UNIVERSITETET I AGDER

FAKULTET FOR HELSE- OG IDRETTSVITENSKAP

Variation in exercise intensity during typical training drills in youth footballers measured via GPS tracking devices

ESPEN GABRIELSEN JOHNSEN

University of Agder, 2020

Supervisor: Matthew Spencer

PREFACE

Writing my master thesis in the field of sports and exercise performance physiology has been an enjoyable experience. It has given me an increased motivation and passion within in the field of sports science and especially the research part of it. Writing the thesis has both been enjoyable and frustrating with huge ups and downs. It has however confirmed what I already expected which is the fact that I personally enjoy doing research and writing research papers, as such I truly hope I can continue within this field someday.

Working as an independent student has truly been challenging, but it has also taught me a lot about working closely with my appointed supervisors. To Matt; Thank you for your guidance during this process. Your dedication towards my project has been truly appreciated, you have guided me throughout this process with a calm and steady hand, and all your feedback and knowledge have been of huge importance. To Live; Thank you so much for your involvement in the data analysis process and for being extremely patient during this whole process, I'm not sure if this thesis would have ever seen the light of day if it weren't for your help!

To my fellow students, thank you for an amazing two years. It has been a true pleasure working with you all during this time.

At last I want to extent my gratitude to my family and friends for their support during this process. Especially my dad for always giving me advice and being there in my biggest moments of frustration, and Marthe for her support and understanding during this period of time.

May 2020

Contents

I. ABBREVIATIONS

SSG	Small Sided games
GPS-TD	GPS-tracking devices
IMU	Inertial measurement units
Pcr	Creatine phosphate
ATP	Adenosine triphosphate
Hz	Hertz
CV	Coefficient of variation
CI	Confidence interval
HR	Heart rate
RPE	Rating of perceived exertion
LA	Blood Lactate
HR_{max}	Maximal heart rate
HIE	High intensity event
SD	Standard deviation

II. ABSTRACT

PURPOSE: The present study aims to investigate the between-athlete and within-athlete variation in intensity occurring during various small-sided games (SSG) formats to determine their relevance within soccer specific drills.

METHODS: 19 youth male football players (age: 14.0 ± 1.0 y, height: 1.6 ± 7.4 m, body mass: 54.5 ± 7.5 kg) were monitored during an 8-week period two times per week. The first two weeks consisted of a familiarization phase followed by 6 weeks of monitoring. Subjects performed a standardized warmup prior to completing various formats of SSG games (3 vs. 3 and 6 vs. 6). Each SSG were performed with a duration of 2 x 4 minutes interspersed with 3 minutes rest. All players were equipped with a player tracking device (OptimEye S5, Catapult Sports, Australia) consisting of both a GPS-TD collecting data at 10 Hz and an IMU measurement unit collecting data at 100 Hz. Selected measurements include Playerload^{TM} (accelerometer-based measurement of external training load), Playerload^{TM} 2D (excluding vertical axis) High intensity events (HIE) which is the combined measurement of accelerations, decelerations, and changes of direction, Total distance, meter per minute and low intensity running (LIER) which is running performed at speeds lower than 11.0 km/h

RESULTS: Significant variation ($p < 0.05$) in intensity was observed for within-athlete variation when Playerload^{TM}, Playerload^{TM} 2D, HIE total and LIER when 3 vs. 3 were compared to 6 vs. 6. A larger variation in intensity between-athlete was observed for Playerload^{TM}, Playerload^{TM} 2D, total distance, meter/min and LIER when 3 vs. 3 was compared to 6 vs. 6. 6 vs. 6 demonstrated a larger variation for HIE medium, high and total when compared to 3 vs. 3.

CONCLUSION: During various formats of SSG training drills 3 vs. 3 demonstrates larger variation in intensity when compared to 6 vs.6. A higher number of accelerations, decelerations and changes of direction is likely to occur during 3 vs. 3

KEY WORDS: Young male footballers, GPS-tracking devices, Small-sided games, training drills, training intensity

III. ABSTRACT IN NORWEGAIN

HENSIKT: Studiets hensikt er å undersøke utøveres variasjoner i intensitet, individuelt og som del av lag, i ulike typer av småspill i treningssammenheng. Hensikten med undersøkelsen er å forsøke å fastslå hvilken relevans småspill har som treningsdriller i fotball.

METODE: 19 unge fotball spillere (alder: 14.0 ± 1.0 år, høyde: 1.6 ± 7.4 m, kroppsvekt: 54.5 ± 7.5 kg) ble observert to ganger per uke over en 8 ukers-periode. De to første ukene bestod av en familiseringsfase etterfulgt av 6 uker med monitorering. Utøverne startet hver økt med en standardisert oppvarming før de utførte to ulike formater av småspill (3 mot 3 og 6 mot 6). Hvert småspill hadde en varighet på 2 x 4 minutt med 3 minutt hvile mellom hvert intervall. Alle spillerne brukte en GPS-enhet (OptimEye S5, Catapult Sports, Australia) som bestod av både en GPS-enhet som samlet data med en frekvens på 10 Hz samt en IMU enhet som samlet data på 100 Hz. Målte variabler inkluderer Playerload^{TM} (en akselerasjons basert variabel som måler ekstern treningsbelastning) Playerload^{TM} 2D (ekskluderer måling av vertikal akse), High intensity events (HIE) som er det kombinerte målet av akselerasjon, deselerasjon og retningsforandringer, total distanse (TD), meter per minutt (m/min) og lav intensitets løping (LIER) som er løping utført på en hastighet lavere enn 11.0 km/t.

RESULTATER: Signifikant variasjon ($p < 0.05$) i intensitet ble observert for Playerload^{TM}, Playerload^{TM} 2D, HIE total and LIER innad i laget når 3 mot 3 ble sammenlignet med 6 mot 6. Det ble observert en større variasjon i intensitet mellom utøverne når Playerload^{TM}, Playerload^{TM} 2D, TD, M/min and LIER når 3 mot 3 ble sammenlignet med 6 mot 6. Imidlertid demonstrerte 6 mot 6 en større variasjon for HIE medium, HIE høy, og HIE total når den var sammenlignet mot 3 mot 3.

KONKLUSJON: Når ulike småspill blir gjennomført i treningssammenheng demonstrerer 3 mot 3 høyere variasjon i intensitet sammenlignet med 6 mot 6. Det er sannsynlig at ett høyere antall akselerasjoner, deselerasjoner og retnings forandringer forekommer under gjennomførelsen av 3 mot 3.

NØKKELORD: Unge fotballspillere, GPS måleenheter, småspill i fotball, trenings driller, trenings intensitet

IV. STRUCTURE OF THE THESIS

The following thesis is presented in three parts. Part 1 represents the theoretical framework and is written as a literature review containing an introduction, a theory chapter followed by the methodology and a discussion of the methodology applied to the research project. Part 2 represents the actual research paper which is written after the submission guidelines of "International Journal of Sports Physiology and Performance". Due to the natural course of the writing process, results of the study are only presented in the research paper. It is important to highlight that according to the guidelines of International Journal of Sports Physiology and Performance tables and figures should be presented after the article and in the article it should only be marked where the table is to be inserted. The author has however chosen to insert the tables in the article for the purpose of making it easier to read for the reader. Part 3 contains any relevant appendices necessary for the reader.

Part 1:

Theoretical Background and Methodology

Espen Gabrielsen Johnsen

University of Agder

Table of contents

1.0 INTRODUCTION

Football is arguably one of the most popular sports in the world and researchers, coaches and support staff are always trying to broaden their understanding of the complex nature of the game. However, there are still many uncertainties regarding the physiological and biomechanical aspects when trying to facilitate optimal performance and training (Aguiar, Botelho, Lago, Maças, & Sampaio, 2012; Stølen, Chamari, Castagna, & Wisløff, 2005). Football is a complex game performed at various exercise intensities which includes both low, medium and high intensities displayed in movements such as running, walking and sprinting (Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010; Dwyer & Gabbett, 2012; Scott, Lockie, Knight, Clark, & de Jonge, 2013). In addition to the locomotive movements listed above, players are exposed frequently to non-linear movements such as tackles, turns, headers, dribbles, passing the ball, kicking and jumping during competitive matches and training (Dalen, Jørgen, Gertjan, Havard, & Ulrik, 2016; Iaia, Ermanno, & Bangsbo, 2009). High intensity movements such as acceleration, decelerations and changes of direction also occur frequently which further places increased physical demands on the players (Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010).

In an attempt to improve the players physical capacity to improve performance over this broad spectrum of movements, coaches and practitioners try to replicate the movements occurring in competitive matches, within training drills, such as the use of small-sided games (SSG) (Hill-Haas, Dawson, Coutts, & Rowsell, 2009). SSG is a training tool which has been developed to concurrently develop players tactical, physical and technical abilities simultaneously (Casamichana, Castellano, & Castagna, 2012; Dellal et al., 2012). SSG are games which are played on limited pitch areas, fewer players, sometimes using modified rules and with or without goal keepers (Dellal et al., 2012; Halouani, Chtourou, Dellal, Chaouachi, & Chamari, 2017; Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011; Hill-Haas et al., 2009).

