysis AND video analysis; GPS AND video analysis; GPS AND sports OR team sports; video analysis AND sports OR team sports; Performance Analysis AND sports OR team sports; Match OR Game analysis AND sports OR team sports

The internet has served as a tool for information gathering. Websites of manufacturers with products in related areas and linking websites, articles and reports regarding video analysis (editing OR event coding) and GPS have been used regarding specific sports performance analysis.

Reference lists of identified journal articles were also scanned to identify relevant literature. Criteria for inclusion in the review were dependent on the subject area and quality of information available.

Literature Review

Introduction

Touch is an exciting, high intensity, multi-directional game which attracts players from many other sporting codes such as Netball, Hockey, Rugby Union, Soccer and Rugby League. By its very nature there is minimal physical contact and hence, it is a very user friendly sport. Touch can be played on any surface, indoor or outdoor, at competitive or social level with men, women or mixed teams. The objective is for one team to score more points, "touchdowns", than their opponents, within a certain time frame.

A report from 'Touch New Zealand' (Touch NZ) in 2009 noted that 230,000 New Zealanders played Touch (http://www.Touchnz.co.nz/). This is comprised of 70,000 under 17 year olds and 160,000 adults. At the elite level, Touch NZ has gained World Champion status in the Mixed Open, Mixed Masters, Mixed Under 21, the Men's Under 18 and Under 21 grades. As of January 2010, Touch NZ Youth teams (Men's Under 21, Mixed Under 21 and the Boys Under 19 and Girls Under 19) hold the status of current World Champions as the result of their achievements at the 2005 Youth World Cup (due to cancellation of 2009 Youth World Cup) (see http://www.Touchnz.co.nz/).

Touch NZ, who are responsible for the New Zealand national elite teams, has as many others realised the value of sport specific research. Important information for the athletes, coaches, and strength and conditioning professionals involved in the sport of Touch, include the patterns and effectiveness of the team, and physiological information such as movement patterns and workload of individual players. To gather this information, a number of different approaches can be used. Approaches such as 'Time-Motion Analysis' (TMA), which includes the use of video recording equipment to capture and analyse games via methods such as event coding. Another more recent development in sports analysis is the use of Global Positioning System (GPS) tracking devices.

Although Touch may be classified as an intermittent multi-directional high intensity team sport, having a high aerobic capacity is also important for Touch players to maintain a high level of activity during the entire game, in both attack and defence (Coffey, 2007). At the elite level regardless of playing grade, Touch tournament events (including National and

international events such as Trans Tasman Series) occur over a period of 3 – 4 days, with approximately 2 – 4 forty minute games per day. This can accumulate to several hours of running over a few days and with the final day being the most crucial, it is important players have a good level of aerobic endurance to assist with recovery during and between games.

In terms of 'Time-Motion Analysis' (TMA) of Touch four studies have analysed the movement patterns and intensities of Australian elite Touch players (Allen 1985; Allen 1989; Coffey, 2007; O'Connor 2002). However, studies by Allen (1985; 1989) may in particular be dated as the game has since undergone many changes. For example, in 1996 the number of players on field at any one time was reduced from seven to six. Such rule changes have substantial influences on the physiological profile of players within and between games (O'Connor, 2002). It would seem apparent that the sport of Touch would benefit from a much more recent and comprehensive analysis of the physiological demands of their sport.

The first major problem to address when looking into a TMA study for a sport such as Touch is, what information is important and how best can it be acquired in a 43-minute Touch game? There are many methods by which information can be gathered. This review focuses on notational analysis through the use of video-analysis (event coding) and GPS athlete tracking technology as the primary method for obtaining data.

The arrival and progression of technology in the sport science research and coaching environment has facilitated the potential to not only 'observe' performance but to carry out detailed 'analyses' (Plowman, 1999; Upton, 2004; Coutts et al., 2009; Wisbey et al., 2009). According to Upton (2004), observing a whole performance from start to finish is based on memory recall which is often subjective due to different perceptions of what actually occurred. In contrast, an analysis using equipment such as video cameras and, or GPS athlete tracking devices involves an objective and permanent record of events that are immune to the shortcomings of 'observation'.

Using such technology, it is possible to be far more objective in relation to assessing performance. The capacities of analysis systems to store and retrieve vast amounts of information (both numerical and visual) quickly and efficiently result in databases of easily accessible data across several performances (Upton, 2004). From this information, trends and

patterns relating to sport specific events can emerge. Such information gathering has been coined in some instances as Time-Motion Analysis.

Time-Motion Analysis (TMA)

In order to design a sport specific assessment and training programme, it is important to identify the discrete requirements of sporting activities. However, strength and conditioning professionals are unable to observe and recall the frequency of the discrete incidents and activities that are required for a complete understanding of performance. It is therefore useful to perform video analysis in sport (Bloomfield et al., 2005). However, for many years the analysis of a sport event has been based on "observation sheets" filled-in during the match. In the 1980's, modern techniques of motion analysis were developed with the help of video recordings (Ali & Farrally, 1991; Pers & Kovacic, 2000). Motion acquisition and analysis were performed manually, which was a time consuming and tedious task. In the past, progress in introducing computer vision technology to the team sports domain was slow, mainly due to inadequate video and computational facilities, as a single match may require processing of tens of thousands of complex images (Pers & Kovacic, 2000). In addition, cameras used to record the sport events had to cover a large area, either by following the players of interest, or by using wide-angle lenses, which resulted in substantial image distortion and low resolution (Pers & Kovacic, 2000).

A popular method of investigating the physical demands of sports is that of TMA. With TMA various modes of motion are subjectively or objectively chosen and each is recorded throughout the performance. The identification of patterns that are not identifiable through simple observation has great benefit not only in match-play but also in establishing the physical demands of the sport. TMA is extensively used to assess the demands of team sport and attempts to evaluate athletic performance by quantifying the times and, or distances in various activities and has been applied to several outdoor sports. Some of these team sports include Rugby Union (Deutsch et al., 1998; Deutsch et al., 2007; Duthie et al., 2003; Duthie et al., 2005; Martin et al., 2001), Rugby League (King et al., 2009), Australian Football League 'AFL' (Coutts et al., 2009; Wisbey et al., 2009), Soccer (Ali & Farally, 1991; Capranica et al., 2001; Hewitt et al.,

2009; Krustrup et al., 2002; Krustrup et al., 2009; Luhtanen et al., 2001; O'Donoghue & Parker 2002; Pino et al., 2007; Stroyer et al., 2004), and Field-Hockey (Lythe et al., 2008, Spencer et al., 2004), and Touch (Coffey, 2007; Kurzawa, 2008; O'Connor 1994; O'Connor, 2002) (see Table 2).

Review of TMA methodologies

Methods of analysing performance have evolved from the simple use of hand notation tracking of players' movements on scale plans of pitches over forty years ago, to the current utilisation of video recordings and computerised analyses (see Table 1). Table 2 provides a summary of 27 TMA studies performed within the last 20 years. Of these 27 TMA studies, Lythe (2008) utilised both video analysis and GPS. Eighteen other research articles utilised some form of video analysis with the remaining eight publications using GPS devices as methods of athlete and, or game analysis.

Work rate during sports such as Soccer, Touch, and Rugby Union may be indicated by each athlete overall "distance covered". 'Distance covered' is a measure of work rate, which represents a compilation of discrete actions or movements for an entire game, and may vary from game to game for any individual player (Bangsbo, 1994). Original methods of assessing 'work rate' or exercise intensity in games involved structured commentary on movements of individual players, validated by film analysis. Trigonometric and computer-aided assessments were later developed (Reilly & Gilbourne, 2003). The most sophisticated contemporary method involves multiple cameras, placed high around a stadium, permitting synchronized observations to be made of every player on the field. The system enables researchers to compile 'work rate' data for physiological interpretations and a tactical (notational) analysis of individual performances. These systems are expensive to employ, yield vast amounts of data and for work rate assessments have not yet been satisfactorily validated (Reilly & Gilbourne, 2003).

Table 1: Summary of TMA studies in Soccer (modified from Bloomfield, 2005) (p 238)

Author, Year	Subjects & Level	Subject (N)	TMA Method	Mean Distance Covered (km)
Winterbottom, 1959	English	8	Hand notation using scale plan of pitch	3.36
Zelenka et al., 1967	Italian	1	No data available	11.5
Brookes & Knowles, 1974	English	40	Hand notion – subjective estimates	4.89
Reilly & Thomas, 1976	English Div 1	40	Tape Recorder – individual stride lengths	8.68
Withers, et al., 1982	Australian National	20	Videotape – mean stride lengths	~11.53
Bangsbo et al., 1991	Danish League	14	Video cameras (24)	10.8
Rienzi et al., 2000	South American International	17	Video camera – subjective stride frequency estimation	~8.64
Strudwick & Reilly, 2001	English Premier League	24	Video camera – subjective stride frequency estimation	11.26

Table 2: Methodologies and variables employed in TMA: Video Analysis and GPS

Author, Year	Subjects Level	Subject (N)	Game (N)	Sport	TMA Method	TMA Variables Measured
VIDEO ANALYSIS						
Alexander & Boreskie, 1989	Elite Athletes	2	2	Handball	Video camera	Total and mean game time, mean pause time (between rallies, i.e. recovery), average length of each rally, strokes per match, number of serves.
Ali & Farrally, 1991	University Athletes	10?	1	Soccer	Video camera	Total time (walking, jogging, cruising, sprinting and standing still).
Capranica et al., 2001	Italian Youth	6	2	Soccer	Video camera	Total time (walking, running, inactivity and jumping); number of passes and tackles.
Deutsch et al., 1998	Elite (Under 19) Male Players	24	4	Rugby Union	Video camera	Total time and speeds (standing still, walking, jogging, cruising, sprinting, utility); static exertion (rucking, mauling and scrummaging).
Deutsch et al., 2007	Elite "Super 12" Male Players	29	8	Rugby Union	Video camera	Total and mean time, frequency, duration (standing still, walking, jogging, cruising, sprinting and utility); static exertion (rucking/mauling, tackling and scrummaging); discrete activities (kicking, jumping, passing).
Duthie et al., 2005	Elite "Super 12" Male Players	47	16	Rugby Union	Digital Video camera	Total time and mean duration (standing, walking, jogging, striding, sprinting, static exertion, jumping, lifting or tackling).
King et al., 2009	Elite "NRL" Male Players	3	3	Rugby League	Video camera	Total and mean game time, frequency, distance covered, duration (standing, walking, jogging, striding and lateral, sprinting and tackling).

Table 2: continued…

Author, Year	Subjects Level	Subject (N)	Game (N)	Sport	TMA Method	TMA Variables Measured
VIDEO ANALYSIS continued...						
Krusrup et al., 2002	Top-class Danish League Referee's	15	22	Soccer	Video camera	Total time and mean speed, distance covered, frequency and duration (standing, walking, jogging, low-speed running, moderate-speed running, and high-speed running, sprinting, sideways running and backwards running).
Krustrup et al., 2009	Elite FIFA Referee's	30	15	Soccer	Video camera	Total time, frequency, and duration (standing, walking, jogging, low speed running, moderate-speed running, high-speed running, sprinting, sideways running and backwards running (10 $km.h^{-1}$) total distance covered, mean velocity heart rate and blood lactate concentrations.
Luhtanen et al., 2001	EURO 2000 Players	?N (from 16 nations)	31	Soccer	Video camera	Total and effective playing time; specific game performance variables (passes, receiving, runs with ball, scoring trials, interceptions, tackles, goals and goalkeeper's savings)
Martin et al., 2001	English Premier Referees	9	19	Rugby Union	Video camera	Total and mean playing time (standing still, walking forward, walking backward, jogging, running, and sprinting).
O'Connor, 1994	Australian Elite Touch Referees	6	6	Touch	Video camera	Total time, frequency and mean time (stationary, walking, jogging forward, running backwards, sideways, sprint, recovery).

Table 2: continued**…**

Author, Year	Subjects Level	Subject (N)	Game (N)	Sport	TMA Method	TMA Variables Measured
VIDEO ANALYSIS continued...						
O'Connor, 2002	Australian Elite Touch Players	50	4	Touch	Video camera	Total time, frequency and mean time (stationary, walking, jogging forward, running backwards, sideways, sprint, recovery).
O'Donoghue & Parker, 2002	FA Premier League	6	38	Soccer	Video camera	Total time, frequency, duration during entire match and ball in-play (high intensity activity, recovery periods).
Spencer et al., 2005	Australian National	14	3	Field-Hockey	Video camera	Total time, frequency and mean time (standing, walking, jogging, striding, sprinting).
Stroyer et al., 2004	Denmark Clubs, Young males	26	?N	Soccer	Video camera	Total time, frequency and mean time (walking, jogging, cruising, sprinting, movement backwards, standing still).
Wilkins et al., 1991	Varsity Referees and Linesmen	10	4	Ice Hockey	Video camera	Total time, frequency and average duration (stoppages, officiating time).
GLOBAL POSITIONING SYSTEM						
Coffey, 2007	Australian Elite Touch Players and Referees	148 players and 72 referees	220	Touch	GPS (SPI 10)	Total and mean time, heart rate, distance, speeds (0-7 $km.h^{-1}$, 7-12 $km.h^{-1}$, 12-17 $km.h^{-1}$, 17-20 $km.h^{-1}$, 20-25 $km.h^{-1}$, >25 $km.h^{-1}$).

Table 2: continued**…**

Author, Year	Subjects Level	Subject (N)	Game (N)	Sport	TMA Method	TMA Variables Measured
GLOBAL POSITIONING SYSTEM continued...						
Coutts et al., 2009	Australian Elite AFL Players	16	65	AFL	GPS (SPI 10)	Total and mean distance, speed (standing 0-0.7 km.h^{-1}, walking 0.7-7 km.h^{-1}, jogging 7-14.4 km.h^{-1}, 14.4-20 km.h-^{1}, high speed running 20-23 km.h^{-1}, sprinting >23 km.h^{-1}).
Hewitt et al., 2009	Australian Elite National Players	15	4	Soccer	GPS? Athlete tracking device	Total and mean distance covered, speed (strolling or slow walking 0-5 km.h^{-1}, walking 5-8 km.h^{-1}, running 8-12 km.h^{-1}, moderate speed running 12-16 km.h^{-1}, high speed running 16-20 km.h^{-1}, sprinting >20 km.h^{-1}).
Kurzawa, 2008	Club Level Mixed Touch Players	11	8	Touch	GPS (SPI Elite)	Total time (attacking and defensive periods), maximum and average speed, distance covered; impacts (changes in accelerations and decelerations); body loads (stress on body due to impacts).
Larsson et al., 2002	Elite group	10	nil	Orienteering	GPS	Total time; total distance covered; mean speed, distance and timing of mistakes; mean relative heart rate.

Table 2: continued…

Author, Year	Subjects Level	Subject (N)	Game (N)	Sport	TMA Method	TMA Variables Measured
GLOBAL POSITIONING SYSTEM continued...						
Lythe, 2008	New Zealand Elite Players	18	5	Hockey	GPS (SPI Elite) & Video camera	Total and mean playing time, frequency, duration, distance, speed (0-6 $km.h^{-1}$, 6.1-11 $km.h^{-1}$, 11.1-14 $km.h^{-1}$, 14.1-19 $km.h^{-1}$, 19.1-23 $km.h^{-1}$, >23 $km.h^{-1}$) heart rate; specific game performance variables (creating space and leading, activity when in possession, defensive play, attacking play).
Pino et al., 2007	Spanish Elite Players	4	1	Soccer	GPS	Total distance, velocity (>3 $km.h^{-1}$, 3.1-6 $km.h^{-1}$, 6.1-9 $km.h^{-1}$, 9.1-15 $km.h^{-1}$, >15 $km.h^{-1}$), distance, heart rate, position.
Schutz & Herren, 2000	University Male Athlete	1	nil	Running	GPS	Total time, distance and speed (walking and running).
Wisbey et al., 2009	Australian Elite Professional AFL Players	519	1749 files	AFL	GPS (SPI 10 & SPI Elite)	Total distance, time, average and max speed (<8 $km.h^{-1}$, 8-12 $km.h^{-1}$, 12-16 $km.h^{-1}$, 16-18 $km.h^{-1}$, >18 $km.h^{-1}$).

Work rate activities can be classified according to type of action or movement, intensity (quality), duration (distance) and frequency of activity (from walking to sprinting), backwards and sideways movements, static pauses and actions with the ball. The activities may be aligned to a time-base so that average work: rest ratio can be determined. This work: rest ratio can be included to indicate loading parameters in athletes training programmes (Bangsbo, 1994; Deutsch et al., 2007; Reilly, 1997; Reilly & Gilbourne, 2003).

To date, researchers in a range of sports have often chosen a variety of TMA classification variables in their investigations. Although the production of an overall distance covered may be of some use in establishing the performance demands, on its own it is far removed from identifying the specific demands. It is therefore essential to investigate not only the total distance covered but also the movements performed in the matching order to reproduce them in practice and training scenarios, and attempt to optimise performance thereafter.

Advances in information technology have made it possible to develop and improve research methods for analysis of different movement patterns. With the use of computer-based TMA systems, it is now possible to control video images and to "enhance sport specific analytical procedures". Moreover, modern technology has had such an impact on sport that many athletes, coaches and strength and conditioning professionals now consider information derived from technological advances to be invaluable (Bloomfield et al., 2005; Coutts, et al., 2009; Liebermann et al., 2002).

Researchers using notational analysis have developed various sport analysis systems, many of which are computer-aided, and are designed to describe in detail the movements and technical actions of the athlete (Liebermann et al., 2002). For example, video analysis and GPS athlete tracking devices can describe in detail the actions of athletes in competition and, or training. Information derived from these types of computer-aided systems can be used for several purposes such as immediate feedback; development of a database; indication of areas requiring performance improvement; evaluation; and as a mechanism for selective searching through a video recording of the game (Coffey, 2007; Liebermann et al., 2002; Reilly & Gilbourne, 2003). All of these are paramount to the analytic process, which is involved in an effective TMA.

In many elite sports today, notational analysis in combination with video analysis is used for TMA to analyse athletes and games (Reilly & Gilbourne, 2003). This means that particular events of the game are manually noted ('event coding'), with a computer program, by searching for specific events from a video recording of a game. The program performs no actual analysis; this is left to the analyst and sport experts for later examination. Although sports such as Soccer have an extensive amount of TMA research available (Ali & Farrally, 1991; Bloomfield, 2005; Capranica et al., 2001; Hewitt et al., 2009; Krusrup et al., 2002; Krusrup et al., 2009; Luhtanen et al., 2001; O'Donoghue & Parker, 2002; Pino et al., 2007; Stroyer et al., 2004), there is limited research available in the sport of Touch. The aim of this review is to investigate possible methodological techniques which could be utilised for TMA of 'Touch', with a particular focus on event coding using digital video-analysis and player tracking via Global Positioning Systems (GPS).

Video Analysis

The most commonly used TMA measurement method during game-play situations in a variety of sports is video-analysis (Alexander & Boreskie, 1989; Ali & Farally, 1991; Capranica et al., 2001; Deutsch et al., 1998; Duthie et al., 2003; Duthie et al., 2005; Krustrup et al. 2002; Luhtanen et al., 2001; Martin et al., 2001; O'Donoghue & Parker 2002; O'Connor, 1994; O'Connor, 2002; Spencer et al., 2004; Stroyer et al., 2004; Wilkins et al., 1991). Video is recognised as an appropriate medium for obtaining qualitative information about performance that can be further used for individual notational analysis hence TMA and game statistics (Liebermann et al, 2002; Setterwall, 2003). Video-based motion analysis (kinematics) and automatic tracking systems, although significantly more expensive than basic video event-coding systems, are used to facilitate information about athletes performance, but are beyond the scope of this review (Liebermann et al, 2002; Setterwall, 2003).

This section will discuss video-analysis with three foci. First, an overview of what 'video-analysis is', including video-analysis methodology, from image acquisition to video-editing will be discussed (Figure 1). Second, the video-editing product SportsCode will be investigated. Third, the methodological advantages and disadvantages of using video-editing for TMA research will be explored.

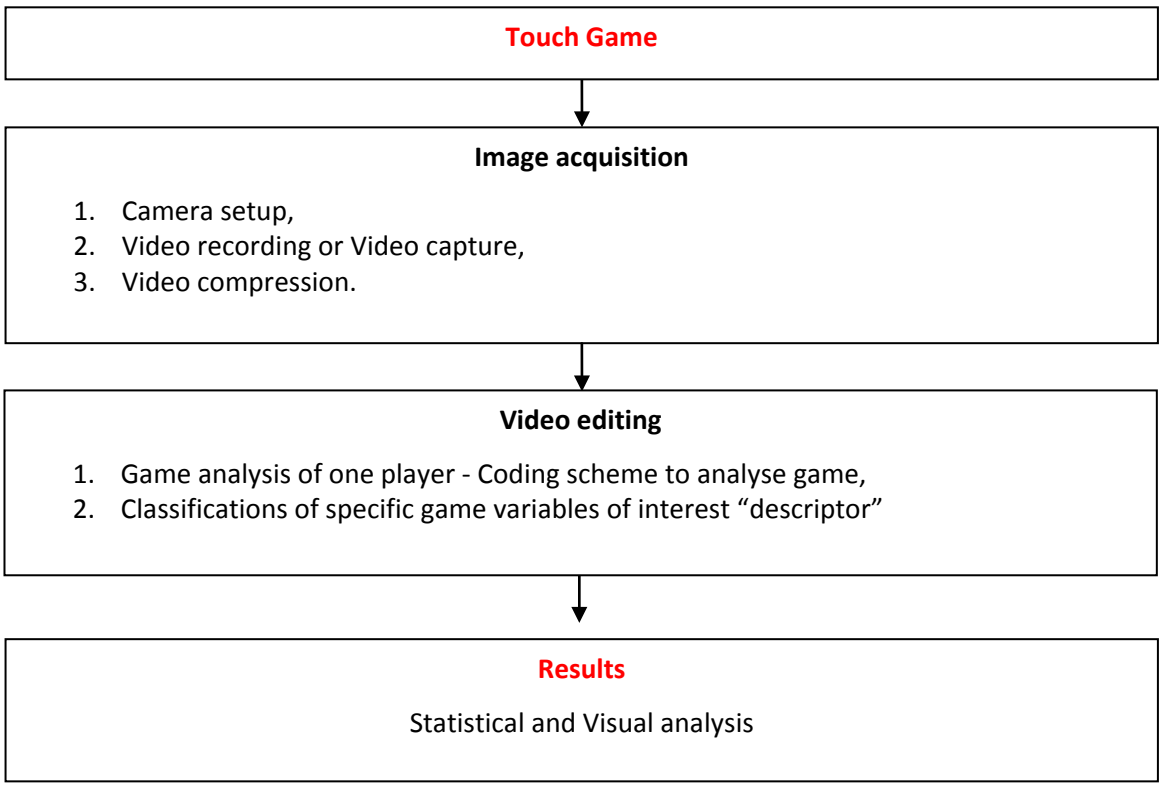

Figure 1. The video-analysis process in detail

Image Acquisition

Proper image acquisition significantly influences the performance of game or player tracking, particularly in the case of player motion acquisition and analysis. However, where certain measurements are performed any degree of uncertainty has to be specified, careful planning of image acquisition proves to be crucial for the success of the whole system (Pers & Kovacic, 2000).

The different camera techniques used will necessitate different collection strategies and associated problems e.g. mobile or stationary camera, one or several cameras, broadcasted television sequences or other video sequences, and normal lens or wide-angle lens. The single stationary camera with normal lens operated by the researchers themselves is the easiest way to avoid technical problems, but a negative effect is the limited analysis spectrum (Setterwall, 2003).

1. *Camera Setup*

Different camera setups are possible to record the match. To determine the movement patterns of the players (or the ball) from the beginning to the end of the game, the objects of interest have to be in the field-of-view for the duration of

the whole game. This can be achieved either by camera movement or use of wide-angle lens (Pers & Kovacic, 2000). 'Camera on the short side' is based on using just one camera. This camera is placed a relatively long distance from the field in order to cover the entire field. There are two problems with this approach. The first is that many locations do not have a place to set up a camera to cover the whole field. The other problem is that the distance to the field may make it hard to meet the resolution requirement (Setterwall, 2003).

2. Video Recording and Capture

Quality of video footage is needed for any TMA, some recommendations for this are given by Plowman (1999). When recording; always use a tripod; take spare batteries for the camera; superimpose a time code (makes transcription and analysis easier), or make sure the tapes are viewed on a video player which has a real time display; avoid interruptions when filming is in progress; and always label video at the time of recording (Plowman, 1999). A sport event can be recorded using single or several cameras. Recorded images are then transferred to digital domain using video acquisition hardware (Pers & Kovacic, 2000; Plowman, 1999). One way of obtaining this type of information from a video recording of a Touch game is to practise recording and tracking the players in order to get the players' positions on the field during the game (Plowman, 1999; Setterwall, 2003). The appearance of a Touch field is not static. The position of the sun, the clouds and the stadiums affect what shadows are cast on the field. Therefore the background image may need to be updated now and then (Setterwall, 2003).

3. Video compression

The ultimate goal of video compression is the bit-rate reduction for storage. Compression technology can increase the storage capacity for video quality. The performance of video compression techniques depends on the amount of redundancy contained in the image data as well as on the actual compression techniques used for coding (Sikora, 1997). The main problem with storing most of the material for analysis on video is that it is relatively inaccessible, hence the reason for video compression then transferring to computer-aided video-editing software (Plowman, 1999).

Video Editing

Once recorded, it is possible to analyse the behaviour in a set-up where the convenience of computer-aided observation and data collection is available. The ability of computers to control the video image makes it possible to enhance existing sport-specific analytical procedures. A computer-controlled system (also referred to in some research as “Video editing system”) allows the coach or sports analyst to provide the athletes with digital and graphical data of performance in addition to edited videotape instances of action that correspond to these data (Liebermann et al., 2002; Pers et al., 2001; Setterwall, 2003; Upton, 2004).

Video editing from one or several games is a powerful tool to use, not only for the coaches themselves but also for players in an educational perspective. Coaches can use the information gathered from several games and make a video sequence of particular events that show recurring patterns (Setterwall, 2003). The video editing tools are inexpensive and often portable. The researcher, coach or team analyst can do all the analysis by themselves and the tools are just software with an interface that can handle the video recorded information. Once he or she has a game on video it can then be edited as their own tactical video. These tools give the opportunity to build a comprehensive database of game and player information (Setterwall, 2003). Unfortunately, this type of tool does not give the analyst any information that cannot be obtained in other ways; it is only a way of structuring information. “You get what you put in and nothing else” i.e. performs no actual analysis (Balsom, 2002, cited in Setterwall, 2003 pp 15).

From the stored database, the interactive video computer program accesses times of all specific events such as points scored, set plays, etc. Then, from the menu of these events, the analyst can choose to view any or all of these events within one specific category (‘descriptive code’). The computer is programmed to control the video such that it found the time of the event on the video and then played back that excerpt of game action. It is also possible to review the same excerpt with an extended ‘lead in’ or ‘trail’ time around that chosen event (Liebermann et al., 2002).

This type of interaction system has been the creative spark for more recent and commercially available analysis packages that offer a generic data-gathering system, which can be customized to any sport and interact with the on-line video. A simple analysis of the data is available and the operator can have immediate access to edited

highlights of the performance, this technology is advancing at a rapid pace (Liebermann et al., 2002).

1. *Game analysis of one player - coding scheme to analyse game*

In order to analyse movement patterns a coding scheme for analysing data with the computer software available needs to be developed. Game analysis of one player involves recording of the initiation and completion of each movement from video playback into a microcomputer using a standard keyboard. Each tracking period is analysed from start to finish ideally by one analyst. A computer program records the player's total time in view, and separates movements into specific categories, for example gait speeds (standing still, walking, jogging, cruising, sprinting, etc.) (Deutsch et al., 1998).

An important issue is what kind of events are to be coded. The more events that are supposed to be inserted, the greater is the risk of operator mistakes. The only kind of events that should be inserted is events of interest for the end analysis. There is no point in inserting information about events that are of no interest for the end user. This would make the operator's task unnecessarily difficult and would increase the risk of information overload for the end user. Thus, it is important to define what kind of events that may happen in a game and which of those that are of interest for technical, tactical or conditioning purposes. Furthermore, according to Setterwall (2003), the operator or coder has to have more than general game knowledge to be able to classify events correctly.

2. *Classifications of specific game variables of interest "descriptor"*

Video-analysis has been used to examine variables such as: mean and total distance covered whilst walking, running or jogging and sprinting during an event; type of movement performed (forward, backward and sideway); number of dropped balls, errors, goals, etc. The definition of game events should be made by an expert. In the interface, these events could be divided into groups. For example player events could be ball contacts, attacking, defending, etc. and other events that the Touch experts are interested in (Setterwall, 2003).

More objective and important information can be obtained from video playback technology; for example, for on-site immediate comparison between one's performance and that of other athletes. In this way, visual qualitative and

meaningful feedback is provided to the athlete. It should be remembered however, that according to Plowman (1999), recording on video is not a substitute for other forms of data collection but it offers a number of advantages, such as the permanence of the record, easy reinterpretation, being able to check findings and retrieve data to share with others.

Video editing products currently being used by a variety of sports

SportsCode: "Game Breaker"

There are a number of commercially available event coding software programs currently available on the market which are designed specifically for sports. Example's are, Sportstecs - SportsCode (see http://www.sportstec.com), Data Project Sport Software - Data Video 3 (see http://www.dataproject.com), LRS Sports Software - LRS Sports Edge™ (http://www.lrs.com/LRSSports/) etc. The focus of this section is on a video editing system called SportsCode – "Gamebreaker" which is currently being used by coaches for analysing athletes during a game of Touch but also has the potential to be used in TMA research.

Gamebreaker is a video editing software system from the Australian company Sportstec, who currently provide several products aimed at coaches and strength and conditioning professionals in many different sports. Team sports such as, Australian Football League, Rugby Union, Soccer, and Hockey are all reported to use Sportstec's video analysis product (see http://www.sportstec.com). There are a number of products that Sportstec have which are widely used today by coaches and team video analysts (i.e., 'event coding') such as SportsCode "Gamebreaker" (Dowson, 1999; Kissane, 2005; Setterwall, 2003; Upton, 2004).

The following is an overview of information of the SportsCode video-editing software "Gamebreaker" taken from the manufacturers' website http://www.sportstec.com:

> *Software*: The software and digital video technology of Gamebreaker allows the analyst to gather information on individuals and teams, to use during performance for comparisons and finetuning, and afterwards to track the development of individual players or teams.

Equipment: Gamebreaker is portable, easy to use and runs on a standard Apple personal computer. It is specifically created for coaches and players, there's no need for special equipment or extensive training.

Research: For the purpose of research, Gamebreaker is designed to; check out the strengths and flaws of athletes; adapt performance to win; identify athlete hence team strengths and weaknesses; improve individual actions and reactions; and compare speed and technique related performances.

Specific features: Gamebreaker features include; recording performances (including the competitors') as and when they happen, make on-the-spot decisions, or save the recording for editing and post-game analysis; viewing any part of the performance instantly, no time wasted searching through video footage to find the right place; select and replay individual video frames to see exactly where people are in repeated, pressured situations. This feature could be useful in a game of Touch. For example, being able to view each consecutive touchdown being scored during an entire game. Other features include; edits material on the spot, and re-edits as often as you wish; creates a chronological record of performance, and prints it out if you wish; finally produces individual "movies" and presentations for players or performances. During a Touch game, this final feature could be another useful tool, for viewing and investigating a players 'game time off the field' (time and actions in the substitution box). That is, what the player is doing during 'rest or recovery' period.

Computer requirements: The minimum recommended computer requirements for Gamebreaker are: iMac or ibook, G3 – 500Mhz; CD-Rom; Apple system software version 9.0 or later; minimum 256MB of available RAM, 20Gb hard disk drive. Other recommended needs include: VST Firewire hard drive – 30/75Gig; Panasonic, Sony or Canon digital video cameras.

A thesis study by Setterwall (2003) investigated the possibilities for the Swedish Football Association to develop a tool for analysis of Soccer, using video technology. Setterwall (2003) also examined the possibility to commercialise such a tool. For example, this study examined a variety of current video analysis systems in order to

identify each of their strengths and weakness before making the recommendations of possible developments to the Swedish Football Association. One of the systems scrutinised was 'SportsCode'. A summary of Setterwall's findings are briefly outlined as follows:

> SportsCode is relatively *inexpensive*, *flexible* and *user friendly* compared to other more expensive automated video analysis systems such as ProZone and Amisco (Setterwall, 2003). It can be used virtually anywhere and anytime. Only additional requirements needed to perform an analysis are a video recording of the game and a computer (Apple Macintosh computer recommended by manufacturers, http://www.sportstec.com). The analysis is made by the user which reduces the need of "outsiders" who do not have to be involved in the analysis process as the case is with other more expensive products. For example one person can perform all the coding requests, whereas other automated video editing systems such as ProZone require the assistance of a team of analysts, due to the amount of information generated. SportsCode is also one of few analysis tools that are affordable for sporting organisations who may have limited funding. The awareness of the importance of technological aid in performance analysis is increasing, and is eventually filtering down at club and team levels in the community more and more. This could make provisional level associations interested in buying SportsCode.

Setterwall (2003) also identified a number of limitations encountered using SportsCode, such as it does not perform an actual analysis. Basically, SportsCode is a video editing program which allows the analyser to notate and store important video sequences. Thus, the actual analysis is entirely left to the analyser, and SportsCode does not give any new information to the user. It also requires a lot of manual work for the user and although the program can be used on any equipment it is recommended to be used on Apple Macintosh computers. According to Sportstec manufacturers this is because Apple is superior for working with video (see http://www.sportstec.com).

A case study report by Upton (2004) from the Adelaide Crows Football Club on http://www.sportstec.com website also came to similar conclusions regarding the usefulness of SportsCode. For example, Upton (2004) found SportsCode software

meets and exceeds the essential criteria of a quality analysis system. The system had the capacity to analyse both technique and individual player performance and was versatile for entering variables and for analysing those variables both statistically and visually. For a game of Touch, this would mean designing a code input template that concentrated on statistics. For example, touchdowns, ball contacts and attacking or defending plays for each player, although some have questioned the value of isolated frequency counts of events. Because many events in a game occur interdependently (i.e. they are the result of another event or situation). Upton (2004) suggested that it is important to code events in the context or environment they occur. For example, in a game of Touch, instead of just coding "ball contacts" as an isolated event you may choose to also add (through "descriptor" buttons) where the ball contacts are directed, who it is directed to (i.e. passing) and whether you maintain possession (i.e. attacking possession). You could also add tactical or strategical descriptors specific to a team's style of play. Upton (2004) summarised this case study with the statement:

> "Through the **correct** application of SportsCode, it is possible to gain *an objective insight* into performance variables that correlate with sports specific requirements," (Upton, 2004 pp 2).

Another testament of the SportsCode system is by Martin Dowson; Manu Samoa's fitness adviser, nutritionist, assistant manager, baggage master and video analysis person for the 1999 Rugby World Cup, who used SportsCode as their video analysis tool. Dowson's statements regarding the use of SportsCode video-editing system "Game Breaker" were as follows:

> "SportsCode" was *efficient*, achieved desired editing in a short period of time; *portable*, carried in a small computer case and was able to edit in buses, planes and airport lounges; *flexible*, coding suited each coaches unique style of analysing games; and *user friendly*, only took 5-minutes to show a player how to use it (Dowson, 1999).

Methodological Advantages and Disadvantages of Video Analysis

Advantages

Flexibility of analytic framework

- Video can be viewed as many times as required, it is possible to delay making final decisions about analysis until the researcher is confident about the appropriate approach and which aspects will be highlighted. This is not possible to the same extent if observational field notes are the only source of information because the situation they record is so fleeting; it is not possible retrospectively to decide to focus on some other aspect (Plowman, 1999).

Video-Editing tools

- *User friendly*

  The video editing tools on the other hand are user friendly and are based on what the user decides to code. SportsCode for example, is a portable system that can be used anywhere (Kissane, 2005; Pers et al., 2001; Setterwall, 2003; Upton, 2004; see http://www.sportstec.com).

- *Relatively inexpensive*
- *Portable*
- *Customisable input template*
- *Minimal personnel required to edit*
- *Simple to capture both 'statistical' and visual information*

  Presentations of your research are much more interesting if the audience can *observe* the interactions you are discussing. Similarly, it is much easier to share and discuss findings with other researchers and practitioners if you can review interesting or problematic sections and other researchers can test the validity of your findings by analysing the same video material. However, the individual needs to be discerning in the quantity of video footage obtained (Plowman, 1999).

- *Space saver for information storage*

With the availability of an external hard drive it is possible to store recordings of multiple performances and form databases specific to important aspects of sport performance (Upton 2004). *Video compression* decreases file size and therefore utilises minimal computer or disk memory, which can be extremely useful when analysis or collating several games for storage in a database (Kissane, 2005).

Disadvantages

- *Time consuming*

  A drawback with video analysis systems is the time taken to record manually and accurately track the events of interest and other points which may be important to the end user (Liebermann et al 2002). The disadvantage is that the time required for data processing can be very long and in some instances the video analysis method utilised may not give any valid information; it is only what the analyst can see with his own eyes that will be part of the analysis (Setterwall, 2003). Therefore, it is an important challenge for manufacturers of video tracking tools for analysis of sport to convince the customers that their tools provide additional benefits in comparison to traditional hand written notational analysis methods (Setterwall, 2003).

- *Operator mistakes*

  Most video tracking and editing systems require human operator supervision. Although capable of tracking players originally through several seconds of the match, both processes need a certain amount of human intervention to maintain error-free tracking and editing. It is up to the analyst to stay alert during the tracking and editing process otherwise the results provided by the analyst will not be accurate (Pers et al., 2001). One way of reducing the number of mistakes made by the operator is to make use of the fact that the occurrence of a particular event precludes some of the other events. For example, a 'touchdown' cannot follow a ball going out of play (because the game stops). Thus, it should not be possible to enter the event 'touchdown' if the preceding event was "ball going out of play" (Setterwall, 2003).

- *Coding is dependent on the user*

  Coding is either manually set or program lead (before) and lag (after) time for each occurrence of specific code or task. Hence, manual coding can reduce the trustworthiness between events (Kissane, 2005).

- *Video compression*

  Compression of original video files reduces the quality of picture, hence the importance of good quality 'original video recording' (Kissane, 2005).

- *Information 'overloads' (how to analyse it?)*

  The new generation of sports analysis tools are more focused on giving information that is very hard or even impossible to obtain by just watching a game in real time or afterwards. With tools like SportsCode (video editing software), the game analysts do not have the capacity to receive a lot of tactical and physiological information about the team and the individual players. This type of video editing information is then later analysed by the experts such as coaches or primary researchers and their job is then to analyse and integrate all sources of information and thereafter act or react accordingly (Setterwall, 2003; Upton, 2004).

- *Additional Expenses - Software compatibility*

  Manufacturers of SportsCode *highly recommend using their products with Apple computers*, which is the preferred brand for event movie or image coding. This therefore requires the extra expense of purchasing an "Apple personal computer" that is compatible with SportsCode (Kissane, 2005; Setterwall, 2003).

Summary

Video is recognized as an appropriate medium for obtaining qualitative information about performance. Video-based motion analysis systems, although significantly more expensive than basic video event coding systems, are also used to collect quantitative information about athletes performance (kinematics), but are beyond the scope of this review. A sport event can be recorded using single or several cameras, using S-VHS video recorders or more advanced camera technology. Recorded images are then

transferred to digital domain using video acquisition hardware i.e. video-editing system.

The video editing tools are relatively inexpensive and often portable systems. The computer is programmed to control the video such that time codes the event on the video and then that excerpt of game action can be played back when required. One product has been found that perhaps could be used for TMA research for analysing athletes during a Touch game is Sportstecs, video editing system called SportsCode – "Game Breaker". The advantages of this system include: user friendly; customisable input template; minimal personnel to edit; simple capturing of statistical and visual information and requires little storage space and computer memory for information storage.

Some limitations of video analysis systems include: the time taken to record manually and accurately; and, coding the events of interest and other points which may be important in the analysis. With tools like SportsCode, the game analysts do not have the capacity to receive a lot of tactical and physiological information about the team and the individual players; coding is dependent on the user; compressing the original video footage loses quality of picture and requires additional expenses to use software.

Global Positioning System (GPS)

A relatively new concept currently being utilised as a measurement tool during performance analysis of game-play situations, includes analysis via a tracking unit called 'GPS' (McErlean et al., 1998; Schutz & Herren, 2000; Terrier et al., 2001). Similar to the video-editing section, this section will discuss GPS with two foci. First, an overview of what 'GPS' is, including the process of how it works, from GPS receiver to data analysis. Secondly, the methodological advantages and disadvantages of using GPS for TMA research are discussed.

What is a GPS and how does GPS devices work?

The GPS is a navigation system that uses 27 operational satellites in orbit around earth. Originally it was developed for military use, but is now increasingly used for aviation, marine, sport and recreational outdoor purposes. Each satellite is equipped with an atomic clock. The satellites first set the clock in the *"GPS receiver"* by synchronising it with the atomic clock in the satellite. The satellites then constantly send information (at the speed of light) about exact time to the GPS receiver. By comparing the time given by a satellite and the time within the GPS receiver (see Figure 2); the signal travel time is calculated (Karboviak, 2005; Larsson, 2003; Schutz & Chambaz 1997; Schutz & Herren, 2000; Terrier et al., 2001).

The distance to the satellite is then calculated by multiplying the signal travel time with the speed of light. By calculating the distance to at least *three satellites*, the exact position can be trigonometrically determined. However, the signal from the satellites is influenced by the atmosphere and by bouncing off various local obstructions before reaching the receiver. This gives an error in the calculated distance to the satellite, and thus the computed position and speed. This error can be reduced with the use of differential GPS (dGPS). To attain dGPS, stationary receivers placed on known locations on the ground, compare their fixed position with the position given by the satellites. The correction signals are sent via radio waves from these fixed receivers via a differential receiver to the GPS receiver.

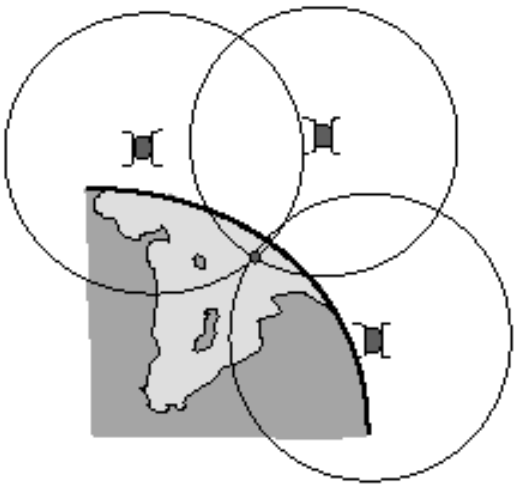

Figure 2. Illustration of the GPS process for determining the distance to at least three required satellites (Larsson, 2003, p. 1094).

Another possibility to enhance the precision of GPS measurements is to set up your own reference stations at known positions, which enables error corrections to be performed after the test is made. There are also carrier-phase GPS systems available that can measure position down to a precision of centimetres. Until recently, these systems have been too cumbersome in size and required a too long sampling time. However, lightweight systems with short sampling times have since been developed (Coffey, 2007; Karboviak, 2005; Kurzawa, 2008; Larsson, 2003; Pino et al., 2007; Schutz & Chambaz, 1997; Schutz & Herren 2000; Terrier et al., 2001; Wisbey et al., 2009).

In most commercially available GPS systems, speed is automatically determined by Doppler shift i.e. measurements of the change in satellite signal frequency due to the movement of the receiver. Speed can also be determined by dividing the difference in cumulative distance with the time difference between two logged positions (Larrson, 2004, cited in Schutz & Herren, 2000). Speed calculations from dGPS data, based on differences in distance and time, rely on changes in position from a bird's eye view. At each logged position, speed of movement, cumulative distance and altitude are determined, and the time stamp of logging is included (Larrson, 2004; Schutz & Chambaz, 1997; Schutz & Herren, 2000).

With additional features such as a heart rate incorporated with GPS technology specifically designed for sports use, this can be utilised in everyday training and testing to assess intensity, progress, and current status of the athlete (Coffey, 2007; Karboviak, 2005; Lythe, 2008; Pino et al., 2007; Wisbey et a., 2009).

GPS Receiver

A commercially available GPS receiver, most often bought for recreational purposes, is of approximately the same size as a cellular phone. A GPS receiver for use in sport science, however, requires some specific features. Firstly, it must be able to provide measurements with sufficient accuracy and precision. The distance to nine satellites should be possible to calculate distances accurately i.e. at least a nine-channel GPS receiver is preferred. Also, it must have a large memory capacity to store positions, cumulative distance and speed. The GPS receiver must also be fitted with a computer interface to enable downloading of GPS information for analysis. In addition, for better accuracy, the GPS receiver must have the capability to connect to a differential receiver (Larsson, 2003; Skaloud & Merminod, 2000).

Measurement Validity

With a solitary GPS receiver, an error in position of less than 15 m in 95% of the determined positions has been reported (Trimble Navigation Limited, Sunnyvale, CA, USA). With the use of dGPS, this error is reduced to around three meters (Trimble Navigation Limited) (Larsson, 2003). Such errors are continually being reduced, meaning the validity of GPS for sports science applications will continue to increase.

GPS Data Analysis

Data from GPS-equipment can be downloaded into a personal computer. Computer software for data analysis is abundant, and many share or freewares are also available; however, certain features are favourable for some computer software. In the monitoring of sport performance, it is important to be able to use the pointer directly on the computer screen to view the speed and cumulative distance in an instant position around a course, and further to study data in a list (Larrson, 2003; see http://www.garmin.com; htt://www.gpsports.com). To study the route of an athlete with a scanned map is also of importance; especially in sports with no predetermined course i.e. Touch (Coffey, 2007; Coutts et al., 2009; Karboviak, 2005; Kurzawa, 2008; Larsson, 2003; Lythe, 2008; Schutz & Chambaz, 1997; Wisbey et al., 2009).

Speed Measurements

Accurate measurements of speed and position have been demonstrated with the use of GPS technology (Larsson, 2003; Lythe, 2008; Schutz & Chambaz, 1997; Schutz & Herren, 2000). Schutz and Chambaz (1997) examined a young man equipped with a GPS receptor while walking, running and cycling at various velocities on an athletic track, to see how useful the GPS tracking device was in assessing walking and running speed in humans. In walking and running conditions (from 2 to 20 $km.hr^{-1}$) as well as cycling conditions (from 20 to 40 $km.hr^{-1}$), there was a significant relationship between the speed assessed by GPS and that actually measured by Swiss certified chronometer ($r = 0.99$, $P < 0.0001$) with little bias in the prediction of velocity. These researchers concluded that the GPS technology appeared very promising for speed assessment, although the relative accuracy at walking speed was still insufficient for research purposes. It is thought that this limitation may be improved by using differential GPS measurement (Larrson, 2003). The GPS instrument used in the above study was a commercially available GPS 45 (Garmin, Lenexa, KS 66125, USA) which is the size of a mini-cellular phone and weighs 0.3 kg. This particular GPS displays velocity of walking and running instantaneously on the GPS receivers screen (Schutz & Chambaz, 1997; see http://www.garmin.com).

Another published descriptive article by Terrier and associates (2001), examined five subjects walking at different stride frequencies, with a Leica System 500 double frequency GPS receiver attached (Leica Geosystems, Heerbrug, Switzerland). The GPS logger (rover) was placed in a backpack tightly fixed to the person (total weight of GPS equipment 4 kg). The objective of the study was to assess the external mechanical work in outdoor walking. The study concluded that GPS (in phase mode) is now able to record small body movements during human locomotion, and constitutes a promising tool for gait analysis of outdoor unrestrained walking. However, the design of the receiver and the antenna must be adapted to human experiments and a thorough validation study remains to be conducted. Also carrying 4 kg of equipment is impractical in most situations including when playing Touch.

Another publication by Karboviak (2005), examined the use of GPS technology in monitoring outdoor athletes' intensity, speed and training volume. Karboviak used a Timex GPS Speed and Distance Monitor was able to determine specific game and training session speeds, distances, intensities (speed and heart rate). Having current

speed, average speed, maximum speed, and distance covered measured instantaneously makes it an excellent assessment tool for all strength and conditioning professionals who need to monitor and design specific training programme.

The following summary of GPS advantages and disadvantages is based on recent research which have utilised GPS systems (Coffey, 2007; Coutts et al., 2009; Coutts and Duffield, 2010; Karboviak, 2005; Kurzawa, 2008; Larsson, 2003; Lythe, 2008; Schutz & Chambaz, 1997; Schutz & Herren, 2000; Terrier et al., 2001; Wisbey et al., 2009) and GPS manufacturers information (see http://www.gpsports.com and http://www.garmin.com).

GPS Advantages:

- *Portable, (light and small size)*
- *Non invasive, non-obstructive measurements*
- *Continuous measurement with 'on line' data obtained on a miniature screen, hence feedback values for the subject*
- *Reasonable cost of GPS device (depending on the model compared to other methods of TMA i.e. automated video systems)*
- *Data could be stored and subsequently retrieved if required.*

  GPS approach allows one to record and easily analyse an almost unlimited number of gait cycles (about 3–4 h of recording, limited only by memory card and battery autonomy) (Terrier et al., 2001).
- *Time saver*
- *Versatile*

  The GPS technique can be used to independently validate measurements of velocity of walking and running by other techniques (such as by accelerometer) (Terrier et al., 2001).

GPS Disadvantages:

- *Monetary*

  GPS Devices retail from $200 - $2,000 NZD depending on the model, specifications and additional features. Information from some models require downloading information on to a computer that is compatible with required software, this then runs into an additional cost of purchasing a personal computer (Karboviak, 2005). Although, this is still cheaper than purchasing an 'automated video analysis system' such as ProZone.

- *Measures can only be obtained outdoors and satellites are influenced by atmosphere and various local obstructions, before reaching receiver;*
  Limiting its use to only those sports trainings and, or assessments which can be conducted outdoors. Outside weather conditions must be fair and clear. Cloudy conditions can interfere with the readings.

  GPS measurements can only be performed in an environment in which access to the satellites is not obstructed (e.g. by tall buildings or terrain etc). Measurements indoors are therefore not possible (Larrson 2003; Schutz & Herren 2000). The combination of position errors and low sampling rate could lead to a false estimate of the energy signal, for example the positive power may be over or underestimated from one step to another (Terrier et al., 2001).

- *Static activities cannot be measured*

- *Precision of measurement is impaired by a radio shadow*
  Access to the satellites is obstructed if you are in a radio shadow, such that not all the data can reach the receiver, the precision of the measurements is impaired (Larsson, 2003)

- *Utilisation of the GPS depends upon the continuous access to at least three satellites simultaneously*

- *Battery life is limited to memory card and battery autonomy*
  Those GPS devices that are powered by battery may require replacements every 6 – 8 hours of function with constant use, hence additional ongoing expenses (Karboviak, 2005). GPS devices powered by memory card need to be constantly recharged after every 3 – 4 hours of functioning.