In recent years there has been an increase in the use of player monitoring devices such as GPS tracking devices (GPS-TD) and inertial measurement units (IMU) (Akenhead, French, Thompson, & Hayes, 2014; Akenhead & Nassis, 2016; Luteberget, Holme, & Spencer, 2017). This technology has proven useful to monitor and analyze athletes training load (Akenhead et al., 2014; Boyd, Ball, & Aughey, 2011; Luteberget et al., 2017). Several studies have also investigated player monitoring and training load in football with many of these studies comparing the physical demands occurring during SSG and competitive matches by measuring the internal and external workload during both SSG and competitive matches (Akenhead, Hayes, Thompson, & French, 2013; Casamichana & Castellano, 2010; Casamichana et al., 2012; Castellano, Casamichana, & Dellal, 2013; Dalen et al., 2016; Dellal et al., 2012; Halouani et al., 2017; Hill-Haas et al., 2009).

1.1 RESEARCH QUESTION AND AIM OF RESEARCH PROJECT

The present study aims to investigate the variation in intensity occurring during the various small sided games formats in order to provide a more accurate and detailed picture of their relevance in soccer specific drills. This study will investigate the variation in intensity for each session, both for the within-athlete and between-athlete variation in two various SSG formats (3 vs. 3, 6 vs. 6). It is postulated that the format containing the largest pitch area and the largest number of players will demonstrate the highest variation in intensity. The authors are, to this date, unaware of any previous research investigating the within-athlete variation in intensity during multiple sessions of SSG, as such this will be a new contribution to the field.

2.0 THEORETICAL BACKGROUND

2.1 TRAINING LOAD AND PLAYER MONITORING

Training load and player monitoring is today being used to determine the physiological state of the individual player, with GPS-TD and IMU devices practitioners can today more accurately determine a players individual training and match load to make decisions or assumptions regarding a players recovery, performance and injury risk (Akenhead et al., 2014; Boyd et al., 2011; Chambers, Gabbett, Cole, & Beard, 2015; Malone, Lovell, Varley, & Coutts, 2017). The physiological demands of football requires an accurate and objective measurement of the activities occurring in matches and training (Dalen et al., 2016). Player monitoring is able to provide us with such details, and the use of devices such as GPS-TD integrated with IMUs has the potential to provide great detail of the players external loading during football activities (Dalen et al., 2016).

Training load is usually classified as either internal or external load (Impellizzeri, Marcora, & Coutts, 2019). External load is classified as the load the athlete is being exposed to as the result of the activity performed, this may come as a result of the training program and is typically prescribed to achieve the desired physiological response (Impellizzeri et al., 2019). In football the external load would be quantified as total distance covered, total number of sprints, total accelerations, decelerations and changes of directions and total distance covered at high intensity etc. (Akenhead & Nassis, 2016; Impellizzeri et al., 2019). Internal load is the result of the external load and is the physiological response the body initiates to manage the external load it is being exposed to, i.e. increased heart rate (HR) , increased blood flow, increased respiration etc. (Impellizzeri et al., 2019). The use of devices such as GPS-TD and IMUs provide coaches and researchers with comprehensive data which can be used to determine the athletes total external training load (Akenhead & Nassis, 2016). Whereas the athletes internal load is typically measured through HR, rating of perceived exertion RPE and blood lactate concentration (LA) (Halson, 2014).

2.1.1 EXTERNAL LOADING DURING FOOTBALL SPECIFIC ACTIVITIES

This section will briefly discuss external loading movements relevant to football.

SPRINT AND HIGH INTENSITY RUNNING:

The ability to perform high speed sprints and high intensity running is believed to be an important factor for optimal performance (Haugen, Tønnessen, & Seiler, 2013). It appears that 90% of sprints performed by professional football players were shorter than 5 seconds and only 10% being longer than 5 seconds, furthermore the average number of sprints performed during a football match were approximately 11 when sprints were defined as running faster than 24.0 km/h (Andrzejewski, Chmura, Pluta, Strzelczyk, & Kasprzak, 2013). The contribution from the energy systems is likely to be approximately 55% from creatine phosphate (PCr) degradation which is the breakdown of PCr to produce adenosine triphosphate (ATP), 32% from anaerobic glycolysis which is the breakdown of carbohydrates to form glucose to enable glucose to produce ATP, and lastly 10% from ATP already stored in the body and 3% from the aerobic system (Majumdar & Robergs, 2011; Spencer, Bishop, Dawson, & Goodman, 2005). It is therefore likely that sprints occurring during team sports requires a considerable amount of energy (ATP) via anaerobic glycolysis and PCr degradation and that it heavily relies on anaerobic power rather than the aerobic energy system (Spencer et al., 2005; Van Praagh & Doré, 2002).

REPEATED SPRINT ABILITY

Football is a team sport which taxes both the aerobic and aerobic energy transfer systems due to short high-intensity activities interspersed with longer medium and low intensity running combined with walking (Bradley et al., 2010; Dwyer & Gabbett, 2012; Scott et al., 2013). Athletes are required to perform repeated sprints of maximal or near maximal intensity during a football match (Spencer et al., 2005), A traditional definition of repeated sprint efforts or typically intense period of repeated sprints is a minimum of 3 sprints with a mean recovery duration of less than 21 seconds between sprints (Spencer et al., 2004). A single bout of repeated sprints have been demonstrated to involve as few as 2 sprints and as many as 7 (Gabbett, Wiig, & Spencer, 2013). Furthermore, it seems that the ability to perform repeated sprints is maintained through an entire match despite the intense intermittent nature of football games (Gabbett et al., 2013). It appears that there is a reduced contribution from anaerobic glycogenolysis during repeated sprints, this can be explained via an increase in the contribution from the aerobic system (Spencer et al., 2005). Muscle biopsies taken after football matches reported 53% depletion of muscle glycogen stores when compared to pre exercise values, demonstrating that there is a depletion of muscle glycogen which could further explain the reduced contribution from glycogen to produce energy during football specific activities (Krustrup et al., 2004).

MEDIUM AND LOW INTENSITY RUNNING

As football demonstrates periods of high intensity where considerable levels of blood lactate is produced, there is a need of periods of lower intensity movements to recover (Stølen et al., 2005). Furthermore due to the intermittent nature of the game and how it’s played, it’s unlikely that every player is constantly working at a high intensity as that would require them to constantly be involved with the ball for 90 minutes (Stølen et al., 2005). Players spend most of the time at 80-90% of $v02_{max}$ where the removal of lactate is equal to its production (Stølen et al., 2005) and with a hearth rate rarely below 65% of HR_{max} suggesting that the blood flow to the leg muscles is continuously higher than at rest (Bangsbo, 2014). It is therefore likely that players spend most of the time at medium and lower intensities when they are moving around the field without being involved with the ball or when they are recovering from high intensity periods (Stølen et al., 2005). It has also been highlighted by more recent research that players spend around 70% of the time during a match at low and medium intensities (Bangsbo, 2014). It is however important to emphasize that due to the very intermittent nature of the game there has been little focus on heart rate sones or lactate thresholds within team sports the last 10 years and that it is discussed during this section to provide a broader picture of the external loading occurring during competitive matches and training.

ACCELERATIONS, DECELERATIONS, CHANGE OF DIRECTION

Players perform numerous accelerations, decelerations and changes of directions due to the need to perform short sprints, jumps, duel play, tackles, dribbles and other football specific movements (Bradley et al., 2010; Dalen et al., 2016; Stølen et al., 2005). Accelerations and decelerations are therefore a vital component of football matches (Osgnach et al., 2010). Accelerations are classified as the rate of change of velocity that allows a player to reach maximum velocity in a minimum of time (Little & Williams, 2005). Decelerations are required after any sprint performance or acceleration to slow down the body's center of mass (Hewit, Cronin, Button, & Hume, 2011). When playing team sports, it may also occur as a result of other players movements or interactions which requires players to react to their movements, causing them to decelerate from various velocities spontaneously (Hewit et al., 2011). The objective of decelerations is to decrease the body's momentum by applying as much force during a short duration in order to achieve a full stop of the body's momentum (Hewit et al., 2011). Successful acceleration has been demonstrated to be largely dependent on the ability to apply mechanical horizontal force (Buchheit et al., 2014). Decelerations are also very common during competitive games and is often followed after accelerations, as such they will also contribute to the total load of the players during competitive games and training (Dalen et al., 2016). Change of direction is something that is usually preplanned and does not entail a reaction to a stimulus, whereas agility is more of a reaction to a stimulus, yet these two movements share a similar component which is rapid acceleration to change the direction of the movement pattern performed (Young, Dawson, & Henry, 2015). To summarize players perform on average approximately 76 accelerations and 54 decelerations during a competitive game (Dalen et al., 2016). Furthermore it seems that acceleration contributes 7-10% of the total player load for football players during competitive games and that deceleration contributes 5-7% (Dalen et al., 2016). And that even at low running speeds, accelerations and decelerations elicit high metabolic demands (Osgnach et al., 2010), furthermore players in the premier league performs approximately 700 turns during a game (Bloomfield, Polman, & O'Donoghue, 2007).