- *Error in position of less than 3 - 15m (depending on the GPS model)*
  With a solitary GPS receiver, an error in position of less than 15 m in 95% of the determined positions has been suggested. With the use of a built-in 'differential' receiver (dGPS) for correction data, this error is reduced to approximately 3 m (Larsson, 2003).

Summary

Recent technological innovations currently being utilised as a measurement tool during performance analysis of team sport game-play, includes analysis via a tracking unit called Global Positioning System (GPS). The GPS is a navigation system that uses 27 operational satellites in orbit around Earth. The satellites then constantly send information (at the speed of light) about exact time to the GPS receiver. By comparing the time given by a satellite and the time within the GPS receiver, the signal travel time is calculated. A GPS receiver for use in sport science, however, requires some specific features. Also, it must have a large memory capacity to store positions, cumulative distance and speed. The GPS receiver must also be fitted with a computer interface to enable downloading of GPS information for analysis.

Until recently, testing of sport performance has mostly been restricted to the laboratory environment. Multiple factors that are hard to control have limited the use of sport-specific field testing. The technique of GPS has now been put forward as a way to monitor the position and speed of an athlete during outdoor activities with acceptable precision, thus controlling important factors of an athlete's performance such as speed. Using a GPS device specifically designed for sports use, the athletes, coaches and strength and conditioning professionals can develop a sense of awareness of maximum intensity; assess the effects of the designed programme (Coffey, 2007; Karboviak, 2005; Lythe, 2008; Wisbey et al., 2009). GPS is capable of capturing speed and distance information for sports that in the past have had difficulty in capturing this information (e.g. running, skiing, and team sports). It can provide second by second information regarding athletes' performance path, which can be instantaneously examined to assess any segment of the event, the effects speed and distance have upon heart rate and to compare results of athlete to athlete. Such parameters include:

time; maximum speed; average speed; distance travelled; maximum heart rate; average heart rate and positional information.

Concluding, for the purpose of determining game measures during a competition game of Touch the GPS technique appears very promising for speed assessments greater than 10 m, i.e. 1 Hertz. However, the relative accuracy of walking is still insufficient for research purposes. Measurements from the GPS on intensity, speed, and training volume can be crucial factors in an effective programme that obtains the desired results from traditional speed training.

Summary of methodological advantages based on current GPS research and information are that the GPS systems is: portable; light and small size; non invasive non-obstructive measurements; able to display continuous measurement with 'on line' data obtained on a miniature screen, hence feedback values for the subject; reasonable in price to purchase (depending on the model compared to other methods of Time-Motion Analysis i.e., automated video systems); versatile and easy to store, and subsequently retrieve, data if required therefore saving time. The methodological disadvantages based on GPS research and information are that the GPS systems are: expensive (depending on the model i.e. extra costs associated with having a built-in differential); can only obtain data outdoors; influenced by atmosphere and various local obstructions, before reaching receiver; impaired by a radio shadow; dependent upon the continuous access to at least three satellites simultaneously and has a limited battery life.

Conclusion

This review has attempted to investigate some of the methodological considerations important in 'Time-Motion Analysis' in particular video event coding and GPS tracking. This was undertaken for the sport of 'Touch' to assist in further research developments for more sport specific assessments and training programmes. The collaboration of testimonial reports and interviews from people within the sporting industry helped immensely in getting an insight into the practical applications of video-analysis and GPS methodologies. Their general comments and thoughts gave valuable information to the review, which would have been hard to obtain otherwise.

In summary, in order to conduct an effective TMA study of elite 'Touch' players during a competition, the advantages and disadvantages of Video Analysis and GPS technology need to be considered. By addressing methodological limitations, this should in turn provide more accurate data collection, in order to design scientifically based, sport specific training programmes for enhancing sports performance. The following recommendations are made with this in mind:

- *In order to conduct an effective 'Time-Motion Analysis' of a Touch player's competition game, using video-analysis (video-editing) and GPS devices, the researcher must consider the methodologies advantages, disadvantages and equipment requirements whilst preparing and performing such a project.*
- *To determine the analysts' video-editing or coding reliability, an analysis of two or more captured recordings should be performed and any difference in manual in-putting identified.*
- *More valid and reliable research is required to establish the accuracy of GPS measurements particularly in TMA studies of team sports which perform several small movements within a confined space.*

Future research could include true validation study of both, for instance, by comparing GPS and a video motion analysis system.

CHAPTER THREE

Time-Motion Analysis of Elite Touch Players During Competition.

Chapter Summary

Purpose: The purpose of the present study was to measure physical demands and skill levels of New Zealand elite Touch players during competition using video and Time-Motion Analysis (TMA), with an aim to gain an understanding of potential differences between Touch players of different grades and genders. ***Methods:*** Thirty-eight elite Touch players gave their informed consent to participate in this study. The sample consisted of 20 males (mean ± SD: age 23.4 ± 3.8 years; height 174.9 ± 6.1 cm; body mass 75.3 ± 8.1 kg) and 18 females (mean ± SD: age 23.9 ± 3.7 years; height 165.9 ± 5.0 cm; body mass 63.9 ± 5.6 kg). Testing was conducted at the Touch New Zealand (TNZ) Open National Tournament. Physical and technical game measures, including video footage (playing time, sport specific skill analysis), blood lactate concentrations (via a portable blood lactate concentration meter) and GPS data information were obtained during one competition game at this tournament. ***Results:*** For each playing grade the overall mean time period spent on and off the field ratios during a game was, male only ~1:1.10, mixed male ~1:1.75, female only ~1:1.40 and female mixed ~1:1.20. Across all grades male mixed players spent significantly ($p < 0.05$) more time sprinting than female only (~50%) Touch players. Maximum speed achieved during a game ranged from ~22 – 25 $km.hr^{-1}$, with male only players attaining significantly higher maximum speed than female mixed (~12%) Touch players. Although no significant between-group differences were found during a competition game for total distance travelled, average speed on the field, post game blood lactate concentration, total distance travelled ranged between ~2.8 – 3.1 km, average speed on the field ~9.0 – 10.0 $km.hr^{-1}$, and post game blood lactate concentrations between ~4 – 7.5 $mmol.L^{-1}$, for each of the three groups. Male only and male mixed players performed significantly more successful attacking skills during a game than female mixed (~47%, both) Touch players. ***Conclusion:*** Results of the present study indicate that there are several physical and technical differences as well as similarities across the three playing grades of elite Touch. These results provide some initial physical and technical game measurement data for elite New Zealand Touch players and can be used as benchmarks for coaches and support staff when planning their athletes training programmes and by sports scientists for further research. Such data is useful due to the lack of research into elite Touch, providing some indication of the different physical and technical game demands of the different elite Touch grades.

Introduction

'Touch' is an outdoor game played on a rectangular grass field (70 x 50 m), which is divided by a middle line into two equal halves. A 20 x 5 metre substitution area is on either sides of the field of play (see Figure 3). At the elite level Touch is played at a fast pace with frequent substitutions particularly since the reduction from seven to six players on the field at any one time was introduced in 1996 (O'Connor, 2002).Touch players can be in any one of three grades; Men's only, Women's only and Mixed gender grade. The Mixed gender grade (where both male and female players are on the field at the same time) is particularly popular with social players, and is widely played in schools. However, at the elite level (national or international) Touch players tend to specialise in one of these three grades. Currently, New Zealand Touch players are ranked in the top two countries around the world in all three playing grades. As of January 2010, New Zealand holds World Champion titles in the Mixed (Open, Masters, Under 21) and Men's (Under 21 and Under 18) grades (www.TouchNZ.com).

Touch is referred to as an intermittent game due to the pattern of repeated short bursts of high intensity activity interspersed with active and passive recovery. During these periods the athlete is forced to make numerous maximal accelerations and decelerations with short recovery forward or backwards walks or jogs in between. Such activity requires lactate removal and quick regeneration of phosphocreatine (PCr) stores to allow for sustained performance (Templeton et al., 2001). For these reasons, Touch is predominantly an anaerobic sport. Despite this, many coaches and players believe that an aerobic base is essential in order to allow sufficient recovery from the anaerobic bursts and also to assist with recovery during a game and over a tournament where a Touch player would play on 3 – 4 consecutive days (depending on tournament schedule) with up to three 40-minute games per day. With a recovery period of between two and five minutes off the field (in the substitution box, either during each half or in the half time break) between efforts, the athlete has to make the most of this time to ensure they are able to give their best possible performance once back on the field (Templeton et. al., 2001). One measure which may give some insight into the amount of work performed on the field and the ability to quickly recover could be the use of blood lactate concentration measures. Blood lactate concentration is a result of lactate rate of appearance and rate of disappearance therefore gives a snapshot of lactate turnover. Blood lactate concentrations at the conclusion of a competition

Touch game have been reported to range between ~6 – 7 mmol.L^{-1} for an elite male Touch player (O'Connor, 2002; Templeton et al., 2001) and ~6 mmol.L^{-1} for an elite female Touch player (O'Connor, 2002). Accumulation of blood lactate concentration (along with other physiological by-products) is highly related to temporary fatigue (Lythe, 2008). However, some caution is warranted when interpreting blood lactate concentration values as many factors, including level of competition, individual differences (age of players, hydration status, and fitness etc.), prior exercise, temperature and humidity, emotional stress, time of measurement, and environmental conditions, may affect the results (Templeton et al., 2001).

Despite an extensive number of TMA studies being conducted on Rugby Union (Deutsch et al., 1998; Deutsch et al., 2007; Duthie et al., 2003; Duthie et al., 2005; Martin et al., 2001), and Soccer (Ali & Farally, 1991; Capranica et al., 2001; Hewitt et al., 2009; Krustrup et al., 2002; Krustrup et al., 2009; Luhtanen et al., 2001; O'Donoghue & Parker 2002; Pino et al., 2007; Stroyer et al., 2004), studies on the physiological demands of Touch players during a competition game are limited (Coffey, 2007; Kurzawa, 2008; O'Connor, 2002; Templeton et al., 2001). Combining accurate and reliable TMA video-analysis and blood lactate concentration data would provide a more comprehensive picture of the demands of Touch than previously achieved. Relative activity time and distance, and physiological indices have never previously been monitored concurrently, or fully distinguished between various genders and playing grades in Touch.

A brief summary of studies that have investigated the time-motion requirements of Touch are presented in Table 3. Although these recent studies have provided a basic understanding of the physical demands of Touch players, there are considerable methodological differences between them which make interpretation and comparison of data difficult. There are also some limitations in these studies most notably the small number of games used by O'Connor (2002), the small number of players studied by Templeton et al. (2001) and little information provided regarding gender details by Coffey (2007) and Kurzawa (2008).

Table 3: Recent Time-motion and lactate data research from 'Touch'

Author, Year	Subject Group	Key findings
Coffey, 2007	Australian National Elite players; (n = 82?, 17 – 49?year), 82 Open player data files No mention of number of games, number of male or females, or locomotive state descriptions only speed.	• Used GPS (SPI 10) for analysis, Total duration of recording 45-47-minutes. • Av distance covered in a game = Open player 3.12 km. • Longest distance covered in a game = M: 4.40 km and F: 4.10 km • Av percent of distance covered in locomotive state 0-7 $km.h^{-1}$ = Open 89.24%. • Av percent of time spent in locomotive state 7-12 $km.h^{-1}$ = Open 6.86%. • Av speed over duration of game = Open 4.51 $km.h^{-1}$. • Maximum speed achieved in a game = Open 32.0 $km.h^{-1}$.
Kurzawa, 2008	Club level Mixed grade players; (n = 11) No mention of ages or number of males or females. Total of 8 games.	• Used GPS (SPI Elite) for analysis. • Time ON field ¥26.75-minute. N.B. All periods< 1 $m.s^{-1}$ were removed in study for analysis. • Total distance covered in a game ¥2.7 km. • Av speed in a game ¥6.57 $km.h^{-1}$. • Maximum speed achieved in a game ¥26.23 $km.h^{-1}$.
Templeton et al., 2001	Australian National Elite male players; (n = 3, 25 ± 2 years, 79.3 ± 3.9 kg). Total 17 recorded files from 7 games.	• Time ON and OFF field measured with stop watch. Lactates measured from the ear using Lactate Pro lactate analyser. N.B. no mention of game duration or substitutions made. • Time ON field (min: sec); Av 1st half 1:50 ± 0:50, Av 2nd half 1:48 ± 0:59, and mean total time ON field 1:49 ± 0:55. • Time OFF field (min: sec); Av 1st half 2:35 ± 1:05, Av 2nd half 2:48 ± 1:18, and mean total time OFF field 2:41 ± 1:11. • Time ON and OFF field ratio was 1:1.75 • Blood lactate concentrations; pre-game 1.5 ± 0.3 $mmol.L^{-1}$, during game (end 1st half) 8.6 ± 1.5 $mmol.L^{-1}$, and conclusion of game (end 2nd half) 7.2 ± 1.5 $mmol.L^{-1}$.

Table 3 continued...

Author, Year	Subject Group	Key findings
O'Connor, 2002	Australian International Elite squad players; n = 50, male (n = 30, 19 – 29 years), and female (n = 20, 16 – 27 years). Total of 4 games, 2 Men's and 2 Women's games.	• Used video cameras for analysis. Blood lactate concentrations were measured using ACUSPORT analyser within 5-minute of game remaining to 5-minute post game. • Total duration of recording 30-minutes (15-minute each half with 5-minute half time). • Percent of time spent in interchange (substitution box) M: 47.29 ± 6.20%, and F: 47.66 ± 7.50% • Percent of time spent in locomotive states = stationary M: 4.74 ± 1.40%, and F: 3.46 ± 1.47%; walking M: 17.87 ± 5.07%, and F: 18.91 ± 4.01%; jogging forward M: 20.04 ± 3.30%, and F: 18.57 ± 2.20%;running backward M: 5.57 ± 1.85%, F: 5.29 ± 1.39%; side M: 0.62 ± 0.80%, and F: 2.31 ± 0.78%; and sprinting M: 2.73 ± 1.05%, and F: 4.19 ± 1.47%. • Walking and jogging forward were the movement most frequently executed. • Av duration of each locomotive state = stationary M: 4.7 ± 1.11 s, and F: 4.52 ± 0.71 s; walking M: 6.2 ± 0.97 s, and F: 5.86 ± 0.62 s; jogging forward M: 4.81 ± 0.70 s, and F: 5.43 ± 0.67 s; interchange (in substitution box) M: 111.4 ± 16.9s, and F: 130.35 ± 23.06 s; running backward M: 3.13 ± 0.55 s, F: 4.28 ± 0.93 s; side M: 1.88 ± 0.31 s, and F: 2.65 ± 0.31 s; and sprinting M: 2.88 ± 0.48 s, and F: 3.26 ± 0.28 s. • Number of interchange (substitutions made) M: 7 ± 1, and F: 6 ± 1. • High intensity activities sprinting, running backward and sideways represented less than 12% of total game time M: 11%, and F: 12%. Low intensity 42% of total game on field. • Blood lactate concentrations at conclusion of game; mean M: 5.7 ± 1.4 mmol.L^{-1}, and F: 5.9 ± 3.1 mmol.L^{-1}. Highest lactate recorded 15.8 mmol.L^{-1}. Outside players recorded lactate 7.5 mmol.L^{-1}, middles registered 4.6 mmol.L^{-1}.

M: male, F: female, Av- average. ,? Information not provided or unclear in study ¥Denotes value, calculated by author using information provided in study

Recommendations have been suggested from these studies to evaluate the demands of Touch with; more subjects, including more females; a video analysis of duration and intensity of each movement type (Templeton et al., 2001); and examination of potential gender differences (Coffey, 2007). Consequently, there is a need to gain a more comprehensive data set , covering specific gender groups and playing grades (Men's, Women's and Mixed) for a number of Touch games so as to adequately describe the demands of top level competition.

No studies have addressed Touch specific skills and tactics. Such data would be useful as it may provide information that allows coaches to change the game or practice specific skills and strategies. A notational analysis system has not been developed to evaluate the technical and tactical skill of a player in order to determine its frequency and hence importance during a Touch game. In fact, for an observer (usually the coach), the traditional method of assessing skill and its importance in a game has been to watch a game and make subjective conclusions about the individual's or team's performance (Thomas, 2009). The coach would then decide how to divide practise time among various skills or tactics. This system of game analysis and subsequent planning of practise time is limited by the coach's knowledge, experience and perspective. Even with the introduction of video recording and the ability to subsequently view games, most coaches still rely on subjective evaluation for allocating practice time. The traditional method of game analysis does not present an objective measure to determine which skills are the most important during a game of Touch. If the most important skills could be objectively determined, then a coach could devote appropriate individualised and, or team practise time to the improvement of that skill.

The purpose of the present study therefore was to measure the physical demands of elite Touch players during competition using TMA, with the aim of profiling playing grade differences during a game of Touch. A secondary purpose was to evaluate successful and unsuccessful performance of Touch specific skills during Touch games at the elite level through the use of notational video analysis. It is hypothesised that male Touch players would achieve greater Time-Motion Analysis measures (playing time, game movements, distances, speeds and blood lactate concentrations) during a competition game than female Touch players, regardless of playing grade. As biological and physiological difference between genders may suggest

male athletes have an obvious performance advantage over female athletes, particularly during a physically demanding sport such as Touch.

Methods

Participants

Thirty-eight elite Touch players gave their informed consent to participate in this study. The sample consisted of 20 males (mean ± SD: age 23.4 ± 3.8 years; height 174.9 ± 6.1 cm; body mass 75.3 ± 8.1 kg) and 18 females (mean ± SD: age 23.9 ± 3.7 years; height 165.9 ± 5.0 cm; body mass 63.9 ± 5.6 kg). Each participant had been selected to represent their respective regional area in the Touch New Zealand (TNZ) Open National Tournament. All Touch players were volunteers from a variety of regional teams around New Zealand, including 28 (7 male, 8 female and 13 mixed (6 male and 7 female) players who were chosen to compete for New Zealand at the following years Touch World Cup. Ethical approval was obtained for all testing procedures from Auckland University of Technology Ethics Committee.

Procedure

Testing was conducted at the TNZ Open National Tournament. All participants were required to complete three testing sessions for this study. The first session involved assessment of the player's pre-game blood lactate concentration. Physical and technical game measures from one game per player at this tournament were obtained during the second session. This included video footage (playing time, sport specific skill analysis), and GPS data (Time-Motion Analysis) information, which was for the duration of one 45-minute competition game at this tournament. The final session involved assessment of the players' immediate post-game and recovery lactate (20-minute post-game); these were obtained at the conclusion of the game analyses.

Physical Game Measures

- *Video-Analysis*

Testing Protocol

Video footage was taken using three cameras for three players simultaneously, one video camera (Panasonic NV GS400) per player and mini-DV cassette tape per game. Each camera was positioned at one end of the Touch field on a tripod in the centre of the field approximately 1.5-metres above the level of the field (See Figure 3), positions varied depending on field location for each player's game. Three assistants were used during the study for video recording (one camera per assistant), all of whom underwent training prior to this study at a previous Touch tournament. Each camera operator was trained to follow one player by panning and zooming to maintain an approximate radius of 5-metres about the player of choice, in the field of view. A player was videoed for the duration of each game; this included all substitutions and the half time break. Camera footage was saved onto individual tapes immediately after each game, downloaded and compressed to a laptop computer at the end of each tournament day for later analysis. The video footage was used to measure the performance variables (playing time and substitutions) and technical outputs (Touch specific skills) of each subject.

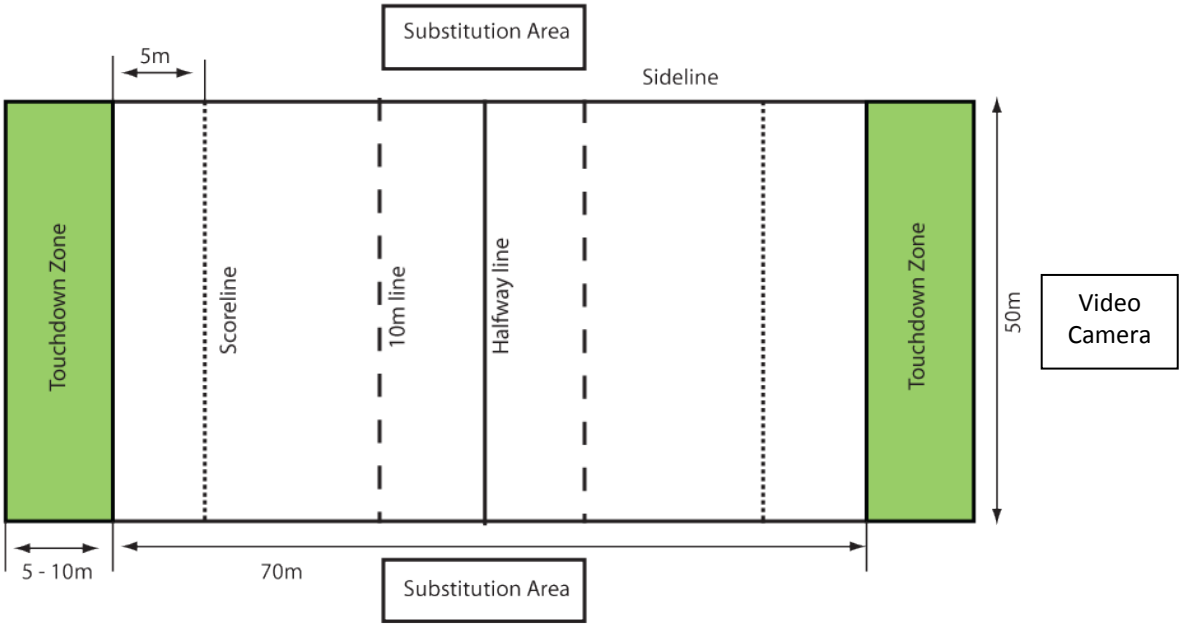

Figure 3: Dimensions of Touch field and video camera position for game recording. Image retrieved from: http://www.dsr.wa.gov.au/981

Analysis and video-editing of each individual video file (n = 38) was examined by the author using a real time display through Windows Media Player Software Program. Data was manually transferred at the same time of viewing each file onto another computer using Excel. Total Video data files analysed were reduced to 36 due to one player injury within the first 10-minutes of a game and because one video data file was not recorded for a complete game.

All Touch games examined for this study were randomly chosen and each game was of 40-minute (two 20-minute halves) duration with a 3-minute interval at half-time. TNZ Open National Tournament was held over three days, with each team playing between 5 – 8 Touch games (5 Men's, 7 Women's and 8 mixed). In order to obtain sufficient TMA data across all three grades during this particular tournament only one game per subject was assessed for this study. Games were randomly chosen (i.e. subject did not have a choice of what game would be analysed) based on when each subject's team was playing during this tournament. Some players had their first game on the first day chosen for analysis, whilst others may have had their fifth or eighth game on the third day assessed. In the weeks leading up to this study, all subjects were participating in their local Touch competitions and training with their respective regional team for this tournament and considered to be in peak physical condition at this tournament.

'Mixed grade' were defined as being Touch players who play in a grade that has both males and females (e.g. Mixed grade team consists of up to 14 players in a team, with no more than three males and three females being on the playing field at any one time). For the purpose of the present study all physical and technical data analysis values of male (n = 10) and female (n = 8) elite Touch players who play in a Mixed grade were separated. This is because male and female Touch players in a Mixed grade although they are given equal opportunities to play in any position during a game, there are obvious physical gender differences. Therefore, separating physical and technical game measures of male and female Touch players would give a better indication of Touch players who specialise in playing in a Mixed grade team only.

Playing Time and Substitutions

Playing time spent on and off the field was measured using Video recordings. Total game time included 43-minutes (2 x 20-minute halves and 3-minute half time break). A player was judged off the field when he or she was in the substitution box, including a three minute half time break. First half and second half information was collated from 20-minute of game time per half. Playing time on field was judged when a player was on field. Number of substitutions made in a game was assessed when a player made an interchange with another team member to go onto the field. The outcome measures calculated from the video analysis of players' time on and game time off the field of play were defined as follows:

Playing time on field: the moment the player entered the field of play; included all locomotive movements (stationary and, or walking, power walking and, or jogging, running and sprinting) during playing **time on the field**. This could also be known as 'work time' during a game.

1st and 2nd Half: included 20-minutes of total game time, and did not include the 3-minute half time interval. This applied to both **playing time on and game time off the field** *for each half*.

Total game time on field: included total period of 40-minutes (1st and 2nd half time on the field only), which is spent **on the field**.

Average playing time on field: determined by dividing playing **time on the field** and number of substitutions during each time period (1st half, 2nd half or total game time).

Game time off field: the moment the player entered the substitution box; included all locomotive movements (stationary and, or walking, power walking and possibly jogging) which is spent **off the field** during a game. This could also be known as 'rest or recovery time' during a game.

Total game time off field: consisted of total game time period of 43-minutes (1st and 2nd half time off the field, plus 3-minute half time break), which is spent **off the field** during a game.

Average game time off field: determined by dividing game time **off the field and number of substitutions** during each time period (1st half, 2nd half or total

game time). Note Average total game time off field included 3-minute half time interval.

On and off field ratio: determined by difference between *'average playing time on field'* ("work") and *'average game time off field'* ("rest") during each **total game time** period. This could also be known as work: rest ratio during a game.