2.1.2 GPS-TRACKING DEVICES

The use of global positioning systems or GPS-TD is now a technology which is implemented in professional clubs across a broad specter of different sports. This technology allows practitioners and coaches to monitor and measure different locomotive movement patterns during competitive matches and training (Akenhead et al., 2014; Akenhead & Nassis, 2016). GPS-TD is usually manufactured with a sampling rate of 1.5 and 10 hertz (Hz) (Cummins, Orr, O'Connor, & West, 2013). Hz is a sampling rate which basically indicates the speed at which the unit gathers data, this is determined through the number of times per second that the device and GPS satellite communicate to establish the location of the device (Cummins et al., 2013; Larsson, 2003). A higher Hz or sampling rate is associated with a more accurate measurement of movements (Cummins et al., 2013).

When assessing the reliability of a 1 and 5 Hz GPS-TD one study found that a standard error when performing a standing start 10 meter sprint was 32.4% for 1 Hz device and 30.9% for the 5 Hz device (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010)**.** In another article some authors found a standard error of 10.9% during a 15 m sprint when using a 10 Hz GPS-TD (Aughey, 2011). These findings indicate that both the 1 and 5 Hz GPS-TD may actually be unable to track high intensity movements accurately, GPS-TD has however demonstrated a good reliability to track movement patterns at lower speeds and over increased distances (Cummins et al., 2013; Scott, Scott, & Kelly, 2016). GPS-TD has however demonstrated a poor reliability to track movements of short duration, high-speed or high-intensity straight line running and movements which includes rapid changes of direction (Cummins et al., 2013; Scott et al., 2016). However, the validity and reliability of GPS-TD would increase for movement patterns occurring in team sports when the units sampling rate is greater than 10 Hz, but there are still some issues regarding validity and accuracy when measuring higher intensity movements (e.g. distance > 7 m/s) (Cummins et al., 2013; Scott et al., 2016). The validity and reliability was measured by a group of authors, their findings indicated that the GPS-TD appears to be acceleration-dependent and that greater accelerations reduced the validity and reliability of measuring accelerations over $4ms^{-2}$ (Akenhead et al., 2014).

2.1.3 INERTIAL MEASUREMENT UNITS

IMU is a device which is embedded with a tri-axial accelerometer, a gyroscope and a magnetometer which are all collecting data at 100 Hz (Luteberget, Trollerud, & Spencer, 2018). The information which is obtained from IMUs is not dependent on GPS signals and can therefore be used indoors as well as outdoors (Luteberget et al., 2018). Furthermore IMUs have been developed in recent years to be able to provide additional information related to external loading during training and competitive matches (Luteberget et al., 2017).

IMUs have demonstrated good reliability and good accuracy when measuring certain sport specific movements within team sports (Boyd et al., 2011; Luteberget et al., 2018; Simons & Bradshaw, 2016; Wundersitz, Gastin, Richter, Robertson, & Netto, 2015). One study investigated the reliability of inertial movement analysis obtained from the IMU device within Catapult Sports OptimEye S5 by comparing the measured variables between to identical devices both placed on the upper back (Luteberget et al., 2017). The results demonstrated good reliability when the inertial movement analysis counts were displayed as total (CV: 1.8, 90% CI: 1,8-2.1), high (CV: 5.3, 90% CI: 4.7-6.2) or high/medium (CV: 3.1, 90% CI: 2.7-3.6) (Luteberget et al., 2017). A moderate reliability was found for forward (CV: 6.6, 90% CI: 5.8-7.6) , backward (CV: 5.5, 90% CI: 4.8-6.3) and left (CV: 4.1, 90% CI: 3.7-4.5) and right (CV:3.9, 90% CI: 3.4-4.5) lateral counts in the field, however when the direction bands were divided into intensity bands the reliability decreased considerably (Luteberget et al., 2017). Based on these findings the authors suggested that intensity bands should be categorized into wider intensity thresholds such as medium/high to reduce variation (Luteberget et al., 2017). Caution should also be taken when dividing inertial movement analysis counts into directional bands, especially when they are categorized into intensity bands (Luteberget et al., 2017).

2.1.5 CATAPULT SPORTS OPTIMEEYE S5

OptimEye S5 is a device manufactured by Catapult Sports (Melbourne, Australia), it is embedded with both a GPS-TD collecting at 10 Hz and a IMU unit embedded with an accelerometer, magnetometer and gyroscope with a sample rate of 100 Hz (Catapult Sports, Melbourne, Australia).

2.1.6 PLAYERLOAD^{TM}

Playerload^{TM} is an accelerometer based measurement of external load in team sport athletes, it is furthermore a workload variable which is based on the information collected by the IMUs (Luteberget et al., 2017; Luteberget et al., 2018). Playerload^{TM} uses a specific algorithm within the software to automatically convert the raw data collected from the device into usable metrics that are instantly ready for analysis by the user (Luteberget et al., 2017). Playerload^{TM} is calculated through an instantaneous rate of change of acceleration which is divided by a scaling factor, Playerload^{TM} is expressed as the square root of the sum of the square instantaneous rates of change in acceleration in each of the three vectors known as X, Y and Z and is divided by

100 (Boyd et al., 2011). The formula for how it is calculated by the catapult S5 device is stated below:

a_y is forward accelerometer, a_x is sideways accelerometer and a_z is vertical accelerometer (Boyd et al., 2011):

Playerload™ = $$\sqrt{\frac{(a_{y1} - a_{y-1})^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}{100}}$$

Playerload™ has demonstrated good reliability as a workload variable when detecting real differences in handball, furthermore the between device reliability for Playerload™ has been demonstrated as good (CV: 0.9, 90% CI: 0.8-1.1) (Luteberget et al., 2017). Playerload™ has also been demonstrated to have moderate to high test-retest reliability and can therefore be used to monitor athletes movement patterns during intermittent and multidirectional running (Barrett et al., 2016).

2.1.7 SUMMARY

GPS-TD and IMU devices are today being used to make decisions or assumptions regarding a players recovery, performance and risk of injury (Akenhead et al., 2014; Boyd et al., 2011; Chambers et al., 2015; Malone et al., 2017). The use of these devices allows us to successfully measure the various movement patterns occurring during football specific activities (Dalen et al., 2016). External training load refers to the various loads players are exposed to and is typically movements such as accelerations, decelerations, changes of direction, running and other football specific movements (Akenhead & Nassis, 2016; Impellizzeri et al., 2019). Sprinting and running at high, medium and low intensity, repeated sprints, accelerations, decelerations and changes of direction all play a vital part in the total external load players are exposed of during football specific movements (Dalen et al., 2016; Gabbett et al., 2013; Osgnach et al., 2010; Spencer et al., 2005; Stølen et al., 2005). It is therefore vital to obtain a better understanding of GPS-TD and IMUs ability to quantify both locomotive data and data obtained from IMUs in order to understand the total physical loading of players (Akenhead & Nassis, 2016; Luteberget et al., 2018; Malone et al., 2017). GPS-TD have demonstrated reduced ability to track movements patterns occurring at higher speeds, short durations and on small areas (Cummins et al., 2013; Jennings et al., 2010). However GPS demonstrates good reliability to track movements at lower speeds and over longer distances (Cummins et al., 2013). IMUs have therefore been developed to be able to accurately measure high intensity and sport specific movements (Boyd et al., 2011; Luteberget et al., 2018). However, there is still some concerns regarding the validity of IMUs, and the proper application of these data within team sports and athlete monitoring (Luteberget et al., 2017).

2.2 SMALL-SIDED GAMES PHYSIOLOGY

The main goal of SSG is to improve both tactical and physiological components related to football and match specific activity and to develop and practice skills under fatigue (Gabbett & Mulvey, 2008; Halouani et al., 2017; Hill-Haas et al., 2011; Jones & Drust, 2008). For these reasons, SSGs are thought of as a valuable training tool for developing fitness, technical and tactical components simultaneously rather than isolating each component which maximizes the coaches contact time with the players and thus increasing the efficiency of their training sessions (Dellal et al., 2012; Hill-Haas et al., 2011). Furthermore some studies have suggested that SSGs are a reliable tool in improving aerobic fitness similar to traditional running or interval training (Impellizzeri et al., 2006), and that it appear to be more appealing and motivating for the players due to it being more sport specific than other training methods (Gregson & Drust, 2000; Little, 2009).

SSG are usually played on reduced pitch areas, using modified rules and modified number of players compared to traditional football in order to change the training stimulus based on the coaches desired outcome for that particular session (Hill-Haas et al., 2011). Furthermore, when one or more variable is manipulated simultaneously, it makes it difficult to predict the stimulus caused by each variable (Bujalance-Moreno, Latorre-Román, & García-Pinillos, 2019). It is therefore important to know the effect each variable can have on the training stimulus (Bujalance-Moreno et al., 2019). As an example, it seems that a concurrent increase of player area and number of players decreases the intensity during SSG, while an increase in player area on its own will actually increase the intensity (Hill-Haas et al., 2011). The following section will discuss and highlight the effects of manipulation of pitch area, number of players, rules changes, coach encouragement and continuous or intermittent design can have on its own when designing SSG formats.