Time-Motion Analysis via GPS

Testing Protocol

TMA was performed once on each player, during one of the three tournament days (total 38 individual samples: Day 1 = 14, Day 2 = 20, and Day 3 (semi finals) = 4). Data was collected using a portable global positioning system (GPS) and video camera from 18 different official games (5 Men's, 5 Women's and 8 Mixed grade games), which included 1–3 samples from each game examined, for a total of 38 individual samples. The time-motion data was only included in the analysis if the player participated > 75% of total game time, which provided 35 completed GPS data files [9 Men's, 10 Women's and 16 Mixed; (8 male and 8 female)].

Global Positioning System

Game distance and speed were collected at 1Hz (1 sample per second) using a portable GPS recording device (SPI 10, GPSports Systems Ltd, Canberra, Australia). A single unit was worn by each player during one Touch game. The small (110mm x 52mm x 25mm) and light (110g) device (Figure 4) was worn on the upper back in a neoprene harness under the playing top. The neoprene harness was fitted and correctly sized for each player prior to team warm-up period (approximately 20-minute before start of game) to allow the player to become more familiar with the device and to cause minimal discomfort and distraction. GPS recording device was turned on within 5-minutes of the game starting (allow time for GPS satellites to communicate) and recording stopped immediately after game.

Figure 4: GPSports SPI10

Image retrieved from: http://www.gpsports.com/products/spi10/index.php

This GPS device has previously been shown to provide valid measures for distance at an acceptable level of accuracy and reliability for total distance (−4.1 ± 4.6% of true distance) and peak speeds [coefficient of variation ± 90% confidence interval: 5.8% (5.2 – 6.6%)] during high-intensity, intermittent exercise (Coutts & Duffield, 2010). However, some GPS devices have been shown to measure poor inter-unit reliability for distance travelled at higher intensity activities [32.4% for high-intensity running distance (>14.4 km.h^{-1}, HIR)] (Coutts & Duffield, 2010).

In all games players wore one of two types of Heart Rate (HR) monitor chest straps (GPS SPI 10, GPSports Systems Ltd, Canberra, Australia; Team Polar, Polar Electro Oy, Kempele, Finland) which recorded HR every 1 – 5 seconds. Following the conclusion of the game the data was downloaded using manufacturer-supplied software (GPSports SPI 10 Analysis; Polar Precision Performance v4.03.043) and processed. However, several players removed their HR monitor chest strap part-way through the game due to perceived interference or slippage of strap. During analysis of HR data it was evident several files either did not record for a complete game or was otherwise non-existent. For these reasons the HR data was excluded from analysis.

GPS Data Analysis

GPS data was edited to only include 43-minute game time, this included a three minute half break and then separated into four speed zones (refer to Table 4). Total GPS data files analysed was reduced to 35 due to one player being injured during game and two players not recorded for a full game.

Game movements: The time spent and distances covered in the four locomotor speed ranges were analysed using the pooled data of 35 data files.

Game distances and speeds: Total distances covered were calculated and the highest speeds recorded during the game for each player were recorded. Average speed ($km.h^{-1}$) was also calculated from the distance covered during the game (using GPS data) divided by the time spent on the field (using Video data) for each individual player.

Table 4: Speed zones used for analysis of GPS game data

Speed Zone	Speed Range	Movement Label	Intensity Label
1	0 - 6 $km.h^{-1}$	***Standing and, or walking** e.g. standing and, or walking on field or off field in the substitution box. This can also include small movements when such movements are not purposeful (e.g. stumbling back and forth, turning side-ways, etc).	**Low intensity**
2	6 - 12 $km.h^{-1}$	***Power walking and, or jogging** e.g. jogging and, or shuffling sideways or backwards on field to change field position, such as repositioning when defending opposition.	
3	12 - 18 $km.h^{-1}$	***Running** e.g. running forwards receive dummy half pass. This can include accelerating with long strides, yet not at maximal effort.	**High intensity**
4	>18 $km.h^{-1}$	***Sprinting** e.g. running with maximal effort off the field to substitution box or sprinting after an intercept to score a touchdown.	

**Denotes each movement category includes forward, backwards or sideways movements within relevant speed range, with or without the ball.*

- *Blood lactate concentrations (Pre and Post Game)*

Testing Protocol

Blood samples were drawn from the participants' finger approximately 20-minutes before the game (Pre-Game), within 5-minutes after the end of the game (Immediate Post-game), and finally 20-minute after the game (20-minute Post-game). For each of the blood lactate concentration samples a portable finger-prick blood lactate concentration meter (Lactate Pro Portable Lactate Analyzer; Arkray Inc, Kyoto, Japan: see Figure 5) was used for lactate measurements.

Before each blood sample was taken, the sample finger site was cleaned using sterile disposable swabs (WEBCOL Alcohol Prep; Kendall Healthcare, Mansfield, USA) then wiped clean again with paper tissue. A small incision was made using a single-use disposable lancet (Easy Let I Safety Lancets; Du Yee Care Inc, Korea: see Figure 5); approximately 5 micro litres of whole blood were then drawn onto a Test Strip (Lactate Pro Test Strip; Arkray Inc, Kyoto, Japan) and the blood lactate concentration immediately analysed using the portable Lactate Pro analyser (see Figure 5). The validity and reliability of the Lactate Pro analyser being used with athletes have been well documented (Pyne et al., 2000).

Pre Game and 20-minute Post Game testing was performed indoors with the player seated on a chair, whilst immediate post game testing was taken outside with the player standing next to their respective playing field substitution box. The changes in blood lactate concentration (pre game – immediate post game, pre game – 20-minutes post game, and immediate post game – 20-minute post game) were determined for each player. Between immediate post game and 20-minute post game samples, players completed their own warm down with their respective teams, and then returned to research head quarters for final lactate testing.

Figure 5: Easy Let I Safety Disposable lancet and Lactate Pro Analyser with Test strip inserted. Images retrieved from: http://www.duyeecare.com/main.html and http://www.arkray.co.jp/english/products/other.html

Technical Game Measures

- *Touch Specific Skills (Video-Analysis)*

Touch specific skills were determined from viewing video footage of each elite athlete's Touch game. The outcome measures calculated from the video analysis of players' Touch specific skill during a Touch game were defined as:

Successful Touch specific skill: a skill correctly performed by an attacking or defending player with good control and retained possession of ball (depending on Touch specific skill).

Unsuccessful Touch specific skill: a skill incorrectly performed by an attacking or defending player with no control, resulting in either a penalty or loss of possession of ball (ball is given to opposition), can also be termed as an error.

[#] *Tap Ball:* performed by an attacking player who placed the ball on the ground at or behind the mark (indicated by referee), releasing both hands from the ball, tapping the ball with either foot a distance of not more than one (1) metre, and retrieving the ball cleanly. The ball does not have to be lifted from the ground for the tap. However, the ball must be at or behind the correct mark prior to the tap being taken (FIT rules, 2003).

[#] *Roll Ball:* performed by an attacking player who is standing on the mark (indicated by referee), facing the opponent's (defending) score line and parallel to the sidelines. Ball is placed on the mark; the player may step over the ball

and roll the ball backwards along the ground between the feet a distance of not more than one (1) metre (FIT rules, 2003).

[#] *Dummy Half Pick Up:* known as 'Dummy Half' and performed by an attacking player standing behind the person who has just completed a 'Roll Ball'. Ball is picked up from the ground immediately (without delay) (FIT rules, 2003). Then passed to another player (see below for 'Pass') N.B. dummy half pick up and pass separated into two separate skills.

[#] *Catch:* performed by an attacking player in an onside position (indicated by referee) who received a pass, flick, knock, throw or otherwise delivered ball.

[#] *Pass:* performed by an attacking player in possession of ball; may pass, flick, knock, throw or otherwise deliver the ball to any other onside player in the attacking team (FIT rules, 2003).

[#] *Touchdown:* is the result of an attacking player, except the 'Dummy Half' (person who performed 'Dummy Half' pick up) placing ball on or over the team's attacking score line, resulting in a point (signalled by referee).

[#] *Total Attacking plays:* included all successful tap balls, roll balls, dummy half pick ups, catching, passing and touchdowns.

Defence ('touch' made): defending player touched 'ball carrier'. A 'touch' is considered as contact on any part of body between an attacking player in possession of the ball and a defending player. A 'touch' included contact on the ball, hair or clothing and may be made by a defending player or by the attacking player in possession (FIT rules, 2003). A 'touch' is recorded and signalled by referee (i.e. within the 1 – 6 touch count), but, does not include touches made after ball has been passed.

Defence (Penalties): defensive penalty is when a player infringes the rules of the game as indicated by referee and results in change in possession of ball.

Defence (touchdown scored): defensive touchdown is the result of a defending player, being scored on by an attacking player.

[#] Denotes skill using ball

Technical Skill Data Analysis

For statistical purposes Touch specific skill values in the present study were reported to one decimal place to illustrate each group's findings. This was done even though it is acknowledged that the smallest observable difference for these skills is one, meaning that it is impossible to perform a fraction of skill. For example, Touch players cannot perform 0.3 unsuccessful dummy half pick ups during a game. However, it was felt that reporting the data to one decimal place was required as the mean frequencies of certain unsuccessful skills were often less than 1 per game per player.

Statistical Analysis

Standard descriptive statistics (mean and standard deviations) were calculated for all demographic (age, height and body mass) and game analysis (playing time ON and game time OFF field, substitution, and percentages of movement), sport specific skills (successful and unsuccessful skills), time-motion variables and blood lactate concentrations measures (pre-game, immediate post-game, 20-minute post-game). Significant between-group differences for all demographic or performance variables were assessed using a one-way analysis of variance (ANOVA). When a significant between-group difference was found using the main effect p-value, a Gabriel post-hoc test was then used to identify which groups were significantly different. The Gabriel test was selected as there were generally some differences in the sample size of each group. The analyses of interest were difference between genders and playing grades (male only, male mixed, female only and female mixed grade Touch players). 'Male only' group were Touch players who played in a Men's only grade, 'female only' were players who played in a Women's only grade. 'male or female mixed' were players who played in a grade that has both males and females in a team (3 male and 3 female on the playing field). Statistical significance was accepted at the 5% level ($p < 0.05$).

Results

Physical Game Measures

- *Playing Time and Substitutions (Video-Analysis)*

Playing time on and off the field of three different playing grades male only (n = 10), male mixed (n = 10), female only (n = 10) and female mixed (n = 8) grade players are shown in Table 5A. Across all grades playing time *on the field* during each halve ranged between ~8 – 10-minutes, with male mixed players spending significantly less time *on the field* in the first half than both male only and female mixed Touch players (~22%, for both). Total time *on the field* ranged between ~16 – 21-minutes, with male only players spending significantly more time *on the field* than male mixed Touch players (~22%).

Across all grades game time *off the field* during each halve ranged between ~9 – 12-minutes, with male mixed players spending significantly more time *off the field* in the first half than male only (~25%), female only (~18%) and female mixed (~19%) Touch players. Total game time *off the field* ranged between ~22 – 26-minutes, with male mixed players spending significantly more game time *off the field* than male only Touch players (~17%).

Percentage of game time during each halve *on the field* ranged between 40 – 55%, and *off the field* (~45 – 60%) across all the grades. Male mixed players spent significantly more percentage of game time *off the field* in the first half than both male only (~24%) and female mixed (~21%) Touch players. Consequently male mixed players spent significantly less percentage of game time *on the field* in the first half than male only (~26%) and female mixed (~23%) Touch players. Overall percentage of game time *on the field* ranged between ~38 – 48% and *off the field* between ~52 – 62% across grades. Male mixed players spent significantly more overall percentage of game time *off the field* (~17%), therefore significantly less overall percentage of game time *on the field* (~23%) than male only Touch players.

Substitution and average playing time of three different playing grades are shown in Table 5B. Touch players from all grades made between five and six substitutions during each half and ~10 – 12 throughout a competition game. No significant differences were found between groups for number of substitutions made. However, there was a trend for male only players to record more interchanges

throughout a competition game than female only (~9%), and, male and female mixed (~17%, both) Touch players.

During each period *on the field* (as indicated by average '*playing time on the field'*) across all grades, more time tended to be spent playing *on the field* in the second half compared to the first half (~7 – 31%). Female mixed players spent significantly more time *on the field* in the first half than male mixed Touch players (~37%). Subsequently, across all grades during each recovery period *off the field* (as indicated by '*average game time off the field'*), more time appeared to be spent in the substitution box *off the field* in the second half compared to the first half (~8 – 32%). Male mixed players spent significantly more game time *off the field* in the substitution box during the first half than male only Touch players (~43%). Average overall game time (*'Total game time'*) spent playing *on the field* during each substitution period ranged between ~1:40 – 2:10-minutes. Female mixed players spent significantly more time *on the field* than female only Touch players (~34%). Average overall game time (*'Total game time'*) spent *off the field* during each substitution period ranged between ~2:00 – 3:00-minutes, with male mixed players spending significantly more time *off the field* in the substitution box than male only Touch players (~40%). For each playing grade the overall mean time period spent *on and off the field ratios* during a game was, male only ~1:1.10, male mixed ~1:1.75, female only ~1:1.40 and female mixed ~1:1.20.

Table 5A: Playing time differences of three different playing grades (Men's, Women's and Mixed)

Variable	Male Only (n = 10)	Male Mixed (n = 10)	Female Only (n = 10)	Female Mixed (n = 8)	Main Effect P-value
Playing Time On Field (min:sec)					
1st Half	10:24 ± 1:33 [a]	8:01 ± 2:00 [e]	9:33 ± 1:36	10:20 ± 0:34	0.011
2nd Half	10:17 ± 1:12	8:07 ± 2:19	8:44 ± 2:10	9:45 ± 2:55	0.190
Total GT	20:41 ± 1:59 [a]	16:07 ± 2:44	18:17 ± 3:15	19:47 ± 2:51	0.009
Playing Time Off Field (min:sec)					
1st Half	9:35 ± 1:33 [a]	12:38 ± 1:57 [d, e]	10:27 ± 1:36	10:15 ± 1:07	0.002
2nd Half	9:44 ± 1:12	11:14 ± 1:51	11.16 ± 2:10	9:59 ± 2:22	0.196
Total GT	22:19 ± 1:59 [a]	26:53 ± 2:44	24:43 ± 3:15	23:13 ± 2:51	0.009
Playing Time On Field (%)					
1st Half	52.0 ± 7.7 [a]	38.8 ± 9.0 [e]	47.8 ± 8.0	50.3 ± 3.4	0.004
2nd Half	54.0 ± 7.5	44.0 ± 12.1	45.5 ± 10.6	52.6 ± 12.2	0.132
Total GT	48.1 ± 4.5 [a]	37.5 ± 6.3	42.6 ± 7.5	46.1 ± 6.6	0.008
Playing Time Off Field (%)					
1st Half	48.0 ± 7.7 [a]	62.5 ± 6.3 [e]	52.2 ± 8.0	49.8 ± 3.4	0.004
2nd Half	46.0 ± 7.5	55.9 ± 12.2	54.7 ± 10.6	47.5 ± 12.5	0.137
Total GT	51.9 ± 4.5 [a]	62.5 ± 6.3	57.4 ± 7.5	53.9 ± 6.6	0.008

All values are mean ± SD, GT = game time.

[a] Denotes significant ($p < 0.05$) difference between male only vs. male mixed grade.

[d] Denotes significant ($p < 0.05$) difference between male mixed vs. female only grade.

[e] Denotes significant ($p < 0.05$) difference between male mixed vs. female mixed grade.

Number of participants slightly decreased for male mixed grade in playing time using video analysis due to injuries sustained or technical difficulty during game (n = 8).

Table 5B: Substitution and average playing time differences of three different playing grades (Men's, Women's and Mixed)

Variable	Male Only (n = 10)	Male Mixed (n = 10)	Female Only (n = 10)	Female Mixed (n = 8)	Main Effect P-value
Substitutions					
1st Half	6 ± 1	5 ± 1	6 ± 1	5 ± 1	0.140
2nd Half	6 ± 2	5 ± 2	5 ± 1	5 ± 2	0.297
Total GT	12 ± 2	10 ± 3	11 ± 2	10 ± 3	0.150
Average Playing Time On Field (min:sec)					
1st Half	1:45 ± 0:24	1:34 ± 0:28 [e]	1:38 ± 0:26	2:10 ± 0:29	0.046
2nd Half	2:09 ± 0:52	1:58 ± 0:26	1:48 ± 0:16	2:36 ± 0:51	0.092
Total GT	1:47 ± 0:21	1:40 ± 0:16	1:38 ± 0:17 [f]	2:09 ± 0:29	0.023
Average Playing Time Off Field (min:sec)					
1st Half	1:36 ± 0:22 [a]	2:36 ± 0:56	1:49 ± 0:32	2:10 ± 0:34	0.011
2nd Half	1:47 ± 0:38	2:44 ± 1:16	2:18 ± 0:50	2:35 ± 1:51	0.339
Total GT	1:56 ± 0:27 [a]	2:56 ± 0:58	2:15 ± 0:32	2:37 ± 1:00	0.042

All values are mean ± SD, GT = game time.

[a] Denotes significant ($p < 0.05$) difference between male only vs. male mixed grade.

[e] Denotes significant ($p < 0.05$) difference between male mixed vs. female mixed grade.

[f] Denotes significant ($p < 0.05$) difference between female only vs. female mixed grade.

Number of participants slightly decreased for male mixed grade in playing time using video analysis due to injuries sustained or technical difficulty during game, (n = 8).

- *Time-Motion Analysis (GPS)*

Game movement performance during competition can be observed in Table 6. Across all grades more distance was covered during a game at low intensity [<12 km.hr^{-1} (walking, power walking and jogging)] as compared to a high intensity [>12 km.hr^{-1} (running and sprinting)] (~60 – 72%). Total distance travelled performing low intensity movements during a game ranged between ~2.00 – 2.20 km, with female mixed players covering significantly ($p < 0.05$) more distance walking (<6 km.hr^{-1}) than female only (~18%) Touch players. Total distance travelled whilst running (12 – 18 km.hr^{-1}) during a game ranged between ~0.50 – 0.70 km, with male only players covering significantly more distance than female mixed (~32%)Touch players. Total distance travelled whilst sprinting (>18 km.hr^{-1}) during a game ranged between ~0.10 – 0.20 km, with male mixed players covering significantly more distance sprinting than female only (~60%) Touch players.

Across all grades total game time spent stationary and, or walking (<6 km.hr^{-1}) ranged between ~33 – 35-minutes and running during a game ranged between ~2:15 – 3:15-minutes. Total time sprinting during a game ranged between ~10 –30 seconds, with male mixed players spending significantly more actual time sprinting than female only (~50%)Touch players. Over ~90% of game time across all grades was spent performing low intensity movements [<12 km.hr^{-1} (stationary, walking, power walking and jogging)] with less than ~9% of game time performing high intensity movements [>12 km.hr^{-1} (running and sprinting)]. Male mixed players spent significantly more percentage of game time sprinting than female only (~59%) Touch players.

Maximum speed achieved during a game ranged from ~22 – 25 km.hr^{-1}, with male only Touch players attaining significantly higher maximum speed than female mixed (~12%) Touch players. However, no significant ($p > 0.05$) differences were found in total distance covered and average speed during a game between groups. Total distance travelled and average speed when *on the field* during a competition game across all grades ranged from ~2.80 – 3.10 km and ~9.0 – 10.0 km.hr^{-1}, respectively.

Table 6: Game movement performance differences of three different playing grades (Men's, Women's and Mixed)

Variable	Male Only (n = 10)	Male Mixed (n = 10)	Female Only (n = 10)	Female Mixed (n = 8)	Main Effect P-value
Game Movement (distance) (km)					
Stationary/walking	1.12 ± 0.09	1.08 ± 0.11	1.02 ± 0.08 [f]	1.23 ± 0.15	0.008
Power walking/jogging	1.09 ± 0.30	0.91 ± 0.17	1.06 ± 0.20	0.93 ± 0.18	0.316
Running	0.72 ± 0.21 [c]	0.60 ± 0.11	0.60 ± 0.15	0.49 ± 0.12	0.052
Sprinting	0.17 ± 0.09	0.22 ± 0.10 [d]	0.09 ± 0.05	0.13 ± 0.05	0.014
Game Movement (time) (min:sec)					
Stationary/walking	32:59 ± 3:13	35:01 ± 1:25	34:12 ± 1:31	35:17 ± 1:50	0.161
Power walking/jogging	7:31± 2:05	5:54 ± 1:04	7:20 ± 1:20	6:26 ± 1:29	0.159
Running	3:09 ± 0:55	2:43 ± 0:28	2:43 ± 0:44	2:16 ± 0:31	0.119
Sprinting	0:20 ± 0:10	0:34 ± 0:21 [d]	0:11± 0:07	0:17 ± 0:06	0.006
Game Movement (time) (%)					
Stationary/walking	74.2 ± 6.8	78.2 ± 3.2	76.3 ± 3.3	78.8 ± 3.9	0.201
Power walking/jogging	16.0 ± 5.9	13.6 ± 2.5	16.7 ± 3.1	14.7 ± 3.4	0.467
Running	7.5 ± 2.1	6.5 ± 1.0	6.3 ± 1.4	5.4 ± 1.1	0.067
Sprinting	1.3 ± 0.6	1.7 ± 0.6 [d]	0.7 ± 0.4	1.1 ± 0.3	0.008
Game Distance (km) and Speed ($km.hr^{-1}$)					
Total Distance	3.10 ± 0.54	2.78 ± 0.31	2.77 ± 0.31	2.78 ± 0.20	0.207
Average Speed On Field	9.0 ± 1.2	9.9 ± 1.1	9.4 ± 1.2	8.7 ± 1.6	0.327
Maximum Speed	25.3 ± 1.4 [c]	24.9 ± 2.5	22.9 ± 2.3	22.3 ± 2.2	0.016

All values are mean ± SD, Maximum speed = highest speed recorded in the game. [c] Denotes significant ($p < 0.05$) difference between male only vs. female mixed grade. [d] Denotes significant ($p < 0.05$) difference between male mixed vs. female only grade. [f] Denotes significant ($p < 0.05$) difference between female only vs. female mixed grade. Number of participants slightly decreased for male only grade in distance, time and maximum speed variables using GPS, due to technical difficulty during game, (n = 9). Average speed on field utilised both video and GPS information for analysis, number of male mixed grade participants reduced due to injuries sustained or technical difficulty during game, (n = 8).

Examples of game movement performance data (time spent and distance travelled within each speed zone, and, maximum speed achieved during a Touch game) for a NZ representative Touch player from each playing grade (male only, male mixed, female only and female mixed) are provided in Appendix 1A (Figure 6 – 9) and Appendix 1B (Figure 10 – 13). All game movement variables for NZ representative Touch players across the three playing grades were either within or above the average for their respective playing grade group as shown in Table 6.

- *Blood lactate concentration (Pre and Post Game)*

Differences in blood lactate concentration of three different playing grades are shown in Table 7. No significant ($p > 0.05$) differences were found in lactate measures between playing grades. Post game lactates across all grades (taken immediately after the conclusion of game) ranged between ~5 – 8 mmol.L^{-1}, with male mixed players recording higher lactate measures than male only (~12%), female only (~15%), and female mixed (~41%) Touch players. Change in blood lactate concentration from pre game to immediately post game measures ranged between 4 – 7.5 mmol.L^{-1} across all grades, with male mixed players recording a greater change than male only (~22%), female only (~25%), and female mixed (~49%) Touch players.

Although there were no significant differences in lactate measures between the three playing grades, the highest lactate measured immediately after playing the game was 14.8 mmol.L^{-1} from a male mixed player, compared to male only 12.0 mmol.L^{-1}, female only 13.7 mmol.L^{-1} and female mixed 9.2 mmol.L^{-1} Touch players. The biggest change in lactate concentration measured from pre game to immediately post game was also from a male mixed Touch player who recorded 13.1 mmol.L^{-1}, compared to male only 8.6 mmol.L^{-1}, female only 12.1 mmol.L^{-1} and female mixed 8.0 mmol.L^{-1} Touch players.

Table 7: Lactate differences of three different playing grades (Men's, Women's and Mixed)

Variable	Male Only (n = 10)	Male Mixed (n = 10)	Female Only (n = 10)	Female Mixed (n = 8)	Main effect P-value
Blood lactate concentrations (mmol.L^{-1})					
Pre Game	2.1 ± 0.9	1.5 ± 0.4	2.0 ± 0.9	1.5 ± 0.4	0.139
Immediately Post Game	7.9 ± 2.9	8.9 ± 4.4	7.6 ± 3.2	5.3 ± 2.8	0.176
20-minutes Post Game	3.2 ± 1.6	3.5 ± 1.4	3.3 ± 1.3	2.6 ± 1.2	0.510
Δ Pre - Immediately Post Game	5.8 ± 2.8	7.4 ± 4.2	5.6 ± 3.7	3.8 ± 3.0	0.194
Δ Pre - 20-minutes Post Game	1.3 ± 1.4	2.1 ± 1.1	1.3 ± 1.9	1.0 ± 1.3	0.487
Δ Immediately Post Game - 20-minutes Post Game	4.1 ± 3.0	5.4 ± 4.1	4.3 ± 2.4	2.7 ± 1.9	0.339

All values are mean ± SD, Δ = Change in or Difference.

Technical Game Measures

- *Touch specific skills (Notational Analysis using video footage)*

The *successful* and *unsuccessful* Touch specific skills of three different playing grades are shown in Table 8. Number of *successful* catches and passes made during a game ranged between ~15 – 25 and ~10 – 30, respectively. Female mixed players performed significantly less *successful* catches and passes during a game than both male only (~40 – 60%) and male mixed (~50 – 55%) Touch players. Across all grades the number of *successful* dummy half pick ups performed during a game ranged between ~10 – 20, with female mixed players completing significantly less than male only (~66%) Touch players. However, no significant ($p > 0.05$) differences were found between playing grades in number of *successful* tap balls, roll balls, and touchdown skills performed during a competition game.