2.2.1 PITCH AREA

The relative pitch area per player is defined as the total pitch area divided by the total number of players present on the field (Hill-Haas et al., 2011). It seems that by increasing the pitch area there is an increase in intensity demonstrated trough an increase of HR, RPE and LA (Hill-Haas et al., 2011). The individual playing area each player has also regulates intensity, with increased intensity via increased individual playing area (Casamichana & Castellano, 2010). Furthermore, an increase by 20% in pitch area resulted in an increase in maximum HR, LA and RPE in games played on a large pitch compared to a medium or small pitch across a variety of different SSG format (3 vs. 3, 4 vs. 4, 5 vs. 5, 6 vs. 6) (Rampinini et al., 2007). It therefore seems that pitch area is a factor which should be considered when wanting to control the intensity during different SSG formats (Hill-Haas et al., 2011; Rampinini et al., 2007). Furthermore, it seems that if the main goal of the session is to increase the amount of high speed sprints the pitch area needs to be increased in length in order for players to have the opportunity to achieve high speed sprints (Köklü, Alemdaroğlu, Cihan, & Wong, 2017). It is therefore suggested that an increase in total pitch area and area per player can alter the intensity of SSG demonstrated trough an increase of internal load variables leading to increased exercise intensity (Casamichana & Castellano, 2010; Hill-Haas et al., 2011; Rampinini et al., 2007).

2.2.2 NUMBER OF PLAYERS

Altering the number of players present on the pitch can also influence intensity, as it seems that reducing the number of players on the pitch can increase intensity while an increase in players on the pitch can reduce the intensity (Hill-Haas et al., 2011). Furthermore, a reduction in player number has demonstrated to increase HR, LA and RPE (Duarte, Batalha, Folgado, & Sampaio, 2009; Owen, Twist, & Ford, 2004). Owen et al., (2004) demonstrated this through a decrease in HR when 2 vs. 2 was increased to 3 vs. 3 and 3 vs. 3 was increased to 4 vs. 4 on a pitch with an area of 25 x 20 meters. When assessing the effect of increased player number, it is important to control for other variables such as pitch area and one way of doing this is to keep the pitch area constant while increasing player number (Hill-Haas et al., 2011).

2.2.3 RULES

Football coaches often manipulate the rules during SSG to achieve greater exercise intensity or develop specific tactical or technical skills (Aguiar et al., 2012; Hill-Haas et al., 2011). For instance, stop ball SSG demonstrated higher intensities than SSG without stop ball (Halouani et al., 2017). Stop ball meant that the players had to stop the ball with their sole of the foot within a 1-m wide zone to score a point, a pass transitioning through the zone was not awarded with a point (Halouani et al., 2017). Furthermore, higher HR has been demonstrated in SSG using only possession play and not playing with goals and goalkeepers compared to SSG with goals and goalkeeper (Castellano et al., 2013; Köklü, Sert, Alemdaroglu, & Arslan, 2015). Many researchers also use the availability of balls, meaning that as soon as a ball is kicked out of play it is replaced instantly by having access to balls on the side of the pitch, thus ensuring a higher intensity (Halouani et al., 2017; Hill-Haas et al., 2009). Further rule changes can include implementing offside rules or playing without offside, unbalanced number on defending or attacking team and altering the number of ball touches allowed (Aguiar et al., 2012). It seems that possession play rules increases the intensity during SSG compared to playing with goals and goalkeepers (Castellano et al., 2013; Halouani et al., 2017; Köklü et al., 2015).

2.2.4 COACH ENCOURAGEMENT

Coaches encouragement seems to be an important factor for how high the intensity is during SSG due to an increase of player effort with coach encouragement compared to without (Rampinini et al., 2007). One study compared 3 vs. 3, 4 vs. 4, 5 vs. 5 and 6 vs. 6 on a small, medium and a large size pitch with various pitch areas for each different format (Rampinini et al., 2007). Their findings indicated an increased HR, LA and RPE with coach encouragement compared to without encouragement, which demonstrated the effect a coach can have on the intensity of a session (Rampinini et al., 2007). Multiple studies have described the use of coaching encouragement as a tool to enhance players work rate during their data collecting phase, which places further emphasis on the effect a coach can have on the intensity of the session (Casamichana & Castellano, 2010; Castellano et al., 2013; Dellal et al., 2012).

2.2.5 CONTINUOUS OR INTERVAL BASED SSG TRAINING

In a systematic review by Hill-Haas et al., (2011) the majority of articles reviewed used a traditional interval training format. This includes the usage of several bouts being repeated for the same duration with an active or passive resting period between them (Hill-Haas et al., 2011). Continuous SSG training would be one bout played for a single duration without any resting periods (Hill-Haas et al., 2011).

It seems that by increasing the bout duration from two to six minutes exercise intensity decreases but without effecting the tactical actions (Fanchini et al., 2011). However, coaches could use durations of two to six minutes to ensure adequate physiological stimulation, this is based on findings suggesting that there is a decrease in HR between four to six minutes, with accompanying increase of RPE (Fanchini et al., 2011). The optimal duration for internal load when SSG is considered therefore seems to be 4 minutes (Fanchini et al., 2011). Furthermore, increasing the length of each bout seems to increase HR while decreasing LA and RPE (Köklü et al., 2017). Continuous SSG training has also demonstrated an increased HR_{max}, LA and RPE compared to interval based training lasting for medium and long duration (continuous: 12 minute duration, medium: 3 x 4 min duration, long: 2 x 6 min) (Köklü et al., 2017). Furthermore, when long duration SSG (2 x 6 min) and continuous (12 min) was compared to short duration SSG (6 x 2 min), long and continuous duration SSG resulted in a significant increase in distance covered at walking speeds and a significant decrease in distance covered at moderate intensity running speeds (Köklü et al., 2017). This suggest that the shorter bouts formats increases the external load, while the longer bouts and continuous formats decreases the external load of the players (Köklü et al., 2017).

2.2.6 SSG AND TRADITIONAL FOOTBALL GAMES PHYSIOLOGY SUMMARY

This section will present a table highlighting some of the key articles used in this thesis and demonstrate their study design, measurements and main results (table 1).

Table 1: A summary of studies investigating SSG and/or traditional football games physiology by documenting different manipulation of variables and their accompanying responses.

Study	Subject description	Study protocol	Measurements	Results
Casamichana et al., 2010	Male youth players, regional level (N=10)	SSG vs. MP F: 5 vs. 5 + GK A: 1:62 x 44 m, 2: 50 x 35 m, 3: 32 x 23 m D: 8 minutes R: CE, NOF,	Physiological Locomotive data Motor response RPE	↑ HR, RPE, TDC, TDC per minute, and other LD, LIE, MIE, HIE running and work-to-rest ration with ↑ individual playing area
Casamichana et al., 2012	Semi-professional male players (N=27)	SSG vs FM F: 3 vs. 3, 5 vs. 5, 7 vs.7 A: 210 m^2 pr player R: Format 1: SSG-P, Format 2: SSG-G, Format 3: SSG-g	Locomotive data Workload Variables	↓ HIE running during SSG compared to FM, DC mean was higher during SSG compared to FM Workload variables (work: rest ratio, player W and exertion index were higher during SSG compared to FM

Castellano et al., 2013	Semi-professional male players (N=14)	F: 1: 3 vs 3, 2: 5 vs. 5, 3: 7 vs. 7 A: 1: 43 x 30 m, 2: 55 x 38 m, 3: 64 z 46 m R: SSG-P, SSG-g, SSG-G, CE	Locomotive data IMU data	↑ HR during SSG-P than SSG-G, SSG-g for 5 vs.5 and 3 vs. 3, TDC, PL and work: rest ratio ↓ during SSG-G compared to SSG-P,SSG-g, PL not effected significantly by players involved ↑ number of accelerations in SSG-G than in SSG-P ↑ player number on pitch results in ↑ HIE running and TDC
Dellal et al., 2012	International players (N=40)	SSG vs MP F: 4 vs. 4, 11 vs. 11 A: SSG: 30 x 20 m, MP: 100 x 60 m D: SSG:4 x 4 min, 3 min rest R: SSG: 1 and 2 touch play, free play MP: traditional, CE	Physiological Locomotive data RPE	SSG demonstrated ↑ HIE running for both one/two touch and free play compared to MP, ↑ distance covered during MP Lower LA during SSG compared to match play, Similar RPE between MP and SSG. Various HR based on playing position for both SSG and MP Changing number of ball touches influence game intensity
Halouani et al., 2017	Young players (N=16)	F: 1: 10 x 15 m , 2: 15 x 20, m, 3: 20 x 25 m, 4: 20 x 25 m R: 1: Stop SB-SSG, 2: SSG-g, CE D: 4 x 4 m, 2 min rest	Physiological RPE	↑ HR, LA during SB-SGG than SSG-g for all three pitch sizes. RPE ↑ in SB-SSG compared to SSG-g only for the small pitch. ↑ physiological response for SSG during SB-SSG on the larger pitch

Harley et al., 2010	Elite youth male soccer players U12(N=22), U13(N=20), U14(N=25), U15(N=21, and U16(N=24)	Competitive matches (14)	Locomotive data	U16 demonstrating ↑ TDC, HIE distance, very HIE distance and sprint distance compared to U12, U13, U14, U15.
Hill-Haas et al., 2009	Male soccer players (N=16)	F: 1: 2 vs. 2, 2: 4 vs. 4, 3: 6 vs. 6 A: 1: 28 x 21 m, 2: 40 x 30, 3: 49 x 37 D: 24 min, continuous R: SSG-g, NOF, CE	Physiological Locomotive data RPE	↓ physiological and perceptual workload as the size of SSG formats increased. ↑ time spent above 90% of HR_{max} during 2 vs. 2 compared to 4 vs.4 and 6 vs. 6 Highest RPE and LA during 2 vs.2, lowest during 6 vs. 6
Moreira et al., 2016	Elite youth players (N=60)	F: 5 vs. 5 R: no specific, instructed to play with high intensity D: 2 x 8 min, 3 min rest, analyzed in 4 min quarters	Locomotive data IMU data	Notable ↓ in TDC (1: 596 ± 92, 4: 462 ± 44) , metabolic power (1:13.5 ± 0.9, 4: 10.2 ± 1.1) frequency of sprints(1:13 ± 3, 4: 7.6 ± 2.8) accelerations(1: 19.2 ± 3.9, 4: 11.3 ± 4.0) and deceleration (1: 11.7 ± 3.1, 4: 8.5 ± 2.8) from the first quarter to the last quarter

Note: ↑ = increased ,↓ = reduced, DC = Distance covered, TDC = Total distance covered, LD = Locomotive data, FM = friendly matches, LIE = Low intensity, MIE = Medium intensity, HIE = High intensity, SSG-P= SSG possession play, SSG-G = With goalkeepers, SSG-g = with small goals but no goalkeeper, CE = Coaching encouragement, PL = PlayerLoad™, HR = Hearth rate, LA = Blood lactate concentration, MP = Traditional match play, A= Areal, D = duration, R = Rules, F= format, NOF = No offside rules

2.2.7 SUMMARY

Various factors regulate the intensity demonstrated during SSG, some modifications increases intensity whereas others reduce the intensity, and simultaneous alternations to these factors may further increase or decrease the intensity (Bujalance-Moreno et al., 2019; Hill-Haas et al., 2011). By increasing the pitch area and relative pitch area per player there is an increase in intensity (Casamichana & Castellano, 2010; Hill-Haas et al., 2011; Rampinini et al., 2007). A reduction in player number has been demonstrated to increase intensity (Duarte et al., 2009; Owen et al., 2004). Player area and number of players are likely to have an meaningful relationship, where manipulation of one on its own, or concurrent manipulation of both is likely to impact intensity during SSG (Hill-Haas et al., 2011). Various rule manipulation have an impact on intensity, the most common changes are the use of possession play or the use of goals, where possession play demonstrates higher intensity compared to use of goals or goalkeepers (Castellano et al., 2013; Köklü et al., 2015). Coaching encouragement is a factor that on its own impacts intensity, as the use of coaching encouragement has demonstrated increased intensity compared to no coaching encouragement (Rampinini et al., 2007). SSG are most commonly either played continuously (a single bout) or interval based (multiple bouts with interspersed rest) where the latter is the most common (Hill-Haas et al., 2011). Multiple factors decide the intensity outcome of the two including length of bout, numbers of bout and rest period between bouts (Hill-Haas et al., 2011). Research has however indicated that the most optimal duration of a bout is approximately 4 minutes, and that shorter bouts interspersed with rest is optimal for increasing external loading (Fanchini et al., 2011; Köklü et al., 2017; Moreira et al., 2016).

3.0 METHODOLOGY

3.1 PARTICIPANTS

20 male youth soccer players (age: 14 ± 1 y, 1.62 ± 7.42 m, body mass: 54.52 ± 7.54 kg) participated in the study. Players were members of the same club and played for the U14 and U15 teams competing at a regional level. Participants experience or level of skill ranged substantially, two of the participants were about to be recruited to the regionals elite club, whereas others held a very standard level of soccer skill when compared to other individuals in the same age group. Participants were training approximately 3 times per week. No performance physical testing was performed, nor any other player assessment. Participants were chosen and recruited via staff members within the university who had connections within the chosen club.

3.2 RESEARCH DESIGN

3.2.1 EQUIPMENT

All players were equipped with a player tracking device (OptimeEye S5, Catapult Sports, Australia) consisting of both a GPS-TD collecting data at 10 Hz and an IMU measurement unit integrated with a tri-axial accelerometer, a gyroscope and magnetometer able to collect data at 100 Hz. The device was worn in a padded pouch located on the upper back between the shoulder blades in a custom-made vest from Catapult Sports. The researchers were located on the side of the field, monitoring the session with a computer installed with the Catapult open field software (Catapult sports, Australia). This software allowed the researchers to track player movements live, and to keep track of players during the various SSG formats and traditional football play.

3.2.2 MONITORING PROCEDURE

Participants were monitored over a six-week period where each session was held at the players home ground where they usually trained. During this period two or three sessions were monitored each week. The number of sessions monitored per week was largely dependent on player availability, if there were too few players available for a session the coach would simply cancel it, or the researchers would simply not monitor this session. Each session consisted of the same design with a 5 to-10-minute preparation phase where players would collect the vests and GPS-TD and prepare themselves. A 15 to 20-minute standardized warmup which the club already used prior to the research project was performed followed by SSG performed in a randomized order (table 3), the duration of the format used is presented in the timelines in table 2.

Table 2: Demonstrates the timeline for a given monitored training session.

Preparation: Duration: 5-10 minutes →	Standardized Warmup Duration: 15-20 minutes →	Small Sided games Duration: 2 x 4 minutes 3 minutes rest Used for all formats →	Session continued the way preferred by the coach Player monitoring concluded.

At the start of each session players would collect the vests and GPS-TD devices handed out by the researchers. Players would then be given instructions by the coach and the training would resume without any further involvement from the researchers. The coach was involved in the project by helping the researchers with overseeing that the protocol was followed. After completing the standardized warm up players would be allocated to teams by their coach. Players were randomly allocated to the various SSG and their skill level or playing position were not accounted for. The researchers would signal the coach when to start and when to end each SSG session, teams were then swapped around the field, so that different players were monitored each time a new SSG was started. After completion of the first format, players would start the second format for the session and resume in the same manner as described above in table 2.

Players not taking part in the monitored session were benched, meaning that the tracking devices would not record any of the movements performed when they were not participating in the monitored session. Any uncertainties regarding correct player benching/replacement was registered when it took place and double checked once the SSG game ended. Players wore the same vest with the same size and the same GPS-TD for each session, with the researcher fully aware of which GPS-TD that belonged to which player. Due to some of the players wearing a too large vest, some of the vests had to be tightened using rubber straps to ensure that the GPS-TD were held in place without any excess movement which could interfere or disrupt the tracking of movements, especially for the data obtained from the IMU device.

Table 3: Timeline of the research project and randomization for SSG and order of monitoring for 11 vs 11.

Week 1		Familiarization period	
Week 2		Familiarization period	
Week 3	S1	S2	S3
	Matchday monitoring (11 vs. 11)	Familiarization session	No monitoring
Week 4	S1	S2	S3
	Matchday Monitoring (11 vs. 11)	6 vs. 6 3 vs. 3	No monitoring
Week 5	S1	S2	S3
	6 vs. 6 3 vs. 3	6 vs. 6 3 vs. 3	No monitoring
Week 6	S1	S2	S3
	No monitoring	6 vs. 6 3 vs. 3	No monitoring
Week 7	3 vs. 3	3 vs. 3	S3
	6 vs. 6	6 vs. 6	No monitoring
Week 8	6 vs. 6	S2	S3
	3 vs. 3	No monitoring	No monitoring

Note: S1= session 1, S2 = session 2, S3 = session 3

3.2.3 RULES

Table 4 demonstrates the rules used for the various SSG formats and the traditional football play. Fast ball availability meant that the players had fast access to balls by having multiple balls placed around the pitch so when a ball was kicked out of play it was instantly replaced with a new one. For both the 6 vs. 6 and 3 vs. 3 small goals were used (1.8 x 1.2 m), points were awarded for scoring a goal and the game was instantly started after one team scored a goal, no goalkeepers were used. The coaches were instructed to encourage and give tactical instruction to the players similarly to what they regularly did. This was used both to ensure optimal effort by the players, and to interfere as little as possible in the daily routine of the players and coaching staff.

Table 4 Demonstrates the field dimensions and rules applied to the various SSG formats.

3 vs. 3	**6 vs. 6**
20 x 15 m	32 x 24 m
Fast ball availability	Fast ball availability
No offside	No offside
Coaching encouragement	Coaching encouragement
Small goals no goalkeeper	Small goals no goalkeeper

3.3 STATISTICAL ANALYSIS

After each training session, data was uploaded to the catapult Openfield cloud for storage. Before data could be extracted certain variables had to be computed within Openfield cloud. Computing data is a process where certain measurements are combined to form a variable, i.e. combinations of low acceleration, deceleration and change of direction to form the variable high intensity event (HIE) low. For the locomotive data running thresholds were defined, these thresholds were then used to create certain variables which is further explained in section 3.3.2. Variables such as total distance and meter per minute were already available within the software and were thus extracted as they were already defined.

For the inertial sensor data, Playerload^{TM} 3D and 2D (excluding vertical) were extracted as defined by the software. For the high intensity events (HIE) variables had to be computed, the definition of HIE and thresholds used is further explained in section 3.3.3. The following variables were computed within the Openfield cloud console: HIE low, HIE medium, HIE high, HIE high/medium, HIE total.

3.3.1 LOCOMOTIVE SPEED THRESHOLDS

Running speed thresholds for low, high, very high intensity and sprinting running was determined by using thresholds used in a study examining time motion demands in U12-U16 football players (Harley et al., 2010). This study highlighted the need to individualize and categorize the speed thresholds according to age due to the large variation in performance characteristics in this age group (Harley et al., 2010). The variables were converted from meters per second to kilometers per hour and is presented in table 5.