Total *successful* attacking skills ranged between ~50 – 90 skills per game, with female mixed players performing significantly less *successful* attacking skills during a game than both male only and male mixed Touch players(~47%, both). Total number of *successful* defensive touches made during a game ranged between ~10 – 20 touches, with female mixed Touch players making significantly less defensive touches

during a game than male only (~49%), male mixed (~52%) and female only (~49%) Touch players.

Across all grades the only significantly different *unsuccessful* skill performed during a competition game was by male only Touch players, who were the only playing grade to record *unsuccessful* dummy half pick ups. Although no significant differences were found between groups across all grades for all other *unsuccessful* skills, at least one pass and catch were performed unsuccessfully by a player during a game. Total *unsuccessful* attacking skills performed across all grades during a game ranged between two to three skills. Female only Touch players were the only playing grade who did not record an *unsuccessful* roll ball and dummy half pick up during a game.

Table 8: Successful and unsuccessful Touch specific skills of three different playing grades (Men's, Women's and Mixed)

Variable	Male Only (n = 10)	Male Mixed (n = 10)	Female Only (n = 10)	Female Mixed (n = 8)	Main Effect P-value
Successful Touch specific skills (number)					
Number of Tap Balls	1.2 ± 0.8	0.8 ± 0.9	0.9 ± 0.9	1.0 ± 1.4	0.806
Roll Balls	15.3 ± 4.7	17.0 ± 6.3	13.6 ± 2.8	11.6 ± 5.1	0.170
Dummy Half Pick Ups	19.5 ± 6.6 [c]	17.4 ± 7.1	17.7 ± 7.5	8.7 ± 5.8	0.020
Catch	23.4 ± 7.0 [c]	26.0 ± 6.9 [e]	19.2 ± 5.7	13.7 ± 5.7	0.004
Pass	28.6 ± 8.7 [c]	26.5 ± 10.2 [e]	24.6 ± 10.2	11.9 ± 7.3	0.006
Touchdown	0.5 ± 0.7	0.3 ± 0.5	0.6 ± 0.9	0.6 ± 0.8	0.800
Total Attacking Skills	88.5 ± 23.3 [c]	87.9 ± 22.1 [e]	76.4 ± 21.5	47.4 ± 24.4	0.004
Defence ('touch'made)	18.3 ± 4.7 [c]	19.3 ± 5.0 [e]	18.4 ± 8.1 [f]	9.4 ± 5.3	0.011
Unsuccessful Touch specific skills (number)					
Roll Balls	0.0 ± 0.0 [†]	0.1 ± 0.4	0.0 ± 0.0 [†]	0.3 ± 0.5	0.155
Dummy Half Pick Ups	0.3 ± 0.5	0.0 ± 0.0 [†]	0.0 ± 0.0 [†]	0.0 ± 0.0 [†]	0.045
Catch	0.3 ± 0.5	0.4 ± 0.5	0.7 ± 0.9	1.0 ± 1.0	0.233
Pass	1.4 ± 1.8	1.1 ± 1.2	1.2 ± 0.8	0.0 ± 0.0 [†]	0.129
Touchdown	0.5 ± 0.5	0.8 ± 1.2	0.3 ± 0.5	0.6 ± 0.8	0.735
Total Attacking Skills	2.5 ± 2.2	2.4 ± 2.1	2.2 ± 1.0	1.9 ± 1.1	0.891
Defence (Penalties, touchdown scored)	0.6 ± 0.8	1.0 ± 1.1	0.2 ± 0.4	1.1 ± 1.5	0.242

All values are mean ± SD. [†]Denotes Touch players in this sample recorded no performance of this skill.
[c] Denotes significant ($p < 0.05$) difference between male only vs. female mixed grade. [e] Denotes significant ($p < 0.05$) difference between male mixed vs. female mixed grade.
[f] Denotes significant ($p < 0.05$) difference between female only vs. female mixed grade. Number of participants slightly decreased for male mixed grade in Touch specific skill variables using video analysis due to injuries sustained or technical difficulty during game, (n = 8 male mixed).

Discussion

The purpose of this study was to: 1) measure physical demands of elite Touch players during competition using video and TMA; and, 2) evaluate through the use of notational video analysis, successful and unsuccessful performance of Touch specific skills during Touch games at the elite level.

There were several main findings in the present study and while many similarities existed across the three playing grades of elite Touch players, many significant differences were also observed across the various player groups. A discussion of physical and technical game measure similarities and differences and their implications for coaching and conditioning will be conducted in the next section.

Physical Game Measures

- *Playing Time and Substitutions (Video-Analysis)*

Playing time spent *on the field*, game time *off the field* and number of substitutions made by Touch players during a game can provide coaches and trainers with a guide to the specific duration of efforts in training that mimics the demands experienced during a game.

In the present study, on average Touch players from all three playing grades (Men's, Women's and Mixed) spent more game time *off the field* (~52 – 62%) than *on the field* (~38 – 48%). This finding may suggest more overall game time (~10%) is spent recovering in the substitution box rather than playing *on the field*. Results from the present study found, male Touch players who play in a Men's only grade spent significantly more time *on the field* (~21 vs. ~16-minutes), consequently significantly less time *off the field* (~22 vs. ~27-minutes), than male mixed Touch players. This finding may suggest male Touch players who play in a Men's only grade spend more time playing *on the field* with less recovery time (in the substitution box, *off the field*) than male mixed players. The practical significance regarding this finding may justify variations in training durations and recovery periods (i.e. work: rest) between male Touch players who specialise in playing Men's only or Mixed grade. For example, longer recovery periods for a male mixed player compared to a male Touch player who is training to play in a Men's grade. These differences may also be due to variations in substitution policies or positional differences utilised during the game between a

Men's only and Mixed grade. For example, male Touch players who played in a Men's only grade in this study may have used a buddy system substitution policy (i.e. subbing in pairs), therefore spending less game time *off the field* in the substitution box, as this policy only allows one player to be *on the field* or *off the field* at any one time during a game. Consequently this particular substitution policy may increase the amount of playing time *on the field* a male Touch player may get during a game, compared to using more substituting players (i.e. three player rotations, where one player is *on the field* and two are *off the field* waiting to substitute). Differences could also be possibly due to the inclusion of the 3-minute half time break in overall game time *off the field* which was not included in time *on the field*.

The average game time *off the field* reported by Templeton et al. (2001), who investigated three Australian male elite Touch players playing in a Men's only grade were higher (~2:40 vs. ~2:00-minutes) than those reported in the present study for New Zealand male elite Touch players. Differences between the two studies game time *off the field* may suggest that New Zealand male elite Touch players who play in a Men's only grade spend less time *off the field* during a competition game than Australian male elite Touch players. However, comparisons between studies has its limitations as the sample size of Templeton et al. (2001) was extremely small which make it less likely that such results are a true representation of Australian male elite Touch players.

The number of interchanges made during Men's only and Women's only competition Touch games reported by O'Connor (2002), who conducted a TMA using video analysis of 50 Australian elite Touch players during four competition Touch games were lower (male 7 vs. ~12, female 6 vs. ~11) than those reported in the present study for New Zealand male elite Touch players who also play in a Men's only grade and female elite Touch players who also play in Women's only grade. However, comparisons between studies have its limitations as the duration of the game used by O'Connor (2002) was 5-minutes shorter in each half than the present study.

Percentage of total game time spent *off the field* (in substitution box) for New Zealand male and female Touch players who played in a Men's only grade (~52%) and Women's only grade (~57%) in the present study were higher than those reported for Australian male and female Touch players who play in similar grades (male ~47%, female ~48%) (O'Connor, 2002). Differences between the studies may suggest New

Zealand Men's and Women's only grade players spend more time in the substitution box. This may be due to differences in game or team tactics, alternatively this could indicate a lack of fitness to stay on the field longer compared to the Australian Men's and Women's grade players. However, comparison between studies has its limitations as the total game time of this previous research was shorter (5-minutes each half) therefore game or team tactics changes would differ to allow for a faster, more intense game as players may not fatigue as quickly compared to playing a longer (20-minutes each half) and possibly less intensely than in the present study. Further playing game time (*on and off field*, substitutions, etc.) research is needed to identify the reason for the difference in game durations and its likely effect on performance.

Touch players in the present study from Men's, Women's and Mixed playing grades, spent on average, more overall game time playing *on the field* (~1:40 – 2:10-minutes; as indicated by average playing time *on the field*) than *off the field* (~2:00 – 3:00-minutes; as indicated by average game time *off the field*). Female mixed players spent significantly more overall game time *on the field* than female Touch players (~34%). This finding suggests female mixed players spend more time *on the field* than female Touch players who play in a Women's only grade. Practical significance of this finding provides evidence that because female mixed players spend more time playing *on the field* they may be required to be fitter than a female Touch player who plays in a Women's only grade in order to cope with the longer and possibly more demanding playing time *on the field*. These results also found more playing time was spent *on the field* in the first half compared to the second half (~7 – 31%). Subsequently, more time was spent in the substitution box recovering *off the field* in the second half compared to the first half (~8 – 32%). Male mixed players spending significantly more game time *off the field* in the substitution box during the first half and overall game time than male Touch players (~43% and 40%, respectively) who play in a Men's only grade. Reasons for this longer game time *off the field* in the second half may be attributed to the onset of fatigue later in the game; hence players require more time to recover therefore stay *off the field* longer. Alternatively, these playing game time *on and off the field* differences between playing grades could also be due to a variation in game plan, tactical or coaches' decisions, etc. A Mixed grade coach may choose to vary the remaining eight substitutions to suit playing positions or gender balances within the game. For example, having three female mixed Touch players *on the field* at all times in

a Mixed grade who may stay *on the field* longer (due to playing as an *outside*) than their male mixed team members (who predominantly play as an *inside*) this will increase overall group average playing time *on the field*. Therefore increasing game time *off the field* for the remaining female substitutions, which are waiting to get onto the field. However, this contention would need to be investigated further with a larger sample size of elite Touch players who specialise in playing in a Mixed grade.

Game time spent *on and off the field* results from this study can be used as a guide for designing Touch specific training programmes (i.e. duration efforts). For each playing grade the overall mean time period spent *on and off the field ratios* during a game was, male only ~1:1.10, male mixed ~1:1.75, female only ~1:1.40 and female mixed ~1:1.20. These findings suggest more time is used for recovery by male mixed Touch players as compared to their respective female mixed players and Touch players who play in a Men's and Women's only grade. These findings can provide coaches and trainers with a guide to the specific duration of efforts in training that mimics the demands experienced during a game, particularly for elite Touch players who specialise in playing in either Men's, Women's or Mixed playing grades (~1:1.10 – 1:1.75 work: rest ratios). Mean time spent *on and off field ratio* for New Zealand male Touch players who played in a Men's only grade in the present study were lower than those reported for Australian male Touch players in a similar grade (1:1.10 vs. 1:1.75) (Templeton et al., 2001). These differences between studies may suggest elite Australian male Touch players spend more time recovering, therefore are able to go back onto the field to play a faster and possibly more intense style of game than New Zealand male Touch players.

- *Time-Motion Analysis (GPS)*

There were no significant differences in game movement distances, time within each speed zone, total distance and speed variables between elite male Touch players who played in a Men's only grade and female Touch players' who played in a Women's only grade. These results suggest that there were no obvious differences in game performance variables [distance covered, time spent in locomotive movements (stationary and, or walking, power walking, jogging, running, sprinting), average and maximum speed] between Men's only and Women's only grade at this Touch

tournament during a competitive Touch game. This could be due to both grades having similar coaching tactics, playing styles, substitution patterns and game plans.

The amount of high intensity activities (running and sprinting) reported by O'Connor (2002) was higher than the present study (male only ~20% and female only ~38%). These differences between studies may suggest elite Australian male and female Touch players play a faster and possibly more intense style of game than New Zealand male and female Touch players who play in a similar grade. This is possibly why the Australian Men's and Women's only Touch teams have never lost a world cup to a New Zealand Men's and Women's only Touch team.

This study is the first to investigate the TMA of elite Touch players who specialise in playing in a Mixed grade. The results demonstrate that female mixed players, covered significantly more distance walking (<6 $km.hr^{-1}$) than female Touch players who played in a Women's only grade (~1.20 vs. ~1.00 km). However, the amount of time spent standing still and, or walking during a game was similar (~34 vs. ~35-minutes). Reasons for these differences are likely due to female mixed players walking more in the game (during the same amount of game time) than female players in a Women's only grade who may have been standing still. For example, walking covers more distance than standing. Male mixed players covered significantly more distance (~0.2 vs 0.1 km) and spent significantly more time (~30 vs. 10 s) during a game sprinting (>18 $km.hr^{-1}$) than female Touch players who played in a Women's only grade. From these findings, it could be speculated that male mixed players play a more physically demanding game (requires more sprinting) than females Touch players who play in a Women's only grade.

Elite male Touch players who played in a Men's only grade travelled significantly further whilst running (~0.7 vs. ~0.5 km) and achieved significantly higher maximum speed (~25 vs. 22 $km.hr^{-1}$) during a game than female Touch players who played in a Mixed grade. However, there were no statistical differences found in the amount of time spent running (~3:10 vs 2:10-minutes) during a game. Running distance differences during a game may imply that male Touch players in a Men's only grade spend more game time running in the faster range (between 15 – 18 $km.hr^{-1}$) of this speed zone to cover more distance than female Touch players who play in a Mixed grade. For example, a male Touch player in a Men's only grade may run more at 15-16 $km.hr^{-1}$ and cover more distance (during the same amount of game time) as compared

to a female Touch player in a Mixed grade who runs at a slower speed of 12-13 km.hr^{-1}, in the same game time.

Touch players in all three playing grades spent the majority of game time performing low intensity movements (<12 km.h^{-1}; male only ~90%, male mixed ~92%, female only ~93% and female mixed ~94%) with only a small portion of the game in high intensity activity (>12 km.h^{-1}; male only ~9%, mixed male ~8%, female only and female mixed ~7%). These findings highlight the importance of having a good aerobic base, as the majority of the game time is supported by the aerobic system when performing low intensity game movements, during recovery periods *on and off the field*. Amount of game time spent performing low intensity movements (includes time in substitution box *off the field*) in the present study by New Zealand male Touch players who play in a Mixed grade were similar to both Australian male and female elite Touch players who play in Men's or Women's only grade (~92 vs ~90%) (O'Connor, 2002). It may be that New Zealand male Touch players who played at the elite level in the Mixed grade spent the same amount of time utilising their aerobic energy system whilst in the substitution box and *on the field* performing low intensity game movements as Australian male and female Touch players who play in a Men's or Women's only grade. However, New Zealand female Touch players who play in a Mixed grade in the present study spent less game time performing high intensity activities than both Australian male and female Touch players in this study (~7 vs 11 – 12%) (O'Connor, 2002). These findings may imply Australian male and female Touch players who play in a single sex grade play a faster therefore, more intense style of game than New Zealand female Touch players who play in a Mixed grade.

Kurzawa (2008) who investigated eleven club level Australian Touch players during a Mixed grade competition (no mention of genders), reported similar distances covered (~2.7 vs. ~2.8 km), lower average speed (~6.6 vs. ~9 – 10 km.hr^{-1}) and higher maximum speed in a game (~26 vs. ~22 – 25 km.hr^{-1}) than both female and male mixed Touch players in the present study. Similarities in distance covered are likely due to similar styles of play, and number of substitutions. In contrast, reasons for average speed differences are likely due to elite Touch players in the present study performing more frequent, shorter but faster movements (for example, faster 5 – 10 metre back, forward and sideways) which increases average speed with little or no change to distance. Maximum speed differences in Kurzawa (2008) study suggest opposition may

have been less challenging, which may have allowed players to reach higher speeds, where as in the present study at an elite level of competition the opposition were more equally matched.

Coffey (2007) investigated 82 elite Australian Open Touch players during a 45 – 47-minute competition game and reported similar total distance (~3.1 vs ~2.8 – 3.1 km), lower overall average game speed (~5 vs. 9 – 10 km.hr^{-1}) and higher maximum speed (~32 vs. ~22 – 25 km.hr^{-1}), as compared to the three playing grades in the present study. Differences in overall average game speed and maximum speed achieved during a game, could suggest Australian elite Touch players are able to reach higher maximum speeds therefore require more slow speed movements (walking or power walking, below 7 km.hr^{-1}) during a Touch game to recovery, which will consequently reduce overall average game speed compared to New Zealand elite Touch players in the present study. For example, these low speed game movements are often seen in the substitution box and *on the field* during 'dead time'. Maximum speed differences between studies could also imply Australian elite Touch players are faster during a game than New Zealand elite Touch players. Alternatively these same findings could be attributed to the level of opposition being easier for Australian elite Touch players and harder for New Zealand elite Touch players in the present study during game analysis.

- *Blood lactate concentrations (Pre and Post Game)*

To gain an insight into a Touch game's intensity, blood lactate concentration samples were measured under field conditions i.e. before and after games. Blood lactate concentration is a result of lactate rate of appearance and rate of disappearance therefore providing a snapshot of lactate turnover. Accumulation of blood lactate concentration (along with other physiological measures) may be linked directly to the causes of temporary fatigue (Lythe, 2008). Therefore, obtaining information on blood lactate concentration before, during and after an intense Touch game could be of interest to the coach and the strength and conditioning personnel.

Pre-game lactate results for New Zealand male Touch players who play in a Men's only grade observed in the present study were quite similar (2.1 ± 0.9 mmol.L^{-1}) to that previously reported for Australian male Touch players who play in a Men's only grade (1.5 ± 0.3 mmol.L^{-1}) (Templeton et al., 2001). The small differences in pre-game

lactate measures between studies could be attributed to different warm-up procedures and, or timing of blood lactate concentration sampling. For example, the present study was 20-minutes prior to the start of the game whereas Templeton et al. (2001) did not document timing of sampling.

Immediate post game lactate results reported in the present study were ~9 – 28% higher than previously reported for male Touch players who play in a Men's only grade [7.9 ± 2.9 vs. 5.7 ± 1.4 mmol.L^{-1} (O'Connor, 2002); and 7.2 ± 1.5 mmol.L^{-1} (Templeton et al., 2001)] and female Touch players who play in a Women's only grade [7.6 ± 3.2 vs. 5.9 ± 3.1 mmol.L^{-1} (O'Connor, 2002)]. The reasons for the differences between studies in post game blood lactate concentrations may be a consequence of the standard of competition, prior exercise, and game duration examined. For example, the study of O'Connor (2002) had a longer half time break (5-minutes) and played shorter halves (2 x 15-minute halves) which allowed more time for recovery, therefore final lactate concentration measures may not increase as much as playing with a shorter half time break (3-minutes) and longer halves (2 x 20-minute halves) as in the present study. Also female Touch players in previous research only played a total of two games (O'Connor, 2002). The present study, examined Touch players on the first day of tournament during their first game, whilst others were examined on the second day during their third game of the day. This may imply that New Zealand Touch players who played in a Men's, Women's or Mixed gender grades have higher post-game lactate concentration measures than Australian male and female players who play in a Men's or Women's only grade because they have; played in a longer game with less recovery time; have played a more intense opposition (consequently may increase lactate production); and have played more games within a short time frame.

The highest lactate concentration measured immediately after playing a game was recorded at 14.8 mmol.L^{-1} from a male mixed player, compared to male only 12.0 mmol.L^{-1}, female only 13.7 mmol.L^{-1} and female mixed 9.2 mmol.L^{-1} Touch players. Male mixed players also recorded bigger changes in lactate concentration measured from pre to immediately post game at 13.1 mmol.L^{-1}, as compared to a male only 8.6 mmol.L^{-1}, female only 12.1 mmol.L^{-1} and female mixed 8.0 mmol.L^{-1} Touch players. As these maximum values are much greater than the group means, it is possible considerable inter-athlete variation in blood lactate concentration levels occur. Reasons for these inter-athlete variations are likely caused by individual physiological

differences (fitness levels, ability to tolerate high levels of blood lactate concentration) and playing differences (opposition, playing position etc.) at the time of lactate testing. Implication for training based on these findings would suggest high intensity anaerobic type trainings would be beneficial for all Touch players, as this may help develop tolerance to high levels of blood lactate concentration which are likely to occur during a competition Touch game.

In summary, these high post-game blood lactate concentrations (>4 mmol.L^{-1}) reported in the present study are an indication that production and tolerance of high blood levels represent an important part of the game. This suggests Touch is an anaerobic type sport and that lactate production, and tolerance, should be considered a part of the training programme for all Touch players regardless of gender or playing grade. However, comparisons between the present study and other more recent TMA studies of athletes in Touch (Coffey, 2007; Kurzawa, 2008; O'Connor, 2002; Templeton et al., 2001) has its limitations due to differences in playing level (Kurzawa, 2008), sample size, number of Touch games examined, duration of Touch game, methodology procedures and lack of information provided. For these reasons, differences and similarities between studies need to be made with caution and comparisons are more likely generalised between subjects and specific playing grades.

Technical Game Measures

This study was the first to investigate technical game measures of elite Touch players during competition. The criteria used to evaluate technical performance of elite Touch players in the present study were developed specifically for this project by the author based on similar manual notational analysis procedures utilised by Rowlinson and O'Donoghue (2009) in Soccer. Touch specific skill definitions were based upon interpretation of Federation International Touch rules (FIT rules, Third edition, 2003) and the process of data analysis was conducted by the author only in such a way as to ensure that consistent interpretation of the criteria was made. The purpose of this Touch specific skill analysis was to outline the technical game measures (*successful*, *unsuccessful* and dominant) and determine if differences were evident across the three playing grades (Men's, Women's and Mixed) of elite Touch players during a competition game.

No significant differences were found between playing grades for all *successful* and most of the *unsuccessful* Touch specific skills performed during a competition game. These similarities should be expected at the elite level, as they are more skilful and likely perform basic Touch specific skills with relative ease. However, male Touch players who play in a Men's only grade were the only grade to record *unsuccessful* dummy half pick ups. Due to the rules within the game of Touch, dummy half pick ups are often observed in a Men's only game being performed on the move at a fairly fast pace. In the present study, male Touch players appeared to spend more time performing movements at a speed >12 km.hr^{-1} than male mixed, female only and female mixed Touch players (~3:30 vs. ~2:30 – 3:20 minute: seconds). Although no statistical significance was found, the practical significance of these findings could possibly imply that because male Touch players spend more time running at speeds >12 km.hr^{-1} during a game than other Touch players, this adds to the pressure of trying to *successfully* perform dummy half pick up which may result in an error being made. Alternatively, the *unsuccessful* dummy half pick up differences between male players who played in a Men's only grade and other Touch players may suggest (because there were no significant differences observed in average speed between these groups during a game), male mixed, female only and female mixed players in the present study were more skilful at performing dummy half pick up than male only Touch players at this particular tournament. Based on these findings it is recommended that male Touch players who play in a Men's only grade may need to practise the dummy half pick up on the move, at a fast pace (>12 km.hr^{-1}), and under pressure to simulate game like conditions, in order to minimise the number of *unsuccessful* attempts made during a competition.

In summary, overall findings for Touch specific skills indicate elite Touch players (irrespective of the grade they play in) are likely to perform more attacking skills (roll balls, dummy half pick ups, catch, pass) than defensive (making a 'touch'), during a competition game. The most common *successful* attacking skills utilised during a competition game in the present study were catching and passing, followed by dummy half pick ups and roll balls. Based on these findings it is recommended that elite Touch players, coaches and strength and conditioners design a skill programme or training which incorporates Touch specific skills such as roll balls, dummy half pick ups, catching, passing, and defensive tasks (making touches) at game pace (average game

speed ~9 - 10 km.hr^{-1}) to stimulate competition game situations as best as possible. For example, a specific Touch play could aim to practise these Touch skills successfully (correctly and with control), at a moderate pace but also under pressure in order to transfer similar skills to the competition game situation.

Limitations

Initially participant heart rate data were recorded. However, due to a number of subjects either removing their heart rate chest straps or not recording during a game, the data recorded was not enough and, or not suitable for further analysis. Having heart rate data available may have added to the blood lactate concentration findings in this study in determining specific physiological demands required by elite Touch players during a game.

Using the same speed zones for the analysis of data of male and female Touch players of varied ages, this generalisation obviously will have some influence on preliminary outcomes. For future research, player speed zones could be specifically based on speed test results prior to game analysis. For example, male or female Touch player speed zones, and, or Men's, Women's or Mixed grade speed zones.

Time constraints, access to GPS units and video cameras during this TNZ Open National Tournament limited the number of subjects examined across each playing grades. Originally the TNZ Open National Tournament in the present study was scheduled as a four day event. However, due to unforeseen extreme weather conditions the Tournament was cancelled for the first day and rescheduled for a three day event. Consequently this affected the number of games and hence Touch players available for analysis. Physical and technical game measures with a larger sample size may have provided more conclusive findings in the present study. Further TMA studies are needed to better determine differences across genders and playing grades, particularly Mixed gender grade.

There were also limitations associated with GPSport 10 units, namely the 1 Hz sampling frequency and the inability to determine backward and sideway game movement patterns. The reliability of speeds recorded > 14 km.hr^{-1} are questionable (Coutts & Duffield, 2010) and without synchronised video footage was unable to determine the amount of game time and speeds when in possession of ball. Future

research using upgraded GPS equipment (which allows more frequent data recording per second) synchronised with suitable video footage, would provide more in-depth reliable and valid analysis of Touch specific game movements.

The quality of video footage gathered during the present study did not allow actual video-analysis of game movement patterns (forwards, backwards, sideways etc.), instead it provided basic game specific information (playing time, number of substitutions and Touch specific skills) which allowed the author to edit, notate and store for analysis. However, this procedure required a large amount of manual work by the author which has its limitations in terms of human error. Therefore, it is recommended that future research for analysis of Touch specific game movements and skills utilise a video-camera with high quality zoom, and more comprehensive event coding software, such as Sports Code: 'Game breaker'. This would then allow players and coaches to view Touch specific skills (events) instantly with no time wasted searching through video footage. For example, when a touchdown is scored or viewing game time *off the field* in the substitution box, being able to instantly see and document a Touch players movement patterns may help with determining if recovery time *off the field* has been utilised effectively.

To obtain a consistent sample of elite Touch players, only subjects who were attending the Touch New Zealand Nationals were studied. It may have been advantageous to study a larger sample of subjects. However, due to time restraints and number of elite athletes available from each of the three playing grades during data collection period sample size for the present study was relatively small. Further research with a larger sample size of male and female Touch players from all playing grades are needed to validate any findings and recommendations discovered in the present study.

Conclusions

It is obvious from the results in the present study that the game of Touch can be broken down into a series of running movement patterns separated by intervals of standing still, walking, and, or jogging. There are very few times during a game when Touch players sprint and even appear to reach maximal speed. Both general and Touch specific skills are often undertaken while moving in relation to playing positions on the

playing field. Skills such as catching, passing, dummy half pick ups, sidestepping, and making touches are all usually performed while moving across the Touch field, in various combinations of forward or backward and sideways. Positioning or re-positioning oneself without possession of the ball, is a prime example of the game movement activity for both defending and attacking players. The amount of time in the substitution box or *on the field* standing, walking, running and, or sprinting required in the game can depend on several factors; number of substitutes in the team, style of play (which is also dependent on the actions and composition of the opposition), playing grade and playing position of the Touch player. Of course the amount of activity an elite Touch player completes in a competition game also depends on personal issues such as general fitness, skill level, psychological and motivational status, game plan and specific coach instructions.

While a limited number of studies have assessed physical game measures (playing time, number of substitutions, TMA variables, and blood lactate concentrations) of Touch players during competition (Coffey, 2007; Kurzawa, 2008; O'Connor, 2002, Templeton et al., 2001), no study has evaluated these parameters on players who specifically play in a Mixed gender grade at the elite level. The results of this study adds to our understanding of the physical and technical skill demands of Touch, and are among the first to be collected in New Zealand and across the three different playing grades, Men's, Women's and Mixed. This is also the first study to investigate Touch specific skills of elite Touch players during competition.

This study provides evidence that there are several physical and technical game measurement differences across the three playing grades and that Touch players have obvious similarities and differences during competition games. These differences and similarities to previous research have also added further insight to the physical demands an elite Touch player performs during a game. The distance covered, time spent in each speed zone and maximum speed findings achieved during a competition game can be utilised by coaches and physical conditioners as guidelines towards designing more specific training programs, particularly for elite Touch players who specialise in playing in either Men's, Women's or Mixed playing grades. Such data can also be used as a benchmark for aspiring players to reach and for sports scientists wishing to conduct further research.

CHAPTER FOUR

Physiological Profiles of Elite Touch Players.

Chapter Summary

Purpose: The purpose of this study was to quantify the physiological characteristics of New Zealand elite Touch players from all three playing grades; Men's, Women's and Mixed. With the aim of understanding the potential differences between Touch players of different grades, various playing positions and genders. ***Methods:*** Thirty-eight elite Touch players participated in this study, 20 males (mean ± SD: age 23.4 ± 3.8 years; height 174.9 ± 6.1 cm; body mass 75.3 ± 8.1 kg) and 18 females (mean ± SD: age 23.9 ± 3.7 years; height 165.9 ± 5.0 cm; body mass 63.9 ± 5.6 kg). All participants underwent measurements of standard anthropometry (body mass and height), sprint speed (5-, 10-, 20-, 30-m sprint) and estimated maximal aerobic power (20 m Multi-stage shuttle run test). ***Results:*** Of the three different grades male Touch players who played in a Men's only grade were significantly taller, heavier, faster and achieved greater predicted VO_2max than female Touch players who played in a Women's only grade (~7%, ~14%, ~7 – 12%, and ~13%, respectively). Male mixed Touch players were significantly taller, heavier and faster than female Touch players who played in a Women's only grade (~5%, ~15%, and ~5 – 9%, respectively) and female mixed Touch players (~5%, ~18%, and ~5 – 9%, respectively). No significant differences ($p > 0.05$) in age, height, body mass, sprint speed and predicted $V0_2$max were found between middle, link and utility playing positions. However, when comparing between gender groups across the three playing positions, male utility Touch players were significantly, heavier and faster than all female positional groups (~16 – 18% and ~7 – 8%, respectively). ***Conclusion:*** These results provide some initial normative anthropometric and physiological data for New Zealand elite Touch Players. The results of this study show that male elite Touch players who play in a Men's only grade are different to female Touch players who play in either Women's only or Mixed grade (on many anthropometric and performance variables) and across various middle, link and utility playing positions. Such data is useful as it provides some indication of the different requirements of the various elite Touch grades and may also suggest that certain Touch players would be best utilised in another grade or playing position. These findings can be used as benchmarks by coaches and trainers to develop fitness and training protocols, particularly for elite Touch players who specialise in playing in Men's, Women's or Mixed playing grades or as middle, link or utility playing position.

Introduction

Little scientific information is available on the physiological profiles and fitness characteristics of the elite Touch player. The game of Touch consists of two 20-minute halves and can be played in a single sex (male or female only) or mixed gender (includes male and females playing in the same team) grade. The Touch player is required to perform many multi-directional movements with intermittent activity of varying intensities. Movement sequences include a range of forwards, backwards or sideways motions with changing intensities from walking to sprinting.

At the elite level, a Touch game is played at a fast pace with limited ball handling errors (O'Connor, 1997). Therefore, running speed is an integral aspect of almost every defensive and offensive manoeuvre performed by Touch players in practices and games, with many instances of players attaining game speed >25 $km.hr^{-1}$ (Coffey, 2007). Due to these high physical demands, Touch players may make an interchange (substitution) as often as he or she feels the need to. Keeping this in mind, players also require good speed to accelerate away from the approaching defenders, to out-manoeuvre their opponents and to cover in defence. Consequently, speed and timing are of paramount importance.

Although Touch may not be classified as an endurance sport per se, having a high aerobic capacity is thought important for the player to maintain a high level of activity during the entire game, in both attack and defence. Most Touch tournaments, especially at the elite level (including National and World Cup fixtures), require a player to participate in several 40 – 45-minute games over a period of 3 – 4 days (approximately 2 – 4 games per day). This can accumulate to approximately 6 – 8 hours of running over a few days, depending on tournament schedule, team warm up and warm down durations. With the final day being the most crucial, it is important players have a good level of aerobic endurance to assist with recovery during and between games.

The uniqueness of Touch compared to other team sports is that it can be played at the elite level in three different playing grades (Men's, Women's and Mixed gender) at the same national or international competition venue. Thus, it might be useful to obtain normative data on players from each of these grades. Only two studies have documented various physical, physiological, and anthropometric characteristics of elite male and female athletes in Touch (O'Connor, 1997; Templeton et al., 2001).

Table 9 presents a summary of the anthropometric and fitness test data thus far collected on Touch players.

From these studies it is apparent that elite male Touch players (Templeton et al., 2001) are heavier than elite female Touch players (Touch: O'Connor, 1997) (see Table 9). Aerobic endurance for elite male Touch players (Templeton et al., 2001) were also reported higher than elite female Touch players (O'Connor, 1997) (see Table 9). In summary, it is evident from these findings that elite male and female Touch players display between-gender differences in anthropometric and physiological characteristics (aerobic endurance). Due to the anthropometric and physiological differences between elite male and female athletes in Touch (Table 9) we could assume male players would have a physical advantage over female players in a Mixed gender team. However, to date there appears to be no peer-reviewed scientific studies published on physiological profiling of athletes in Mixed gender sports.

Table 9: Elite athlete anthropometric and fitness test research from Touch

Author, Year	Subjects (N)	Fitness test measures	
	Age, Height, Weight	**Speed (s)**	**Estimated VO_2max ($ml.kg.min^{-1}$)**
Male Athletes			
Templeton et al., 2001	3 Australian National 25 ± 2 yr, ?Height, 79.3 ± 3.9 kg	?	Level: Shuttle; 13:4 Laps; ¥122 Est. VO_2max; 58.4 ± 1.6 (lab)
Female Athletes			
O'Connor, 1997Ω	25 Australian International 22.1 ± 3.2 yr, 162.5 ± 7.6 cm, 56.8 ± 4.2 kg	10m: 1.82 ± 0.09	Level:Shuttle; ¥11:2 Laps; ¥96 Est. VO_2max; 50.8 ± 3.2

Est. = Estimated, ? Information unclear or not provided in study. ΩDenotes estimated VO_2max (VO_2 max: maximal aerobic power) testing was measured using 20 m Multi-stage shuttle run test (MST). ¥Denotes value, calculated by author using information provided in study N.B.: Not all research information is provided in table, only subjects, and physical characteristics have been included. See specific research for more detail.

The majority of research from the sport of Touch to date has focussed on male or female players from a single gender grade (Men's or Women's Open). To date, no studies have investigated grade-specific or physiological or physical characteristics of New Zealand elite Touch players. With this in mind, the purpose of this study was to

detail the physical and physiological characteristics of New Zealand elite Touch players from all three playing grades; Men's, Women's and Mixed. With the aim of determining if differences existed between playing position and gender. Knowledge of the physical and physiological characteristics of New Zealand Touch players participating at an elite level will aid coaches and strength and conditioning professionals in determining training goals, designing and evaluating training programmes and implementing talent identification programmes for this sport. Time-Motion Analysis findings (from Chapter 3) suggest male Touch players who played in a Men's only grade are able to achieve higher maximum speed and greater total distance travelled during a competition Touch game. Therefore, it is hypothesised that male Touch players who play in a Men's only grade would be faster and achieve a greater VO_2max than male mixed, female only and female mixed Touch players.

Methods

Participants

Thirty-eight elite Touch players gave their informed consent to participate in this study. The sample consisted of 20 males (mean ± SD: age 23.4 ± 3.8 years; height 174.9 ± 6.1 cm; body mass 75.3 ± 8.1 kg) and 18 females (mean ± SD: age 23.9 ± 3.7 years; height 165.9 ± 5.0 cm; body mass 63.9 ± 5.6 kg). Each participant had been selected to represent their respective regional area to compete at the Touch New Zealand (TNZ) Open National Tournament. All Touch players were volunteers from a variety of regional teams around New Zealand, including 28 [(7 male, 8 female and 13 mixed (6 male and 7 female)] players who were chosen to compete for New Zealand at the Touch World Cup.

At the time of testing for this study, all subjects were currently participating in their local Touch competitions and training with their respective regional team. Ethical approval was obtained for all testing procedures from Auckland University of Technology Ethics Committee.

Procedures

Testing was conducted within two weeks of competing in the TNZ Open National Tournament so that all Touch players had sufficient training and, or game time in the month(s) prior to testing. All participants were required to complete two testing sessions for this study. The first session involved assessment of the player's speed and aerobic endurance. Anthropometric profile assessments were obtained during the second session at the TNZ Tournament, which was conducted within 1 – 2 weeks of the speed and aerobic endurance testing session.

Fitness Test Measures (Speed and Aerobic Endurance Testing)

Playing positions

The playing positions of choice were defined as:

> *Middle:* can be one of two Touch players who predominantly position themselves in the centre of the field during a game. Also known as playing position number 3 or as an '*inside'*.
>
> *Link:* can be one of two Touch players who predominantly position themselves on either outside of the 'middles' on the field during a game. Also known as playing position number 2 or as an '*inside'*.
>
> *Winger:* can be one of two Touch players who are positioned closest to the sideline on either side of the field during a game. Also known as playing position number 1 or as an '*outside'*.
>
> *Utility:* a Touch player who plays a combination of *middle*, *link* and, or *winger* playing positions during a game. For example, they may routinely interchange between two or more playing positions at any time during the game. Such combinations may include *winger* or *link*, *middle* or *link*, *middle* or *link* or *winger*.

During analysis of playing positional data it was evident that no participant from this study had recorded their playing position as a *'winger'*. For this reason the *'winger'* playing position was excluded from futher analysis for this study.

Testing protocol

Sprint speed and aerobic endurance tests were performed in the first session. The participants were familiar with the test protocols since they routinely performed these tests for regional testing purposes. Each player was instructed and verbally encouraged to give a maximal effort during all tests. Prior to the testing session, participants completed a standard warm-up that consisted of 5 to 10-minutes jogging, a series of dynamic stretches, and a sequence of 10 to 40 metre warm up sprints (60 – 90% efforts). Each test was separated by at least 5-minutes of recovery, but players were allowed more rest if it was required.

Sprint tests

The participants performed three maximal 30 metre sprints (with 5, 10 and 20 metre split times also recorded). During recovery (2 – 3-minutes), the participants walked back to the starting line and waited for the next sprint. Sprint time was recorded with a precision of 0.01 seconds using timing lights (Speed Light athletic timing system; model TB4, Lismore, Australia). All participants commenced the sprint when ready from a split, parallel stance (standing start) 0.5 m behind the first timing gate. The average time of the two fastest 30 metre sprints was selected for data analysis.

Aerobic endurance test

A 20 metre Multi-stage shuttle run test was performed to estimate the maximal aerobic capacity of each athlete. This endurance test involved participants running a series of 20 metre shuttle runs in tandem with an audio signal that became progressively faster. The audio signal was played through a sound system from a compact disc player.

Participants were required to maintain the given speed and instructed to complete as many 20 metre shuttles as possible. The test was terminated when the participant voluntarily dropped out due to exhaustion or could no longer maintain pace with the audio signals. The number of shuttles completed was recorded and an equivalent VO_2max was estimated (Australian Sports Commission, 2005).

Anthropometry

Height and body mass for all athletes were recorded on another day, at the TNZ Open National Tournament, approximately 1 – 2 weeks after the speed and aerobic endurance testing session. Standing height was measured without shoes using a wall-mounted stadiometer to the nearest 0.5 cm. Body mass was measured to the nearest 0.1 kg using an electronic scale (Seca 770 Super Heavy-Duty Digital Floor Scale, Hamburg, Germany).

Statistical Analysis

Standard descriptive statistics (mean and standard deviations) were calculated for all demographic (age, height and body mass) and performance measures (sprint times: 5-, 10-, 20- and 30 metre; and aerobic endurance level: shuttle, final shuttle number and predicted VO_2max) test variables. Significant inter-group differences for all demographic or physiological variables were assessed using a one-way analysis of variance. When a significant between-group difference was found using the main effect p-value, a Gabriel post-hoc test was then used to identify which groups were significantly different. The Gabriel test was selected as there were generally some differences in the sample size of each group. Significant differences between these test variables were compared three ways: 1) gender differences across three playing grades (male only, male mixed, female only and female mixed grade Touch players); 2) playing position differences (middles, links and utility Touch players); and, 3) within and between gender differences across playing positions (male and female middles, links and utility Touch players). 'Male only' group were Touch players who played in a Men's only grade, 'female only' were players who played in a Women's only grade. 'male or female mixed' were players who played in a grade that has both males and females in a team (3 male and 3 female on the playing field). Statistical significance was accepted at the 5% level.

Results

Anthropometric characteristics and fitness tests measures of male and female Touch players from three different playing grades are shown in Table 10. No significant differences ($p > 0.05$) in age were found between groups. Across all grades standing height ranged between ~173 – 177 cm and body mass ranged between ~75 – 76 kg for male Touch players, and ~165 – 166 cm and ~62 – 65 kg for female Touch players. Male only players were significantly taller and heavier than female Touch players from a Women's only grade (~7% and ~14%, respectively) and (~7% and ~17%, respectively) Mixed grade. Similarly, male mixed Touch players were significantly taller and heavier than female Touch players from a Women's only grade (~5% and ~15%, respectively) and female Touch players who played in a Mixed grade (~5% and ~18%, respectively).

Sprint times across all grades for a male Touch player ranged from 5 m ~1.0 s; 10 m ~1.7 s; 20 m ~ 3.1 s; and 30 m ~4.1 – 4.2 s and female Touch players times ranged between 5 m ~1.1 s; 10 m ~1.8 s; 20 m ~ 3.3 s; and 30 m ~4.5 – 4.6 s. Significant differences were found between the three different playing grades for all of the split times obtained from the average of two fastest 30 m sprints. Male Touch players who played in a Men's only grade were significantly faster than female Touch players from both Women's only and Mixed grades (~7 – 12%, for both). Male mixed Touch players were significantly faster than female Touch players from both Women's only and Mixed grades (~5 – 9%, for both). However, no significant differences in 5 m sprint times were found between male mixed Touch players and female Touch players from both Women's only and Mixed grades.

Predicted VO_2max across all grades, as indicated by 20 m Multi-stage shuttle run test for a male Touch player ranged between ~54 – 56 ml.kg.min^{-1} and ~49 – 50 ml.kg.min^{-1} for a female Touch player. Male Touch players who play in a Men's only grade achieved a significantly greater predicted VO_2max than female Touch players who played in a Women's only grade (~13%).

Table 10: Anthropometric and fitness test results of male and female Touch players from three different playing grades (Men's, Women's and Mixed)

Tests	Male Only (n = 10)	Male Mixed (n = 10)	Female Only (n = 10)	Female Mixed (n = 8)	Main Effect P-value
Age (yrs)	23.5 ± 3.9	23.3 ± 4.0	23.2 ± 2.4	24.9 ± 4.8	0.786
Height (cm)	176.6 ± 6.8 [a, b]	173.2 ± 5.0 [c, d]	165.8 ± 4.5	166.0 ± 5.9	<0.001
Body mass (kg)	75.1 ± 7.6 [a, b]	75.5 ± 9.0 [c, d]	64.9 ± 6.3	62.6 ± 4.8	<0.001
Sprint Times (sec)					
5 m	1.00 ± 0.06 [a, b]	1.02 ± 0.08	1.09 ± 0.04	1.09 ± 0.05	0.003
10 m	1.70 ± 0.06 [a, b]	1.72 ± 0.11 [c, d]	1.85 ± 0.05	1.86 ± 0.09	<0.001
20 m	3.05 ± 0.07 [a, b]	3.09 ± 0.11 [c, d]	3.25 ± 0.07	3.33 ± 0.12	<0.001
30 m	4.10 ± 0.07 [a, b]	4.24 ± 0.17 [c, d]	4.56 ± 0.12	4.63 ± 0.15	<0.001
Aerobic					
20 m MST (Level: Shuttle)	12:8 ± 2:7 [a]	12:4 ± 3:1	10:8 ± 2:3	11:1 ± 3:7	0.009
Final Shuttle Number (Beep Number)	114 ± 13 [a]	110 ± 16	91 ± 9	95 ± 22	0.007
Predicted VO_2max (ml.kg.min^{-1})	55.8 ± 3.7 [a]	54.7 ± 4.8	49.1 ± 2.8	50.2 ± 6.3	0.006

MST = Multi-stage shuttle run test.

[a] Denotes significant ($p < 0.05$) difference between male only vs. female only grade.

[b] Denotes significant ($p < 0.05$) difference between male only vs. female mixed grade.

[c] Denotes significant ($p < 0.05$) difference between male mixed vs. female mixed grade.

[d] Denotes significant ($p < 0.05$) difference between male mixed vs. female only grade.

Number of participants slightly decreased for female only, male mixed and female mixed grade in sprint speed and aerobic endurance tests due to injuries sustained close to the time of testing. Sprint speed for female only (n = 8), and male mixed (n = 9). Aerobic endurance for female only grade (n = 9), male mixed (n = 8) and female mixed grade (n = 7).

Anthropometric characteristics and fitness tests measures of male and female Touch players from three different playing positions are shown in Table 11. Although no significant differences in height and body mass were found across three playing positions for male only groups, male utility players appeared to be heavier than link Touch players (~10%). However, when comparing between gender groups across the three playing positions, male middle and male utility players were both significantly taller and heavier than female utility Touch players (~7% taller and ~18% heavier, for both). Male utility players were also significantly heavier than both female middle (~17%) and link (~16%) Touch players.

No significant ($p > 0.05$) differences were found within gender positional groups in sprint speed. However, when comparing between gender positional groups, male middle players were significantly faster than all three female playing positions (middle ~6 – 9%, link ~7 – 9%, and utility ~7 – 10%). Similarly, male utility Touch players recorded significantly faster 20 m split times than all three female playing positions (middle ~7%, link and utility ~8%, for both).

No significant differences in predicted VO_2max were found across playing positions within and between gender groups. Across three playing positions within gender groups predicted VO_2max (indicated by 20 m Multi-stage shuttle run test) for male Touch players ranged between ~54 – 57 ml.kg.min^{-1} and female Touch players ranged between ~49 – 50 ml.kg.min^{-1}. While no significant differences were found in predicted VO_2max when comparing between gender positional groups, male link players appeared to record higher VO_2max measures than female link (~12%), middles (male ~4% and female ~13%) and utility (male ~2% and female ~14%) Touch players.

Table 11: Anthropometric and fitness test results per playing position of male and female Touch players

Tests	**Male**			**Female**			Main
	Middle (n = 9)	Link (n = 3)	Utility (n = 8)	Middle (n = 5)	Link (n = 7)	Utility (n = 6)	Effect P-value
Age (yrs)	22.9 ± 3.4	24.3 ± 2.5	23.6 ± 4.9	24.8 ± 2.0	23.1 ± 3.8	24.2 ± 4.8	0.953
Height (cm)	175.0 ± 6.3 [c]	171.7 ± 5.5	176.0 ± 6.3 [f]	166.8 ± 5.8	167.7 ± 5.3	163.0 ± 3.0	0.001
Body mass (kg)	76.1 ± 8.2 [c]	69.4 ± 5.1	76.7 ± 8.8 [d, e, f]	63.7 ± 5.2	64.8 ± 5.3	63.0 ± 7.1	0.001
Sprint Times (sec)							
5 m	1.01 ± 0.08	1.01 ± 0.03	1.01 ± 0.07	1.10 ± 0.05	1.09 ± 0.04	1.08 ± 0.04	0.023
10 m	1.70 ± 0.10 [a, b]	1.71 ± 0.09	1.72 ± 0.08	1.86 ± 0.07	1.86 ± 0.07	1.84 ± 0.09	0.002
20 m	3.09 ± 0.11 [b, c]	3.09 ± 0.06	3.05 ± 0.09 [d, e, f]	3.26 ± 0.09	3.31 ± 0.12	3.30 ± 0.11	<0.001
30 m	4.19 ± 0.18 [a, b, c]	4.15 ± 0.16	4.14 ± 0.11	4.53 ± 0.15	4.58 ± 0.10	4.66 ± 0.16	<0.001
Aerobic							
20 m MST (Level: Shuttle)	12:4 ± 3:3	12:11 ± 3:1	12:7 ± 2:5	10:9 ± 2:2	11:1 ± 4:3	10:8 ± 2:4	0.045
Final Shuttle Number (Beep Number)	110 ± 18	117 ± 16	113 ± 12	92 ± 9	95 ± 26	91 ± 11	0.041
Predicted VO_2max (ml.kg.min^{-1})	54.7 ± 5.0	56.8 ± 4.3	55.7 ± 3.4	49.6 ± 2.6	50.0 ± 7.4	49.2 ± 3.5	0.036

MST = Multi-stage shuttle run test.

[a] Denotes significant ($p < 0.05$) male middles vs. female middles playing position difference.

[b] Denotes significant ($p < 0.05$) male middles vs. female links playing position difference.

[c] Denotes significant ($p < 0.05$) male middles vs. female utility playing position difference.

[d] Denotes significant ($p < 0.05$) male utility vs. female middles playing position difference.

[e] Denotes significant ($p < 0.05$) male utility vs. female links playing position difference.

[f] Denotes significant ($p < 0.05$) male utility vs. female utility playing position difference.

Number of participants slightly decreased for both male and female groups in sprint speed and aerobic endurance tests due to injuries sustained close to the time of testing. Sprint speed male link (n = 2), female link (n = 6) and female utility (n = 5). Aerobic endurance male middle (n = 8), male link (n = 2), and female link (n = 5).

Discussion

The purpose of the present study was to outline the physical and physiological characteristics of New Zealand elite Touch players from all three playing grades; Men's, Women's and Mixed. With the aim of determining if differences existed between playing position and gender. There were five main findings from the present study: (1) anthropometric measures (height and body mass) and performance characteristics (sprints and aerobic capacity) were significantly higher in Touch players who played in a Men's only grade than female Touch players who played in Women's only grade; (2) male mixed Touch players were significantly taller, heavier and faster than female mixed Touch players and female Touch players who played in a Women's only grade; (3) no significant differences in aerobic capacity performance were seen between Touch players from a Men's only grade and Mixed grade (male mixed and female mixed); (4) no significant differences in anthropometric measures (height and body mass) and performance characteristics (sprint and aerobic capacity) were observed between three different playing positions (*middle*, *link* and *utility*); and, (5) anthropometric measures (height and body mass) and sprint performance characteristics were significantly greater in male *middles* and male *utility* Touch players than female Touch players from each positional group, when this data was collapsed across genders for *middle*, *link* and *utility* playing positions.

Male Touch players who played in a Men's only grade were taller, heavier, and faster and had a higher estimated VO_2max than elite female Touch players who played in a Women's only grade. This finding is similar to previous Touch studies of elite male athletes who play in a Men's only grade (Templeton et al., 2001) and elite female athletes who play in a Women's only grade (O'Connor, 1997). Between-gender differences in speed and estimated VO_2max suggest that these physiological characteristics may contribute to the higher intensity playing standard of male elite Touch players who play in a Men's only grade, which is often observed during a game of Touch at this level.