Table 5: Locomotive thresholds used in the current paper for the individual age group U14 with comparisons towards other age groups (U13, U15) (Harley et al., 2010).

	U13	**U14**	**U15**
LIR	<11,00 km/h	<11,00 km/h	<12,00 km/h
HIR	>15,00 km/h	>15.00 km/h	>16,00 km/h
VHIR	>18,00 km/h	>18,00 km/h	>18,00 km/h
Sprinting	>20,00 km/h	>20.0 km/h	>22.00 km/h

3.3.2 INERTIAL MEASUREMENT UNITS SPEED THRESHOLDS

High intensity event (HIE) threshold is classified as HIE low (1.5 – 2.5 $m \cdot s^{-1}$), HIE medium (2.5 – 3.5 $m \cdot s^{-1}$), HIE high (> 3.5 $m \cdot s^{-1}$), and HIE total (>1.5 $m \cdot s^{-1}$). High intensity events are the combination of acceleration, decelerations and change of directions and these thresholds are based on thresholds used in the reliability study of OptimEye S5 (Luteberget et al., 2017).

3.3.3 ANALYSIS PROCESS

Within Microsoft excel the mean, coefficient of variation (CV) and standard deviation (SD) were calculated for all the variables. The mean is the central tendency within the data set and is the average of all the variables (Polit & Beck, 2018). CV is a statistical measure of the distribution of the data point around the mean, it is useful in order to compare the variation of one set of variables to another set of variables (Polit & Beck, 2018). SD is a measurement of the dispersion within the variables, a low SD would indicate a low dispersion from the mean, while a high SD would indicate that the values are spread further away from the mean (Polit & Beck, 2018). Within statistics a high SD would indicate higher statistical error within a data set, whereas a low SD would indicate low statistical error of the data set, it provides us with a measurement of how confident we can be that we have an accurate measurement (Polit & Beck, 2018).

Prior to extracting the data to excel the researchers decided to split each monitored session into 4 quarters which meant that each session would contain 4 quarters with 2 quarters for each measured format, this was performed in the Openfield software. An average was calculated for each player and the for the whole team for both 3 vs. 3 and 6 vs. 6, and the 4 different quarters, this was performed in order to be able to answer the research question stated in section 1.1.

A Levens test is used to verify the assumption that the variance in a sample are equal or of homogeneity (Vorapongsathorn, Taejaroenkul, & Viwatwongkasem, 2004). A p-value less than 0.05 will detonate a significant difference, which will conclude that there is a difference between the variance observed in the measured variables (Vorapongsathorn et al., 2004). Thus, Levens tests were used for the purpose of measuring if there was a significant difference in the observed variance between the measured variables for the various formats. The Levens test were performed within Excel, thus all statistical analysis and organization of the data were performed with the use of Excel. After completion of analysis, figures and tables were created within excel before they were extracted to the research paper.

4.0 DISCUSSION OF METHODOLOGY

The following section will discuss and highlight strength and weaknesses related to the projects research design and highlight any challenges associated with the research design.

4.1 RESEARCH DESIGN

This study was carried out by a single master student accompanied by an appointed supervisor as such the research design was self-chosen. From the start of the project the researchers was determined to interfere as little as possible to the daily training of the players and as such an non experimental or observational study design were used for this master's thesis (Polit & Beck, 2018). Due to the coach being very resilient and positive to the current study, the researchers were able to monitor the players in a very controlled yet normal setting, which has provided us with some good and reliable data for the current subject group**.** All participants were included in the research project, and there were no inclusion/exclusion criterions preventing them from being involved. Participants were not informed about how many sessions they were required to participate in in order to be included in the data analysis as we wanted them to be motivated for the project regardless of this. This in turn lead to some participants being excluded after the monitoring phase were concluded, which could potentially affect the strength of the study. The research design is similar to other research designs investigating research questions related to IMUs within team sports (Luteberget et al., 2018) and similar to other research within the field of football, player monitoring and SSG (Casamichana & Castellano, 2010; Hill-Haas, Coutts, Dawson, & Rowsell, 2010; Köklü et al., 2015). The current research design was aimed at youth players due to there a being lack of research on youth players in this field based on the authors knowledge, especially when GPS-TD and IMUs are considered.

4.2 PARTICIPANTS

Participants were young soccer players aged 13 and 14 years old playing at a recreational level training approximately 3 times per week. The research project started with a total number of 21 participants, out of these participants, 19 reached the inclusion criteria of minimum 1 monitored training session. Some players were unable to meet this criterion due to injuries, whereas others did not attend training due to absence of motivation.

It is possible that recreational youth football players are not able to maintain the same intensity as elite youth players, this is based on findings suggesting that elite soccer players demonstrates higher maximal isometric force, force at 100 ms, reactive force index, vertical jump height, maximum pedaling rate and 10 m sprint time compared to recreational youth football players (Gissis et al., 2006). In the current subject group, the technical and physical level of the players varied considerably, with some having technical and physical skills above average and some being below average. Furthermore, even though players had fast ball availability to ensure higher intensity, the players could stop and argue about a foul before continuing to play, this could potentially affect the intensity demonstrated during the SSG. For reasons mentioned one cannot therefore exclude the fact that this might have affected the results presented in the current study.

The physical characteristics of players were not measured; thus, we are not able to determine the fitness of the players involved in this study which could potentially have an influence on the results. Research has demonstrated that physical fitness is a vital component in order to achieve optimal performance in young football players (Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009), in elite football players (Rampinini et al., 2007) and in female football players (Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005). When the importance of physical fitness has been demonstrated across a broad aspect of different football athletes, one cannot exclude the importance of knowing how fit the athletes are when interpreting the results. It is therefore important to acknowledge that in this research paper it could potentially affect the results via lower intensities demonstrated and that the athletes used in the current study are unable to achieve same intensities as older or professional athletes at the same age.

4.3 RULES AND SSG FORMATS

The SSG formats used in the current research paper is similar to those used in previous research, both for player number (3 vs. 3 and 6 vs. 6) and areal (20 x 15 m, 32 x 24 m) (Hill-Haas et al., 2011). The available player area per player in SSG is very likely to influence the intensity of SSG where a larger player area per player would increase the intensity (Casamichana & Castellano, 2010; Hill-Haas et al., 2011). In the current research paper, the player area per player for 3 vs. 3 were 50 m^2 and for 6 vs. 6 64 m^2 respectively. A**s** such both formats contain a different area per player, thus it is likely that the area per player is influencing the intensity more than the actual player number itself in the current study. Therefore, it should be accounted for as a potential weakness of the study when one of the goals were to assess player numbers influence on intensity. However, player number will in turn influence the area per player regardless if the pitch area is kept constant or not. As such it is likely that pitch area is the largest factor in determining intensity and that player number is a factor which is influencing pitch area.

Apart from the rules implemented during the SSG to achieve desired intensity, other uncontrollable factors such as the players concentration, players involvement in the game, ball movement, tackles resulting in stoppage of play and loss of ball availability could all affect the intensity (Köklü et al., 2015). As the authors wanted to interfere as little during the monitoring phase in order to have representative data for the current age group, these factors are hard to control for and should as such be mentioned as factors potentially affecting the results.

4.4 MEASUREMENTS

Previous research has demonstrated the need of establishing correct speed zones for younger athletes so that they are more able to reflect the work rate patterns of younger players (Cummins et al., 2013). In this thesis the speed zones or running thresholds were established based on previous research investigating speed zones in younger players, and are thus determined to be relevant for the current subject group (Harley et al., 2010). The IMU thresholds are based on adult handball players (Luteberget et al., 2018), as such one could argue if these are relevant and will provide us with accurate and representative measurement for the current subject group. There are however to this authors knowledge no established IMU thresholds for younger athletes to date and as such the current thresholds have been used.

The monitored sessions between the participants varied considerably, with the lowest monitored periods per format being 4 and highest being 14, the average monitored periods were 8 ± 3. One cannot exclude that this potentially could affect the reliability of the mean for the team total, as some players would have contributed considerably more than others. The minimum periods monitored for inclusion were 4, due to being able to include as many participants as possible.

4.5. CATAPULT SPORTS VESTS

In order to get the most accurate measurements each player had to wear the vests tight to the body every session to avoid excessive movement of the device. The Catapult Sports Vests available to the researchers consisted of size small, medium, large and extra-large. Most of the players had to wear size small and hardly any of them could fit either a small or a medium vest. This meant that the researcher had to use tiny rubber bands to tighten the vests of almost each player every session to ensure that the device didn't move excessively during training. This problem has led to some methodological issues. Even with the application of rubber bands both on the front of the chest and on the lower back (around the thoracic vertebrae) some of the vests still would not fit perfectly. This can potentially have led to some excessive movement of the device, which could reduce the reliability of some of the data which have been collected.

4.6 STATISTICAL ANALYSIS

In order to find the mean, SD and CV excel and its accompanying formulas were used within a spreadsheet. The data was checked for errors by others than the researcher multiple times and the researcher checked the datasheet for errors multiple times. However, one cannot exclude that human error may occur, and that some places there might be a wrong formula somewhere, but the researcher have taken steps to ensure that the chance of this is limited.