Two studies have documented anthropometric and physiological characteristics of elite Touch players (O'Connor, 1997; Templeton et al., 2001). The study by O'Connor (1997), outlining fitness profiles of 25 Australian female elite Touch players who play in a Women's only grade, reported similar heights, 10 metre sprint time and aerobic power compared to the results found in the present study for New Zealand female

elite Touch players who played in a Women's only grade and female mixed Touch players (163 vs. 166 cm, 1.82 vs. 1.85 – 1.86 s and predicted VO_2max 51 vs. 49 – 50 ml.kg.min^{-1}, respectively). Such similarities probably reflect the comparability between subjects playing level and those little physical differences are evident between Australian and New Zealand female elite Touch players.

However, the body mass of New Zealand female elite Touch players who played in a Women's only grade and female mixed Touch players in the present study were higher than those reported for Australian female elite Touch players from a Women's only grade (63 – 65 vs. 57 kg) (O'Connor, 1997). Differences between the studies may suggest New Zealand female Touch players, because they are of similar height, differ in body mass composition to the Australian female Touch players. For example, New Zealand female Touch players may have higher muscle and, or fat mass compared to Australian female Touch players which could explain difference in body mass. However, further anthropometric (leg length, sum of skin folds, body fat percentage etc.) research is needed to identify the reason for the difference in body mass and its likely effect on performance. Such differences in body composition may also reflect ethnic differences in these groups, with for example a greater proportion of Maori and Polynesian players found in New Zealand compared to Australian Touch studies.

The study by Templeton et al. (2001), who investigated physiological demands of three Australian elite male Touch players from a Men's only grade, reported slightly higher body mass than those in the present study. New Zealand male elite Touch players in the present study who play in either Men's only or Mixed grade were lighter (75 - 76 vs. 79 kg), height was not documented. Aerobic capacity for this study were also higher than those found in the present study for New Zealand male elite Touch players who play in either Men's only or Mixed grade (~58 vs. ~55 – 56 ml.kg.min^{-1}) (Templeton et al., 2001). Such differences probably reflect the disparities in physiological make up of individuals. However, comparisons between studies has its limitations as the sample size of Australian research was extremely small which makes it less likely that such results are representative of the elite male Touch playing population.

This study is the first to investigate the anthropometric and physiological characteristics of elite Touch players who specialise in a Mixed grade. The results

demonstrate that male mixed Touch players were significantly taller, heavier and recorded faster 10- to 30 m split sprint times than female Touch players who play in Women's only grade and female mixed Touch players. However, male mixed Touch players were not significantly different to female Touch players who play in a Women's only grade or female mixed Touch players with respect to their 5 m sprint times and aerobic power. From these findings, it could be speculated that female Touch players who play in a Women's only grade and female mixed players have similar 5 m speed and aerobic power to that of male mixed Touch players. However, once the distance becomes greater male mixed players were faster than female Touch players who played in a Women's only grade and female mixed Touch players. This is probably due to low statistical power. Alternatively, this may suggest a biological and physiological difference between male mixed players and female Touch players has no or little effect on 5 metre and aerobic power. However, this implication would need to be investigated further with a larger sample of both male and female elite Touch players who specialise in playing in a Mixed grade.

This study is the first to investigate the anthropometric and physiological characteristics of elite Touch players across multiple playing positions. No significant differences in anthropometric characteristics and fitness tests measures were found when comparing *middle*, *link* and *utility* playing positions within each gender group. However, this could be a reflection of the small sample size within each male and female positional group. Further research is needed with larger sample sizes of both male and female within each playing position to warrant this claim.

The analysis between male and female *middle*, *links* and *utility* positional groups found several significant differences in some physiological variables. Male *utility* Touch players were significantly heavier (~16 - 18%) and recorded faster 20 m split times (~7 – 9%) than all female positional groups. Reasons for these body mass differences between genders and playing positions are likely due to biological and physiological differences between male and females. Differences in speed possibly suggest that male *utility* Touch players are able to reach higher game speeds during a Men's only or Mixed game compared to female Touch players who play a similar position or as *middle* or *link*.

Limitations

The sample size of this study is comparable with most physiological profiling studies of elite athletes in Touch (see Table 9). To obtain a consistent sample of elite Touch players, only subjects who were attending the Touch New Zealand Nationals were studied. It may have been advantageous to study a larger sample of subjects. However due to time restraints and number of elite athletes available from each of the three playing grades during data collection period was relatively small.

Although further anthropometric (leg length, sum of skin folds, body fat percentage etc.) and fitness testing (agility speed, anaerobic tests etc.) measures may have provided additional information on the physiological profiles of elite Touch players, the time and personnel available limited the number of tests included in the testing battery. Clearly, further comprehensive studies are needed to completely determine the anthropometric and physiological characteristics of elite Touch players, particularly within and between *middle*, *link* and *winger* positional groups.

Conclusions and Practical Applications

This study was designed to outline and investigate the anthropometric and physiological characteristics of New Zealand Touch players from all three playing grades; Men's, Women's and Mixed participating at an elite level, with the aim of profiling playing position and gender differences. The results of this study show that male elite Touch players who played in a Men's only grade were taller, heavier, faster and obtained a greater aerobic capacity than female elite Touch players who play in a Women's only and Mixed grade. Male mixed Touch players where taller, heavier, faster and obtained similar aerobic capacity than female elite Touch players who play in either a Women's only or Mixed grade. Consistent with findings from other Touch research of male and female elite Touch players, significant differences exist across genders for body mass, 10-, and 20-m speed, and estimated maximal aerobic power.

This study found that New Zealand female elite Touch players' (who play in a Women's only or Mixed grade) physiological characteristics (speed and estimated VO_2max) were similar to Australian female elite Touch players. However, New Zealand female elite Touch players were heavier than Australian female elite Touch players.

This could suggest that a slight increase in body mass for New Zealand female elite Touch players may not necessarily affect a player's performance in sprint time and aerobic capacity. Although to verify this implication further anthropometric and physiological studies are needed.

Anthropometric and fitness test results from the present study have highlighted a greater understanding of the physiological characteristics of elite Touch players from the three different playing grades. While a limited number of studies have assessed some of the anthropometric and physiological characteristics of elite Touch players (O'Connor, 1997; Templeton et al., 1989), no study has evaluated these parameters on players who specifically play in a Mixed grade at the elite level or across various playing positions. These findings can provide coaches and trainers with baseline data required to develop fitness and training standards, particularly for elite Touch players who specialise in playing in either Men's, Women's or Mixed playing grades or as *middle*, *link* or *utility* playing position.

These results provide normative anthropometric and physiological data for elite New Zealand Touch players. During practises and games Touch players running speed is an essential part of all defensive and offensive movement patterns. For example, Touch players require good speed to out-manoeuvre opponents, cover in defence and accelerate away from the approaching defenders. Consequently, speed and timing are of paramount importance. The relationship between speed and performance suggests that speed is an important characteristic for Touch players and therefore including speed drills in the conditioning programme is beneficial.

Although the data in this and previous studies would suggest that Touch is not classified as an endurance sport *per se*, having high values of cardiopulmonary functions would appear important for each player to maintain a high level of activity during the entire game, in both attack and defence. Hence, when preparing for Touch tournament events, especially at the elite level (including National and World Cup fixtures, which schedule several 40 – 45-minute intense games over 3 – 4 days with the final day being the most crucial), it is important players have a good level of aerobic endurance to assist with recovery during and between games. Therefore, including some form of aerobic endurance sessions in the conditioning programme would appear advantageous. These conditioning sessions are not limited to just aerobic type training but may also include interval trainings at a variety of work: rest ratios.

Finally, results in this study show some of the most commonly utilised anthropometric and physiological measures in field testing of team sports. However, to effectively prepare elite Touch players for competition (for example; being able to tolerate the physiological demands of playing Touch at the elite level, increase playing performance, reduce fatigue-related errors in skill execution, and decrease the risk of injury), there would appear to be a general need to develop all physiological parameters (body composition, speed, agility, flexibility, strength, aerobic, anaerobic capacity) (Gabbett, 2007). It is therefore recommended that coaches and strength conditioners implement regular physiological testing sessions (e.g., off-season, pre-season, mid-season, and post-season) to monitor physiological progression and development of athletes.

CHAPTER FIVE

Summary, Conclusion, Limitations and Future Research.

Overall Summary and Conclusion

A relatively small amount of published literature exists for elite Touch players. This project sought to provide a detailed analysis of the physiological demands of elite Touch players and to also determine if any differences exist across the three playing grades and various Touch player positional groups. The objectives of this thesis were to use methods of performance analysis to measure the physical and technical variables of elite Touch players during a competition game and to determine differences across the three playing grades and various Touch player positional groups.

Chapter three provides evidence that there are several physical and technical game measurement similarities and differences across the three playing grades during competition games. Thirty eight elite Touch players were investigated over a three day Touch New Zealand Open national tournament. Physical and technical game measures of players were recorded using portable GPS units, video cameras and portable lactate pro analysers. For each playing grade the overall mean time period spent *on and off the field ratios* during a game was, male only ~1:1.10, mixed male ~1:1.75, female only ~1:1.40 and female mixed ~1:1.20. There were no differences in game movement distances, time within each speed zone, total distance and speed variables found between elite male Touch players who played in a Men's only grade and female Touch players' who played in a Women's only grade. However, male mixed players spent ~50% more time sprinting (>18 $km.h^{-1}$) than female players who play in a Women's only grade. Male Touch players from a Men's only and Mixed grade performed ~47% more *successful* attacking skills during a game than female players from a Mixed grade.

Chapter four investigated physiological profiles and fitness characteristics of elite Touch players from all three playing grades and various Touch player positional groups. Thirty eight elite Touch players were fitness tested within 1-2 weeks of playing at the Touch New Zealand Open national tournament. Running speed and aerobic capacity tests were performed using timing gates and 20 m Multi-stage shuttle run fitness test. Of the three different grades male Touch players who play in a Men's only grade were taller, heavier, faster and achieved higher predicted VO_2max than female Touch players who play in Women's only grade. However, predicted VO_2max was not significantly different for male only, male mixed and female mixed grade Touch players. No differences in age, height, body mass, sprint times and predicted $V0_2$max

were found between *middle*, *link* and *utility* playing positions. However, male *utility* Touch players were significantly, heavier and faster than all female positional groups.

This was the first investigation conducted at the elite level in New Zealand for the sport of Touch across the three playing grades (Men's, Women's and Mixed). The combination of TMA and video-analysis and physiological data examined in this project has provided a more comprehensive picture of the demands of Touch than previously achieved. The findings of this study have added to the limited literature for elite Touch players which had generally involved Australian Touch players only, small samples of male and female Touch players who play in a single sex grade (Men's or Women's Open) and no mixed Touch player data.

The project provides some initial Touch specific physical and technical game measurement data for New Zealand elite Touch players. The results from this study provide evidence that Touch players have obvious similarities and differences during competition games and that there was several Touch specific physical and technical game measurement differences across the three playing grades. Playing time *on and off field ratio*, maximum speed achieved, distance covered and time spent in each speed zone during a competition game can be utilised by coaches and support staff (physical conditioners) as guidelines towards designing more Touch specific training program, particularly for elite Touch players who specialise in playing in either Men's, Women's or Mixed playing grades.

This study has also presented some initial normative anthropometric and physiological data for New Zealand elite Touch players. This was the first research project in the sport of Touch which has profiled playing positions of elite Touch players from all three playing grades; Men's, Women's and Mixed. Such data can be used as a point of reference to assist coaches and elite Touch players to better prepare and may also suggest that certain Touch players would be best utilised in another grade or playing position. These findings can also be used by sports scientists as a guideline towards further research.

Limitations

Using an elite athlete subject group during competition may provide the most representative data but also poses some challenges. On the positive side, the data obtained is real and reflects current, high level performance. Findings are therefore directly applicable to athletes at the same and similar levels and provide lower level athletes with benchmarks to strive towards. Negatively, the ability to control variables and create a stable research environment is reduced. Injuries to players during matches, influence of coaching tactics and umpires etc are all intrinsic qualities of sporting competition that can confound the results. Due to the lack of comparable studies genuine comparison is difficult as a consequence. There are inherent difficulties in investigating both physical and technical game measures during a team sport and it is acknowledged that the present study was conducted using only one competition game for each elite Touch player against various oppositions. One game for each elite Touch player limits the statistical power of the findings and recommendations but does provide insight into the physical and technical demands elicited during competition. Typically, most elite level Touch is played in tournament situations with clusters of 3-8 games over a short time period (3-days).

A limitation to the comparison of three playing grades and various Touch player positional groups is the assumption that all elite Touch players are equal. In all teams there is likely to be a difference in playing position and ability between Touch players. This project did not take into consideration number of years playing experience for each Touch player.

A final limitation is the interaction of the opposition team on physical and technical performance. No team plays in an identical fashion for each competition game. The variation in performance of the opposition for the present study was not measured. The physical and technical game measures of these elite Touch players will have had an impact on the outcomes of the subject team and variations would have reduced the ability of the project to measure the effect of the Touch players' conditions.

Future Research

As there has been only a relatively small amount of published literature on elite Touch players it is likely that there is still much to learn and significant benefit to be gained from performance analysis research. It is important that basic notational analysis of Touch continues so as to thoroughly document the physical and technical demands of the game at all levels and grades including Men's, Women's, Mixed and Youth.

Investigating player-positional variants on whether there are different physical and technical requirements for *insides* and *outsides* i.e., would an *inside* Touch player cover more distance, achieve higher average speed, make more substitutions, perform more *successful* Touch specific skills than an *outside* Touch player? Therefore should an *inside* Touch player be given different physical and technical training programmes to an *outside* Touch player?

Certain conditions beyond the control of the present study are likely to have affected the performance measures of elite Touch players. Coaching tactics and game plans, number of players used for each game, 12 vs. 14 players (affects the number of substitutions in the box), positional substitutions (ratio of substitutions for *insides* vs. *outsides*), active or passive recovery strategies (during the game in substitution box and at the conclusion of games), style of play and playing position of each Touch player. Replicating the present study using a larger sample of competition games for each Touch player would be beneficial. This would strengthen the statistical power and representativeness of the findings.

Further research into other and inevitably more complex (but undoubtedly more relevant) issue is the overall substitution system used by a team. This would require investigation into a variety of substitution policies currently being utilised by coaches and teams from the three different playing grades. For example, would playing with a team of eight *insides* (four on field and four substitutes) during a competition game be physically less demanding than playing with six *insides* (four on field and two substitutes)? Similarly, would playing six *outsides* (two on the field and four substitutes) be less demanding than playing four *outsides* (two on the field and two substitutes)? What substitution policies are most effective for each specific playing grade? Furthermore, should a coach use partner or small group rotations substitution strategies for all players so as to allow physical, technical and performance outputs to be maximised. Tracking of several Touch players from the same team over an entire

Tournament or a national team over a series of international tournaments or tours may provide enough information to identify trends and suggest recommendations to help coaches with this difficult question.

Competing at national and international tournaments with the most important games (finals for medals) usually on the last day and normally after several 40-minute games, it would seem obvious that some form of fatigue is likely to occur. How much an athlete fatigues could be further investigated by tracking entire teams (from various playing grades and positional groups) over the duration of the tournament. For example, what are the physiological effects of playing several games over three or four day event compared to playing several games in a one day Touch tournament? Should physical preparation for these events be the same or different, if so how and why? Also in order to minimise any signs of fatigue from occurring during a tournament, further research could examine the effects of various recovery strategies implemented over the duration of Touch tournament which could provide additional information regarding maximising an elite Touch player's physical performance during competition games. For example, should Touch players be encouraged to keep moving (active vs. passive recovery) in the substitution box during a game, in an attempt to minimise lactate build up? Using heart rate data would provide further information to identify trends, particularly when examining activity patterns in substitution box.

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GPS Garmin product information. http://www.garmin.com/

GPSports – product and research information. http://www.gpsports.com/

Interview

Desmond Kissane. Head Coach, World Rugby Club, Rokko Island, Japan. Several discussions and interviews between October and November 2005.

Wally Rifle. Head Coach, 2005 New Zealand Under 21 Men's Touch Team (Current world champions due to cancellation of 2009 Youth World Cup), and Head Coach, 2008 and 2010 Waikato Touch Men's Open, Hamilton, New Zealand. Several discussions and interviews between March 2004 and March 2010.

APPENDICIES

APPENDIX 1A:
GAME MOVEMENT PERFORMANCE OF NZ REPRESENTATIVE TOUCH PLAYERS
"Percentage of time spent in each speed zone"

Figure 6 illustrates the percentage time spent in each speed zone for a male Touch player who played in a Men's only grade (NZ representative). He spent 74% of the total duration of the game in speed zone 1 – stationary and, or walking (less than 6 km.h^{-1}), this is within the average for male Touch players in a Men's only grade (see Table 6). Note that this player only spent 2% of the game duration in speed zone 4 – sprinting (above 18 km.h^{-1}). Although, this may seem very small it is above the average for male Touch players who play in a Men's only grade (see Table 6).

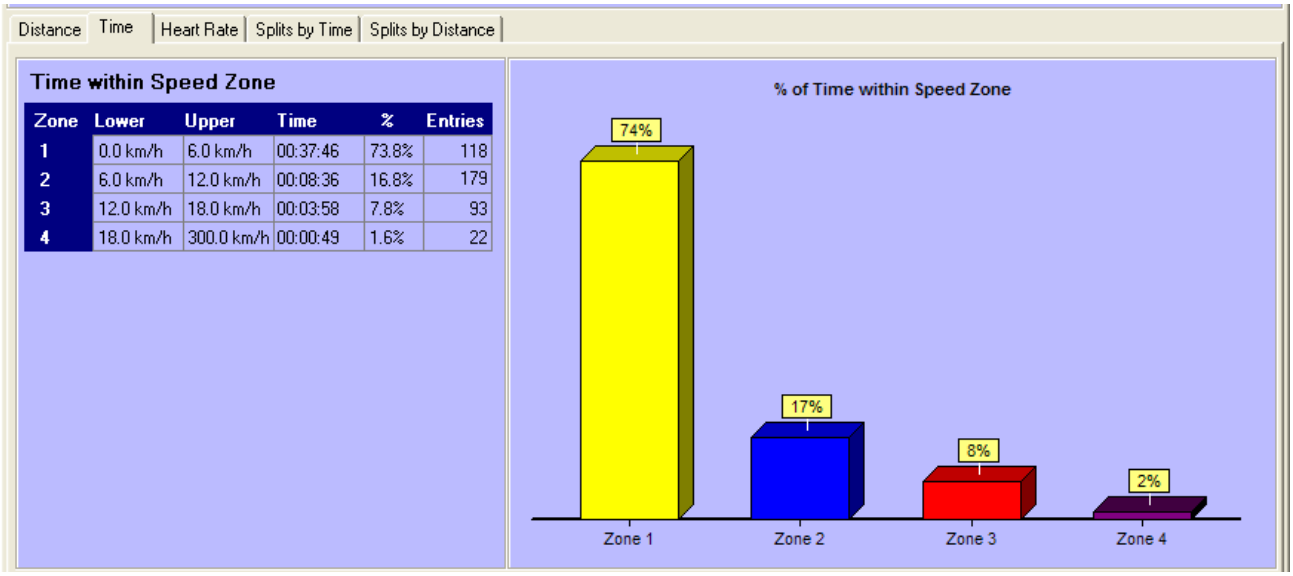
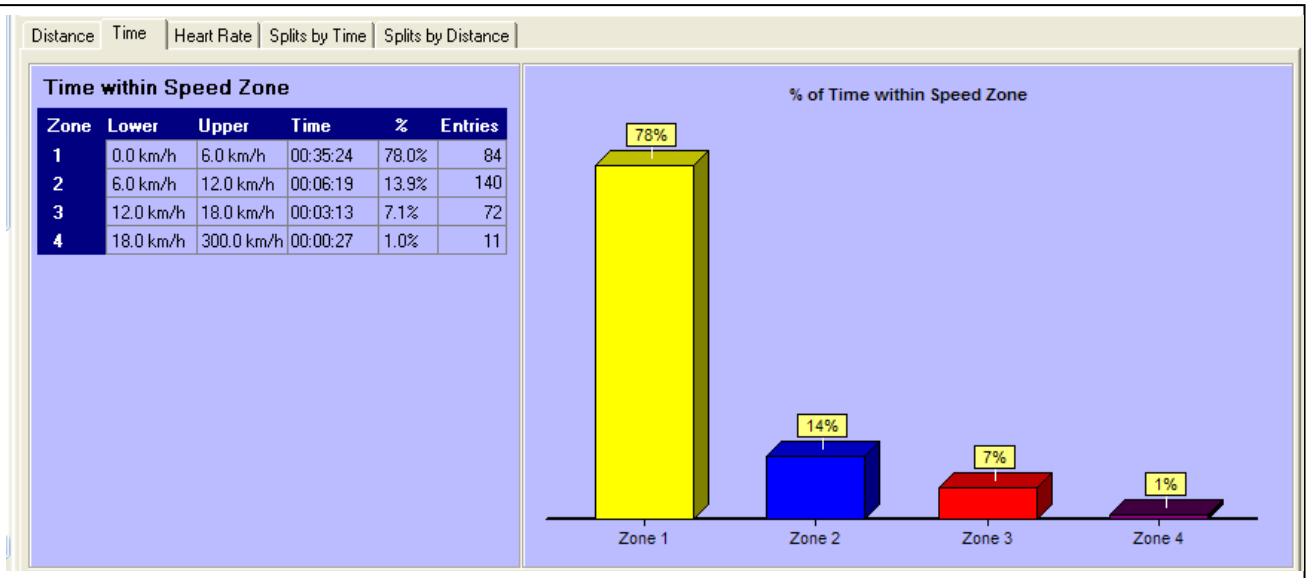


Figure 6: Game movement times within each speed zone during a competition Touch game for a male elite Touch player who plays in a Men's only grade.

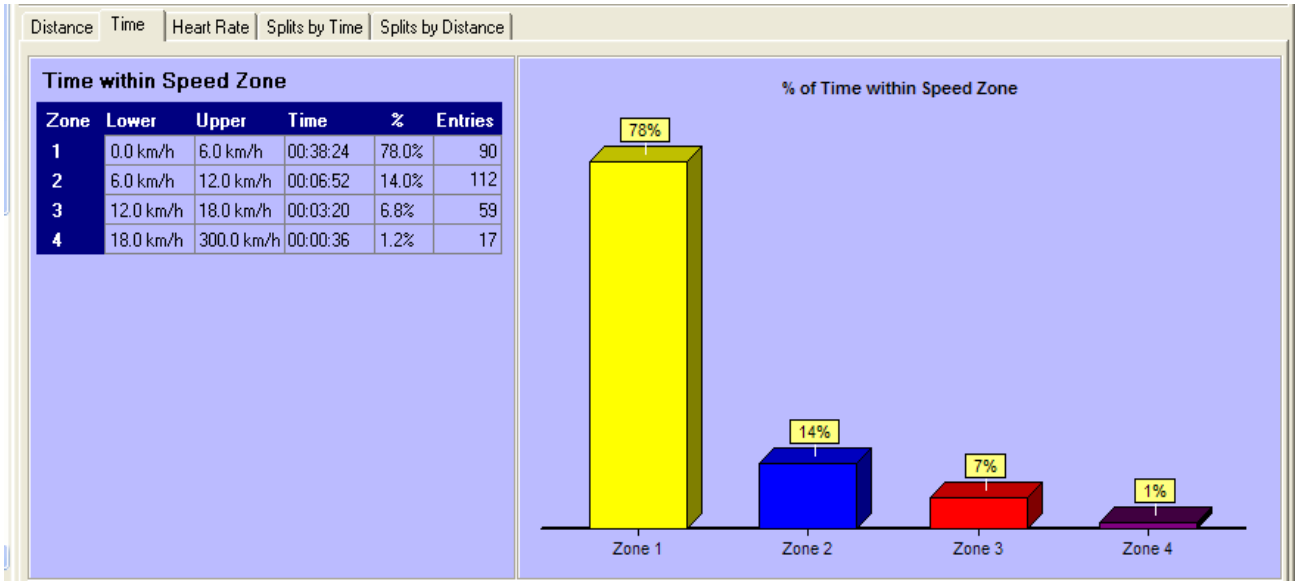
Figure 7 illustrates the percentage time spent in each speed zone for a female Touch player who played in a Women's only grade (NZ representative). She spent 78% of the total duration of the game in speed zone 1 – stationary and, or walking (less than 6 km.h^{-1}) this is within the average for female Touch players in a Women's only grade (see Table 8). Note that this player only spent 1% of the game duration in speed zone 4 – sprinting (above 18 km.h^{-1}). Although, this may seem very small again it is within the average for female Touch players who play in a Women's only grade (see Table 6).



Zone	Lower	Upper	Time	%	Entries
1	0.0 km/h	6.0 km/h	00:35:24	78.0%	84
2	6.0 km/h	12.0 km/h	00:06:19	13.9%	140
3	12.0 km/h	18.0 km/h	00:03:13	7.1%	72
4	18.0 km/h	300.0 km/h	00:00:27	1.0%	11

Figure 7: Game movement times within each speed zone during a competition Touch game for a female elite Touch player who plays in a Women's only grade.

Figure 8 illustrates the percentage time spent in each speed zone for a male Touch player who played in a Mixed grade (NZ representative). He spent 78% of the total duration of the game in speed zone 1 – stationary and, or walking (less than 6 $km.h^{-1}$) this is within the average for a male Touch player who plays in a Mixed grade (see Table 6). Note that this player only spent 1% of the game duration in speed zone 4 – sprinting (above 18 $km.h^{-1}$). Although, this may seem very small again it is within the average for a male Touch player who plays in a Mixed grade (see Table 6).