Levens test is typically used as a preliminary check of the equal variance assumption in a classical ANOVA test, it is also used to check the equality of variance observed in a population (Gastwirth, Gel, & Miao, 2009). In most cases however, it seems that the Levens test is followed by another statistical analysis test, and that is usually not performed on its own. One could therefore argue whether its propriate to use a Levens test in the current study. Yet the results of the test are able to determine whether the variance in a sample is of significance or not (Vorapongsathorn et al., 2004). However, this is something that needs to be acknowledged, and taken into an account when interpreting the results of the current study.

4.7 SUMMARY - STRENGTHS AND LIMITATIONS OF THE CURRENT STUDY

The main strength of the current study includes the self-chosen, self-designed research design providing the ability to control the observation phase and monitoring in a positive way, providing us with reliable data relevant for the current subject group. Another strength is the fact that the speed thresholds were based of similar research investigating youth athletes, as such they have been used prior to this project and are therefore considered to be valid. Main weaknesses are the level of the participants which include the lack of physiological measurements leaving us unable to determine their physical capabilities. Another weakness is the catapult sports vests fitting and the IMU thresholds based of older athletes than the current subject group. Another weakness is the number of monitored session per player which also needs to be considered when interpreting the results from the current study.

Based on these strengths and weaknesses of the current study we believe that the study might only be representative for the current subject group and not necessarily representative for elite young athletes or older elite/recreational athletes. Future research should investigate these group of athletes and consider the problem with the catapult sports vests and come up with a better solution in order to fit them better to each player.

4.8 ETHICAL CONSIDERATIONS

4.8.1 PARTICIPANTS

All participants with their legal guard/parents consented to participation in the research project, due to the age of the participants (U16) written consent from the parents was deemed necessary. Participants and their legal guard/parents were presented with an info letter containing the purpose of the research, potential benefits of the research project and any potential risks associated with the project prior to the projects start date. Participants and their legal guards/parents were informed they at any given time could withdraw their participation from the research project without providing any reason.

As this was an observational study only there was not identified any additional risks for the participants as they were observed in a familiar environment doing an activity which they were regularly exposed too. Injured participants were not included in the study, and they were instructed not to participate if they had or obtained any serious injuries during the research project.

4.8.2 STORAGE OF PARTICIPANTS DATA/PERSONAL INFORMATION

All information regarding the participants information were kept confidential and only personnel associated with the research project had access to it. Data was stored in accordance with the new guidelines from NSD (Norwegian Centre for research data) and each subject received a code which identified them to the researcher and thus no names were stored alongside the data. Only a connection key which held the participants name and code were used by the researcher during the data collection to ensure that the correct player received the correct GPS-TD unit.

4.8.3 APPLICATIONS

Prior to the start of the research project applications was sent to FEK (The ethical committee of the faculty) and NSD, which were both approved prior to the project start date.

5.0 REFERENCES:

Aguiar, M., Botelho, G., Lago, C., Maças, V., & Sampaio, J. (2012). A review on the effects of soccer small-sided games. *Journal of human kinetics*, *33*, 103-113.

Akenhead, R., French, D., Thompson, K. G., & Hayes, P. R. (2014). The acceleration dependent validity and reliability of 10 Hz GPS. *Journal of Science and Medicine in Sport, 17*(5), 562-566.

Akenhead, R., Hayes, P. R., Thompson, K. G., & French, D. (2013). Diminutions of acceleration and deceleration output during professional football match play. *Journal of Science and Medicine in Sport, 16*(6), 556-561.

Akenhead, R., & Nassis, G. P. (2016). Training load and player monitoring in high-level football: current practice and perceptions. *International journal of sports physiology and performance, 11*(5), 587-593.

Andrzejewski, M., Chmura, J., Pluta, B., Strzelczyk, R., & Kasprzak, A. (2013). Analysis of sprinting activities of professional soccer players. *The journal of strength & conditioning research, 27*(8), 2134-2140.

Aughey, R. J. (2011). Applications of GPS technologies to field sports. *International journal of sports physiology and performance, 6*(3), 295-310.

Bangsbo, J. (2014). Physiological demands of football. *Sports Science Exchange, 27*(125), 1-6.

Barrett, S., Midgley, A. W., Towlson, C., Garrett, A., Portas, M., & Lovell, R. (2016). Within-match PlayerLoad™ patterns during a simulated soccer match: potential implications for unit positioning and fatigue management. *International journal of sports physiology and performance, 11*(1), 135-140.

Bloomfield, J., Polman, R., & O'Donoghue, P. (2007). Physical demands of different positions in FA Premier League soccer. *Journal of sports science & medicine, 6*(1), 63.

Boyd, L. J., Ball, K., & Aughey, R. J. (2011). The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *International journal of sports physiology and performance, 6*(3), 311-321.

Bradley, P. S., Di Mascio, M., Peart, D., Olsen, P., & Sheldon, B. (2010). High-intensity activity profiles of elite soccer players at different performance levels. *The journal of strength & conditioning research*, *24*(9), 2343-2351.

Buchheit, M., Samozino, P., Glynn, J. A., Michael, B. S., Al Haddad, H., Mendez-Villanueva, A., & Morin, J. B. (2014). Mechanical determinants of acceleration and maximal sprinting speed in highly trained young soccer players. *Journal of sports sciences, 32*(20), 1906-1913.

Bujalance-Moreno, P., Latorre-Román, P. Á., & García-Pinillos, F. (2019). A systematic review on small-sided games in football players: Acute and chronic adaptations. *Journal of sports sciences, 37*(8), 921-949.

Casamichana, D., & Castellano, J. (2010). Time–motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *Journal of sports sciences, 28*(14), 1615-1623.

Casamichana, D., Castellano, J., & Castagna, C. (2012). Comparing the physical demands of friendly matches and small-sided games in semiprofessional soccer players. *The journal of strength & conditioning research, 26*(3), 837-843.

Castagna, C., Impellizzeri, F., Cecchini, E., Rampinini, E., & Alvarez, J. C. B. (2009). Effects of intermittent-endurance fitness on match performance in young male soccer players. *The Journal of Strength and Conditioning Research, 23*(7), 1954-1959.

Castellano, J., Casamichana, D., & Dellal, A. (2013). Influence of game format and number of players on heart rate responses and physical demands in small-sided soccer games. *The journal of strength & conditioning research, 27*(5), 1295-1303.

Chambers, R., Gabbett, T. J., Cole, M. H., & Beard, A. (2015). The use of wearable microsensors to quantify sport-specific movements. *Sports medicine, 45*(7), 1065-1081.

Cummins, C., Orr, R., O'Connor, H., & West, C. (2013). Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports medicine, 43*(10), 1025-1042.

Dalen, T., Jørgen, I., Gertjan, E., Havard, H. G., & Ulrik, W. (2016). Player load, acceleration, and deceleration during forty-five competitive matches of elite soccer. *The journal of strength & conditioning research, 30*(2), 351-359.

Dellal, A., Owen, A., Wong, D. P., Krustrup, P., van Exsel, M., & Mallo, J. (2012). Technical and physical demands of small vs. large sided games in relation to playing position in elite soccer. *Human movement science, 31*(4), 957-969.

Duarte, R., Batalha, N., Folgado, H., & Sampaio, J. (2009). Effects of exercise duration and number of players in heart rate responses and technical skills during futsal small-sided games. *The Open Sports Sciences Journal*.

Dwyer, D. B., & Gabbett, T. J. (2012). Global positioning system data analysis: Velocity ranges and a new definition of sprinting for field sport athletes. *The journal of strength & conditioning research, 26*(3), 818-824.

Fanchini, M., Azzalin, A., Castagna, C., Schena, F., Mccall, A., & Impellizzeri, F. M. (2011). Effect of bout duration on exercise intensity and technical performance of small-sided games in soccer. *The journal of strength & conditioning research, 25*(2), 453-458.

Gabbett, T. J., & Mulvey, M. J. (2008). Time-motion analysis of small-sided training games and competition in elite women soccer players. *The journal of strength & conditioning research, 22*(2), 543-552.

Gabbett, T. J., Wiig, H., & Spencer, M. (2013). Repeated high-intensity running and sprinting in elite women's soccer competition. *International Journal of Sports Physiology and Performance, 8*(2), 130-138.

Gastwirth, J. L., Gel, Y. R., & Miao, W. (2009). The impact of Levene's test of equality of variances on statistical theory and practice. *Statistical Science*, 343-360.

Gissis, I., Papadopoulos, C., Kalapotharakos, V. I., Sotiropoulos, A., Komsis, G., & Manolopoulos, E. (2006). Strength and speed characteristics of elite, subelite, and recreational young soccer players. *Research in sports Medicine*, *14*(3), 205-214.

Gregson, W., & Drust, B. (2000). The physiology of football drills. *Insight, 3*(4), 1-2.

Halouani, J., Chtourou, H., Dellal, A., Chaouachi, A., & Chamari, K. (2017). The effects of game types on intensity of small-sided games among pre-adolescent youth football players. *Biology of sport*, *34*(2), 157.