Zone	Lower	Upper	Time	%	Entries
1	0.0 km/h	6.0 km/h	00:38:24	78.0%	90
2	6.0 km/h	12.0 km/h	00:06:52	14.0%	112
3	12.0 km/h	18.0 km/h	00:03:20	6.8%	59
4	18.0 km/h	300.0 km/h	00:00:36	1.2%	17

Figure 8: Game movement times within in each speed zone during a competition Touch game for a male elite Touch player who plays in a Mixed grade.

Figure 9 illustrates the percentage time spent in each speed zone for a female Touch player who played in a Mixed grade (NZ representative). She spent 77% of the total duration of the game in speed zone 1 – stationary and, or walking (less than 6 $km.h^{-1}$) this is within the average for a female Touch player who plays in a Mixed grade (see Table 6). Note that this player only spent 1% of the game duration in speed zone 4 – sprinting (above 18 $km.h^{-1}$). Although, this may seem very small again it is within the average for a female Touch player who plays in a Mixed grade (see Table 6).

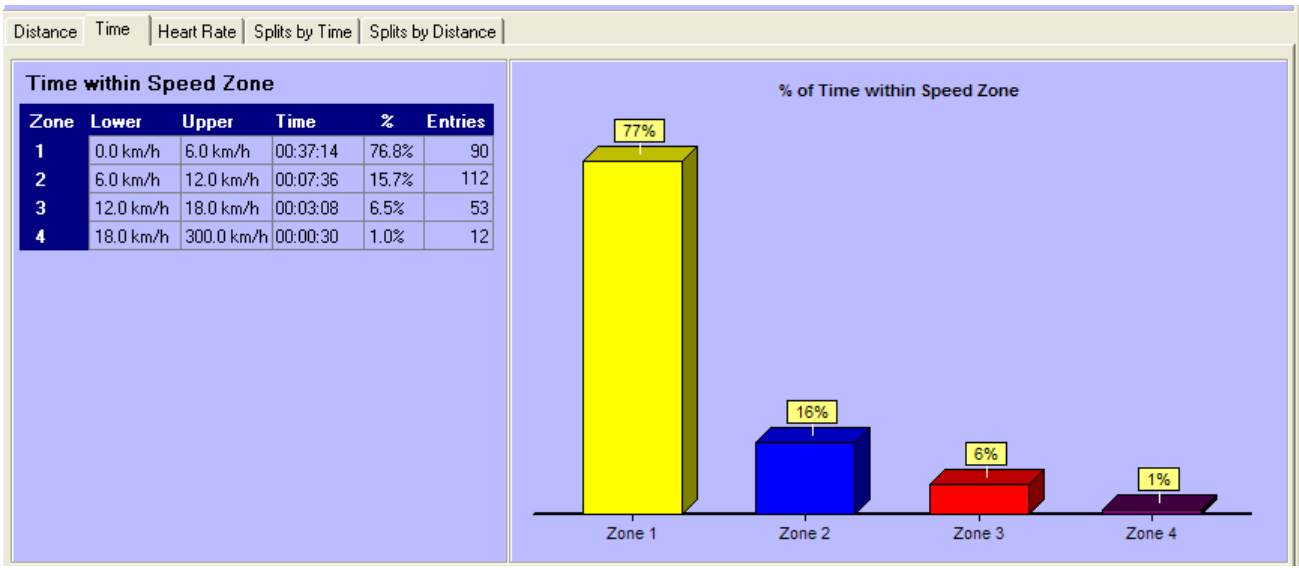


Figure 9: Game movement times within each speed zone during a competition Touch game for a female elite Touch player who plays in a Mixed grade.

APPENDIX 1B:
GAME MOVEMENT PERFORMANCE OF NZ REPRESENTATIVE TOUCH PLAYERS
"Distances travelled in each speed zone and maximum speed during a game"

Figure 10 is an example of game movement distances travelled in each speed zone for a male Touch player in a Men's only grade (NZ representative). He travelled a total distance of ~3.70 km during the duration of game (includes 3-minute half time interval), this is higher than the average male Touch player who plays in a Men's only grade (see Table 6). His maximum speed during the game reached 26.9 km.h^{-1} in speed zone 4 – sprinting (above 18 km.h^{-1}), this is higher than the average male Touch player who plays in a Men's only grade (see Table 6). This player travelled the greatest distance 69% (~2.55 km) during the game in speed zone 1 and 2; either walking, power walking or jogging (low intensity <12 km.h^{-1}) and only 31% (~1.15 km) in speed zone 3 and 4; running and sprinting (high intensity >12 km.h^{-1}). These are all higher than the average male Touch player who plays in a Men's only grade (see Table 6).

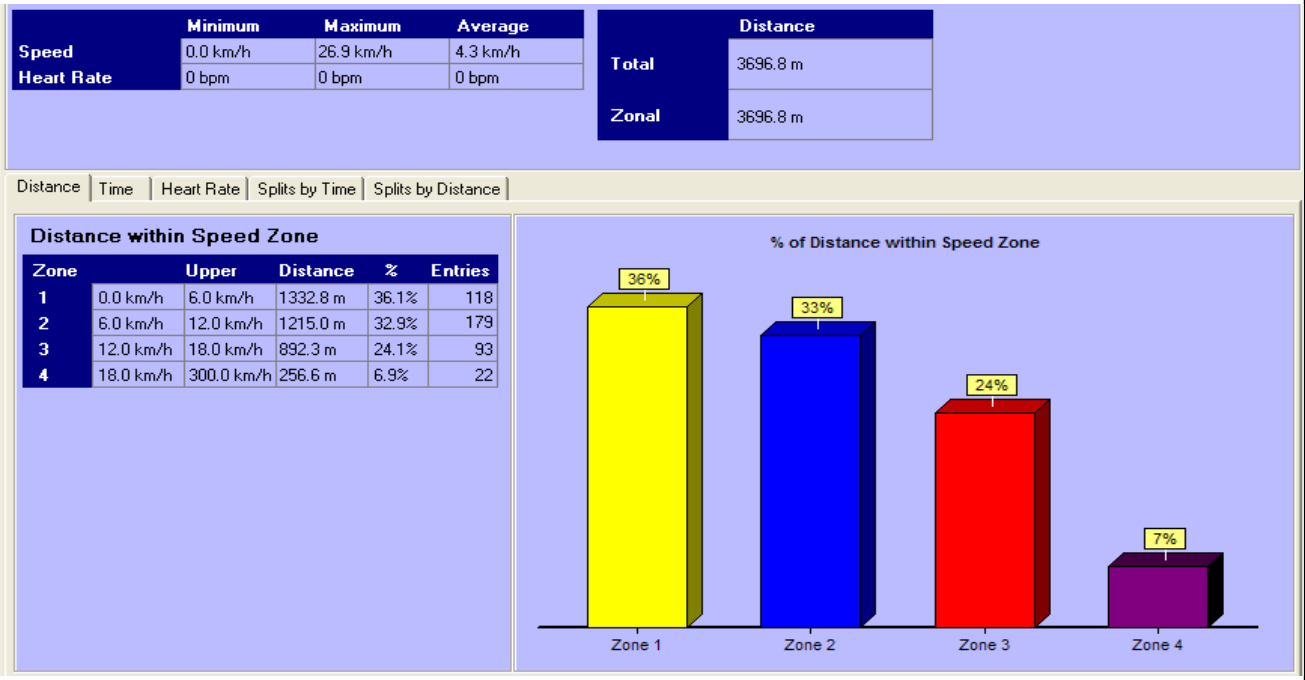
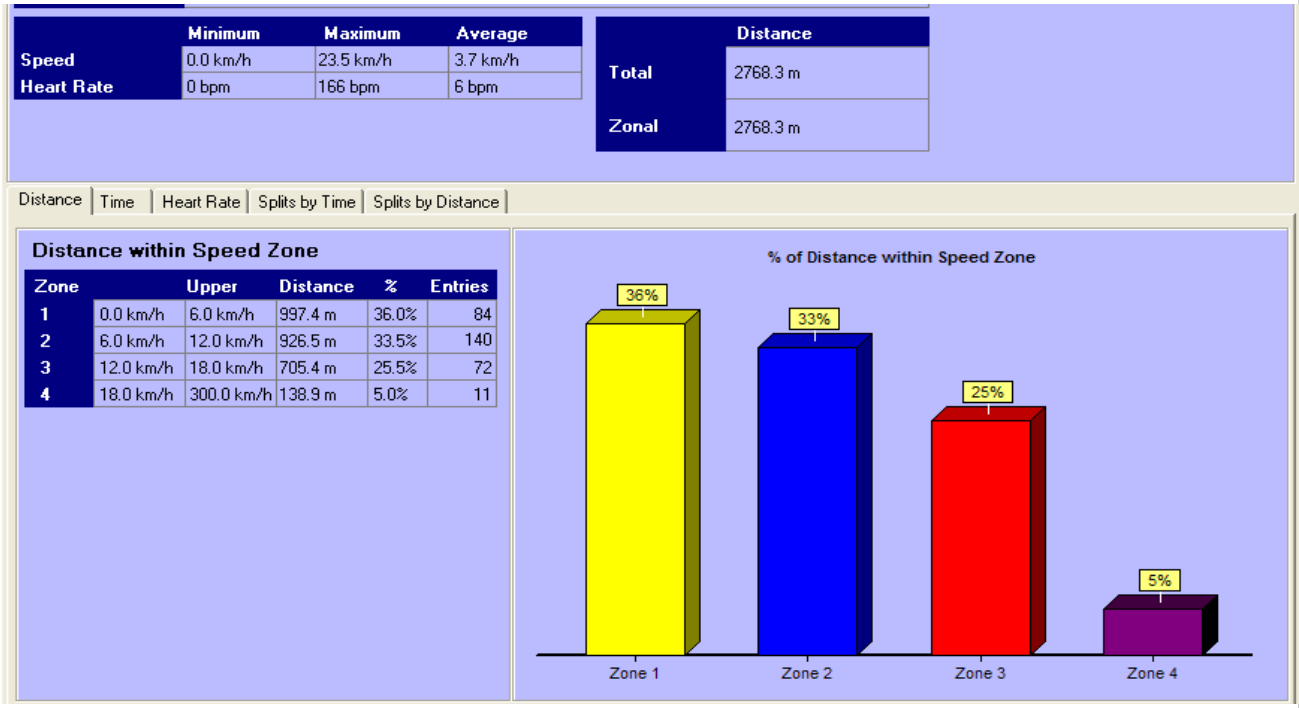


Figure 10: Game movement distance travelled within each speed zone during a competition Touch game for a male elite Touch player who plays in a Men's only grade.

Figure 11 is an example of game movement distances travelled in each speed zone for a female Touch player (NZ representative). She travelled a total distance of ~2.77 km during the duration of game (includes 3-minute half time interval). Her maximum speed during the game reached 23.5 km.h^{-1} in speed zone 4 – sprinting (above 18 km.h^{-1}). This player travelled the greatest distance 69.5% (~1.92 km) during the game in speed zone 1 and 2; either walking, power walking or jogging (low intensity <12 km.h^{-1}) and only 30.5% (~0.84 km) in speed zone 3 and 4; running and sprinting (high intensity >12 km.h^{-1}). These are all within the average for a female Touch player who plays in a Women's only grade (see Table 6).



	Minimum	Maximum	Average
Speed	0.0 km/h	23.5 km/h	3.7 km/h
Heart Rate	0 bpm	166 bpm	6 bpm

	Distance
Total	2768.3 m
Zonal	2768.3 m

Distance | Time | Heart Rate | Splits by Time | Splits by Distance

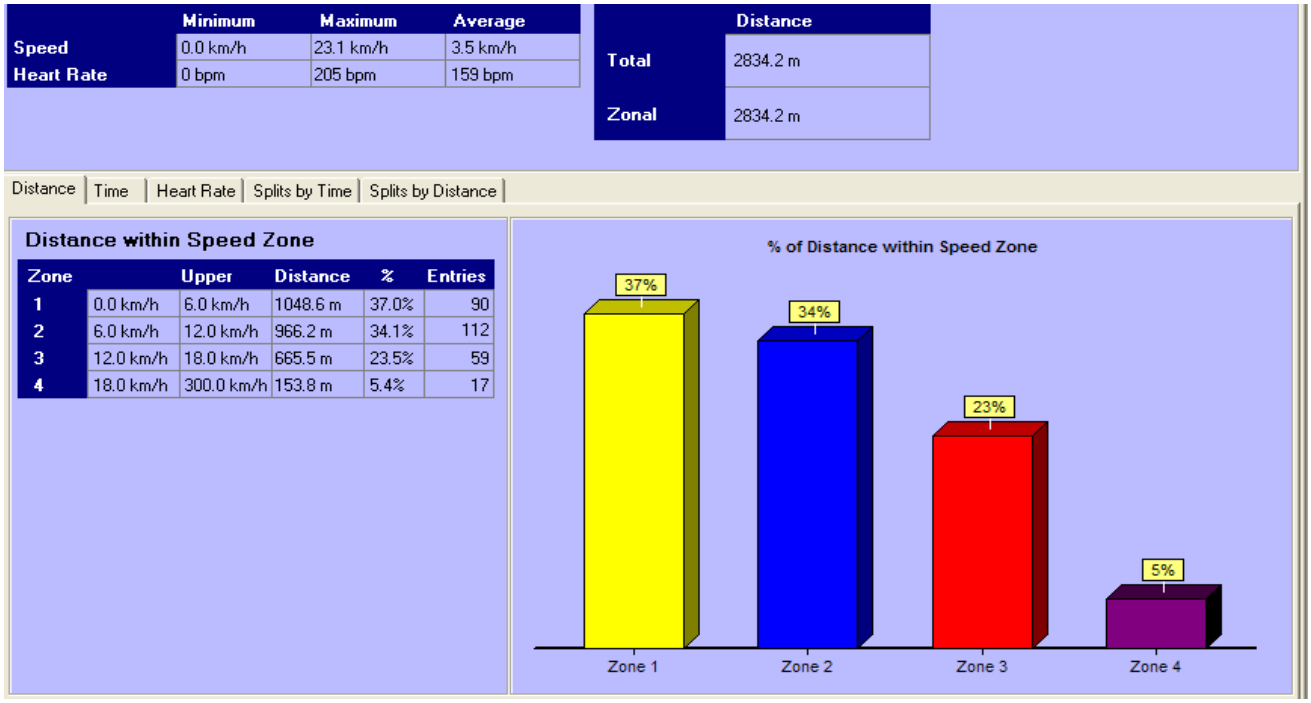
Distance within Speed Zone

Zone		Upper	Distance	%	Entries
1	0.0 km/h	6.0 km/h	997.4 m	36.0%	84
2	6.0 km/h	12.0 km/h	926.5 m	33.5%	140
3	12.0 km/h	18.0 km/h	705.4 m	25.5%	72
4	18.0 km/h	300.0 km/h	138.9 m	5.0%	11

Figure 11: Game movement distance travelled within each speed zone during a competition Touch game for a female elite Touch player who plays in a Women's only grade.

Figure 12 is an example of game movement distances travelled in each speed zone for a male Touch player who plays in a Mixed grade (NZ representative). He travelled a total distance of ~2.83 km during the duration of game (includes 3-minute half time interval); this is within the average for a male Touch player who plays in a Mixed grade (see Table 6). His maximum speed during the game reached 23.1 km.h^{-1} in speed zone 4 – sprinting (above 18 km.h^{-1}), this is within the average for male Touch player who plays in a Mixed grade (see Table 6). This player travelled the greatest distance 71.1% (~2.01 km) during the game in speed zone 1 and 2; either walking,

power walking or jogging (low intensity <12 km.h^{-1}) and only 28.9% (~0.82 km) in speed zone 3 and 4; running and sprinting (high intensity >12 km.h^{-1}). These are all within the average for a male Touch player who plays in a Mixed grade (see Table 6).



	Minimum	Maximum	Average
Speed	0.0 km/h	23.1 km/h	3.5 km/h
Heart Rate	0 bpm	205 bpm	159 bpm

	Distance
Total	2834.2 m
Zonal	2834.2 m

Distance | Time | Heart Rate | Splits by Time | Splits by Distance

Distance within Speed Zone

Zone		Upper	Distance	%	Entries
1	0.0 km/h	6.0 km/h	1048.6 m	37.0%	90
2	6.0 km/h	12.0 km/h	966.2 m	34.1%	112
3	12.0 km/h	18.0 km/h	665.5 m	23.5%	59
4	18.0 km/h	300.0 km/h	153.8 m	5.4%	17

Figure 12: Game movement distance travelled within each speed zone during competition game for a male elite Touch player who plays in a Mixed grade.

Figure 13 is an example of game movement distances travelled in each speed zone for a female Touch player who plays in a Mixed grade (NZ representative). She travelled a total distance of ~2.89 km during the duration of game (includes 3-minute half time interval); this is within the average for a female Touch player who plays in a Mixed grade (see Table 6). Her maximum speed during the game reached 25.6 km.h^{-1} in speed zone 4 – sprinting (above 18 km.h^{-1}), this is slightly higher than the average for a female Touch player who plays in a Mixed grade (see Table 6). This player travelled the greatest distance (~2.13 km) during the game in speed zone 1 and 2; either walking, power walking or jogging (low intensity <12 km.h^{-1}) and only 26.4% (~0.76 km) in speed zone 3 and 4; running and sprinting (high intensity >12 km.h^{-1}). These are all within the average for a female Touch player who plays in a Mixed grade (see Table 6).

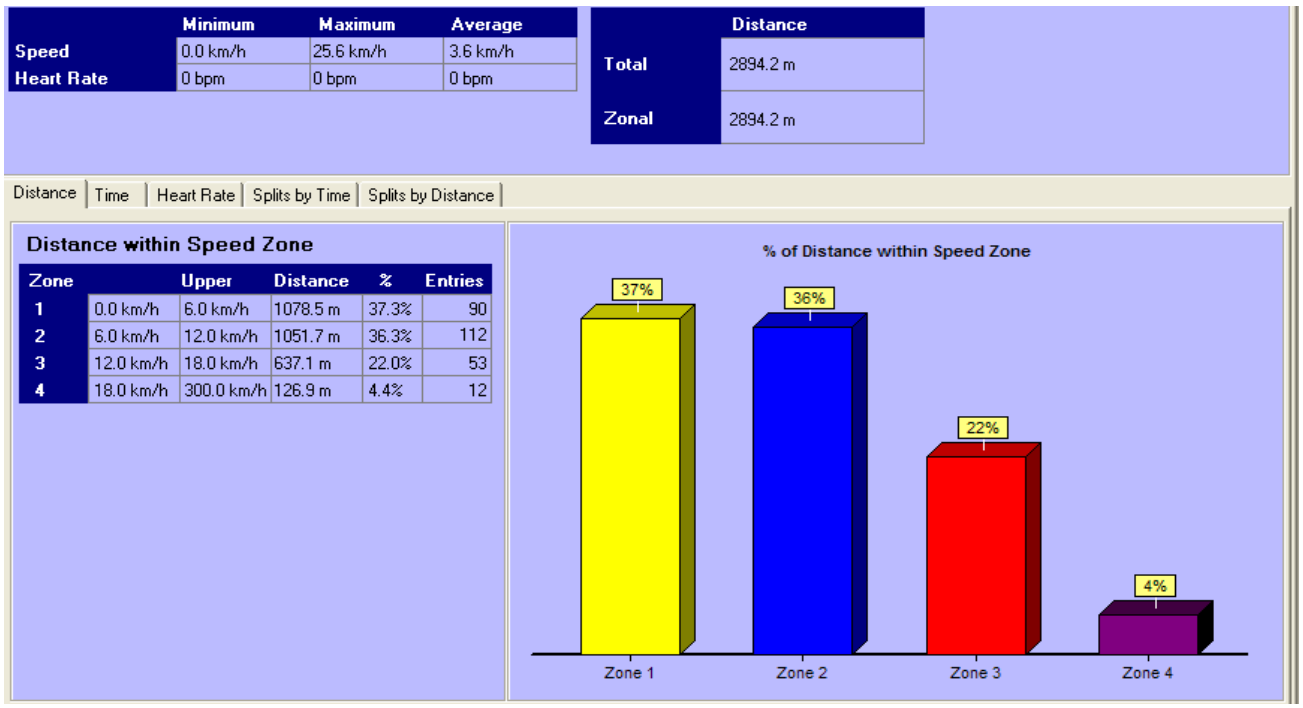


Figure 13: Game movement distance travelled within each speed zone during competition game for a female elite Touch player who plays in a Mixed grade.

APPENDIX 2: PARTICIPATION INFORMATION SHEET

Participant Information Sheet

Invitation

We are looking for 50 elite Touch players to take part in this masters thesis research entitled:

"Time-Motion Analysis and Physiological Profile of Elite New Zealand Touch Players During Competition"

AUCKLAND UNIVERSITY OF TECHNOLOGY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

What is the purpose of the study?

- The purpose of this study is to analyse the movement patterns and associated physiological responses during the game of Touch football. Such an analysis will allow a better understanding of the demands of the game and hence parameters for more sport specific movement assessment protocols and training programmes.

Can I join the study?

- To participate in this study you must be aged between 18-35 years, be currently competing at an elite level and playing Open grade at the Touch New Zealand nationals in Palmerston North.
- You must be free from injury (including sprains or strains) and bone fractures or breaks at the commencement of the study (mid February).

What happens in the study?

This project is divided into two parts. Part one will occur within two weeks prior to the Touch New Zealand nationals. Part two will occur at the Touch New Zealand nationals. The assessments are described in greater detail below.

- **Part one** - consists of an athlete briefing and two assessments, and will take about 60-minutes to complete at a venue near your Touch Association.

Athlete briefing	Speed assessment	Rest 5 min	Aerobic assessment
Familiarisation with procedures and equipment.	3 x 30 m sprints		20 m Multi-stage shuttle run test (Beep Test)

Figure 1: An outline of session one.

- **Part two** – at the Touch New Zealand Nationals' ***one*** of your games (either on day one, two or three - not finals day) will be monitored (See-Figure 2).
- You will be expected to, have a body composition assessment, give three blood lactate concentration samples (taken from a finger prick), wear a light weight position tracking unit and will be video-taped during this ***one*** game.

30min Prior to game	20min Prior to game	Warm up with team as usual	During game	Immediately After game (Within 5min)	20min After game
1. Anthropometry assessments Body Composition (height, weight, leg length and sum of 8 skinfolds)	1. Lactate sample #1 2. Set up GPSports tracking unit		GPSports tracking & Video analysis	1. Lactate sample #2 2. Take off GPSports tracking unit	Lactate sample #3

Figure 2: An outline of session two (approximately 1.5hr).

What are the discomforts and risks?

- The risks associated with this study are minimal. However, as with all physical interventions, there is a possibility that harm may occur due to mishaps such as falling, tripping etc.
- There may be some sensation of discomfort associated with the pin prick on the end of your finger (blood lactate concentration sample) but this quickly diminishes.
- As athletes within this study you will have had been training for several months therefore be physically fit and healthy to participate and thus the possibility that injury may occur in minimised.

What are the benefits?

- The benefits to participants in this study are:
  1. All subjects will receive a final report of study findings at their request.
  2. The findings from this study will be used to enhance assessment and conditioning practice, and ultimately your performance.

What compensation is available for injury or negligence?

- Injury experienced during the research will be covered by ACC.

How is my privacy protected?

- All subjects' consent forms and pre-exercise questionnaires will be stored securely. Only researchers directly involved in this study will have access to the documents (John Cronin and Teresa Ogden).
- For the purposes of data collection, analysis and storage, identification codes will be assigned to subjects' data.
- No participants will be named in reports, publications or presentations resulting from this study.

Costs of Participating

- Apart from your time, the there are no costs associated with participating in this study.

Opportunity to consider invitation

- Should you wish to participate and, or if you have questions regarding this study, please contact Teresa Ogden (details below).
- Prior to agreeing to participate you have the opportunity to consult with whanau or bring a support person along with you.

Participant Concerns -

Any concerns regarding the nature of this project should be made in the first instance to the Project Supervisors, John Cronin john.cronin@aut.ac.nz (09 917 9999 ext. 7353) or to Projects Researcher, Teresa Ogden teresa.ogden@gmail.com (0274 858575).

Concerns regarding conduct should be directed to the Executive Secretary, AUTEC, Madeline Banda, *Madeline.banda@aut.ac.nz* (917 9999 ext. 8044).

Approved by the Auckland University of Technology Ethics Committee on 21 January 2004 **AUTEC Reference number** 04/07.

APPENDIX 2: CONSENT FORM

Consent to Participation in Research

This form is to be completed in conjunction with, and after reference to, the AUTEC Guidelines

Title of Project: **Time-Motion Analysis and Physiological Profile of Elite New Zealand Touch Players During Competition.**

Project Supervisors: **John Cronin**

Researcher: **Teresa Ogden**

- I have read and understood the information provided about this research project.
- I have had an opportunity to ask questions and to have them answered.
- I understand that this project will be video-taped.
- I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- If I withdraw, I understand that all relevant tapes and transcripts, or parts thereof, will be destroyed.
- I agree to take part in this research.

Participant signature: .....

Participant name: .....

Date: .....

Project Supervisor Contact Details:

Mail John Cronin
Auckland University of Technology
Division of Sport and Recreation
Private Bag 92006
Auckland 1020

Telephone (09) 917 9999 ext. 7353

Email john.cronin@aut.ac.nz

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Approved by the Auckland University of Technology Ethics Committee on 21 January 2004 **AUTEC Reference number** 04/07

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