Halson, S. L. (2014). Monitoring training load to understand fatigue in athletes. *Sports medicine, 44 Suppl 2*(Suppl 2), S139-147. doi:10.1007/s40279-014-0253-z

Harley, J. A., Barnes, C. A., Portas, M., Lovell, R., Barrett, S., Paul, D., & Weston, M. (2010). Motion analysis of match-play in elite U12 to U16 age-group soccer players. *Journal of sports sciences, 28*(13), 1391-1397.

Haugen, T. A., Tønnessen, E., & Seiler, S. (2013). Anaerobic performance testing of professional soccer players 1995–2010. *International journal of sports physiology and performance, 8*(2), 148-156.

Hewit, J., Cronin, J., Button, C., & Hume, P. (2011). Understanding deceleration in sport. *Strength and conditioning journal, 33*(1), 47-52.

Hill-Haas, S. V., Coutts, A. J., Dawson, B. T., & Rowsell, G. J. (2010). Time-motion characteristics and physiological responses of small-sided games in elite youth players:

the influence of player number and rule changes. *The journal of strength & conditioning research, 24*(8), 2149-2156.

Hill-Haas, S. V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football. *Sports medicine, 41*(3), 199-220.

Hill-Haas, S. V., Dawson, B. T., Coutts, A. J., & Rowsell, G. J. (2009). Physiological responses and time–motion characteristics of various small-sided soccer games in youth players. *Journal of sports sciences, 27*(1), 1-8.

Iaia, F. M., Ermanno, R., & Bangsbo, J. (2009). High-intensity training in football. *International journal of sports physiology and performance, 4*(3), 291-306.

Impellizzeri, F. M., Marcora, S. M., Castagna, C., Reilly, T., Sassi, A., Iaia, F., & Rampinini, E. (2006). Physiological and performance effects of generic versus specific aerobic training in soccer players. *International journal of sports medicine, 27*(06), 483-492.

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load: 15 years on. *International journal of sports physiology performance, 14*(2), 270-273.

Jennings, D., Cormack, S., Coutts, A. J., Boyd, L., & Aughey, R. J. (2010). The validity and reliability of GPS units for measuring distance in team sport specific running patterns. *International journal of sports physiology and performance, 5*(3), 328-341.

Jones, S., & Drust, B. (2008). Physiological and technical demands of 4 v 4 and 8 v 8 games in elite youth soccer players. *Kinesiology: International journal of fundamental and applied kinesiology, 39*(2), 150-156.

Krustrup, P., Mohr, M., Ellingsgaard, H., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: importance of training status. *Medicine and science in sports and exercise, 37*(7), 1242.

Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjaer, M., & Bangsbo, J. (2004). Muscle metabolites during a football match in relation to a decreased sprinting ability. *J Sports Sci, 22*(6), 549.

Köklü, Y., Alemdaroğlu, U., Cihan, H., & Wong, D. P. (2017). Effects of bout duration on players' internal and external loads during small-sided games in young soccer players. *International journal of sports physiology and performance, 12*(10), 1370-1377.

Köklü, Y., Sert, Ö., Alemdaroglu, U., & Arslan, Y. (2015). Comparison of the physiological responses and time-motion characteristics of young soccer players in small-sided games: The effect of goalkeeper. *The journal of strength & conditioning research, 29*(4), 964-971.

Larsson, P. (2003). Global positioning system and sport-specific testing. *Sports medicine, 33*(15), 1093-1101.

Little, T. (2009). Optimizing the use of soccer drills for physiological development. *Strength & Conditioning Journal, 31*(3), 67-74.

Little, T., & Williams, A. G. (2005). Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res, 19*(1), 76-78. doi:10.1519/14253.1

Luteberget, L. S., Holme, B. R., & Spencer, M. (2017). Reliability of wearable inertial measurement units to measure physical activity in team handball. *International journal of sports physiology and performance, 13*(4), 467-473.

Luteberget, L. S., Trollerud, H. P., & Spencer, M. (2018). Physical demands of game-based training drills in women's team handball. *Journal of sports sciences, 36*(5), 592-598.

Majumdar, A. S., & Robergs, R. A. (2011). The science of speed: Determinants of performance in the 100 m sprint. *International Journal of Sports Science & Coaching, 6*(3), 479-493.

Malone, J. J., Lovell, R., Varley, M. C., & Coutts, A. J. (2017). Unpacking the black box: applications and considerations for using GPS devices in sport. *International journal of sports physiology and performance, 12*(s2), S2-18-S12-26.

Moreira, A., Aoki, M. S., Carling, C., Lopes, R. A. R., de Arruda, A. F. S., Lima, M., . . . Bradley, P. S. (2016). Temporal changes in technical and physical performances during a small-sided game in elite youth soccer players. *Asian journal of sports medicine, 7*(4).

Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & Di Prampero, P. E. (2010). Energy cost and metabolic power in elite soccer: a new match analysis approach. *Med Sci Sports Exerc*, *42*(1), 170-178.

Owen, A., Twist, C., & Ford, P. (2004). Small-sided games: the physiological and technical effect of altering pitch size and player numbers. *Insight, 7*(2), 50-53.

Polit, D. F., & Beck, C. T. (2018). *Essentials of Nursing Reaserch* (Ninth Edition ed.): Wolters Kluwer Health, Lippincot Williams & Wilkins.

Rampinini, E., Bishop, D., Marcora, S., Bravo, D. F., Sassi, R., & Impellizzeri, F. (2007). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International journal of sports medicine, 28*(03), 228-235.

Rampinini, E., Impellizzeri, F. M., Castagna, C., Abt, G., Chamari, K., Sassi, A., & Marcora, S. M. (2007). Factors influencing physiological responses to small-sided soccer games. *Journal of sports sciences, 25*(6), 659-666.

Scott, B. R., Lockie, R. G., Knight, T. J., Clark, A. C., & de Jonge, X. A. J. (2013). A comparison of methods to quantify the in-season training load of professional soccer players. *International journal of sports physiology and performance, 8*(2), 195-202.

Scott, M. T., Scott, T. J., & Kelly, V. G. (2016). The validity and reliability of global positioning systems in team sport: a brief review. *The journal of strength & conditioning research, 30*(5), 1470-1490.

Simons, C., & Bradshaw, E. J. (2016). Do accelerometers mounted on the back provide a good estimate of impact loads in jumping and landing tasks? *Sports biomechanics, 15*(1), 76-88.

Spencer, M., Bishop, D., Dawson, B., & Goodman, C. (2005). Physiological and metabolic responses of repeated-sprint activities. *Sports medicine, 35*(12), 1025-1044.

Spencer, M., Lawrence, S., Rechichi, C., Bishop, D., Dawson, B., & Goodman, C. (2004). Time–motion analysis of elite field hockey, with special reference to repeated-sprint activity. *Journal of sports sciences, 22*(9), 843-850.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer. *Sports medicine, 35*(6), 501-536.

Van Praagh, E., & Doré, E. (2002). Short-term muscle power during growth and maturation. *Sports medicine, 32*(11), 701-728.

Vorapongsathorn, T., Taejaroenkul, S., & Viwatwongkasem, C. (2004). A comparison of type I error and power of Bartlett's test, Levene's test and Cochran's test under violation of assumptions. *Songklanakarin J. Sci. Technol, 26*(4), 537-547.

Wundersitz, D. W., Gastin, P. B., Richter, C., Robertson, S. J., & Netto, K. J. (2015). Validity of a trunk-mounted accelerometer to assess peak accelerations during walking, jogging and running. *European journal of sport science, 15*(5), 382-390.

Young, W. B., Dawson, B., & Henry, G. J. (2015). Agility and change-of-direction speed are independent skills: Implications for training for agility in invasion sports. *International Journal of Sports Science and*

Coaching, 10(1), 159-169.

5.1 Table summary

Part 2:

Research paper

Variation in exercise intensity during typical training drills in youth footballers measured via GPS tracking devices

This paper is written in accordance with the guidelines from International Journal of Sport Physiology and Performance.

https://journals.humankinetics.com/page/authors/ijspp

ESPEN GABRIELSEN JOHNSEN

UNIVERSITY OF AGDER

"Variation in exercise intensity during typical training drills in youth footballers measured via GPS tracking devices"

Submission type: *Original investigation*

Espen Gabrielsen Johnsen[1]

[1]Faculty of Health and Sport Scienes, University of Agder, Kristiansand, Norway, [2]Faculty of Physical Performance, Norwegian School of Sport Science, Oslo, Norway

The present article is written as part of a Master thesis in Sport science. Relevant co-authors: Matthew Spencer[1], Live Luteberget[1,2]

Corresponding author:
Espen Gabrielsen Johnsen
University of Agder, Faculty of Health and Sport Science
Postboks 442, 4604 Kristiansand, NORWAY
Email: espegj13@uia.no
Telephone: +47 90 25 16 16

Preferred running head: Variation in exercise intensity during typical training drills in football

NOTE: As explained in section IV. Structure of the thesis, tables and figures have been inserted into the article even tough it is not in accordance with the guidelines from International Journal of Sports Physiology and Performance. This have been done to make it easier for the reader.

ABSTRACT

PURPOSE: The present study aims to investigate the between-athlete and within-athlete variation in intensity occurring during various SSG formats in order to determine their relevance within soccer specific drills.

METHODS: 19 youth male football players (age: 14.0 ± 1.0 y, height: 1.6 ± 7.4 m, body mass: 54.5 ± 7.5 kg) were monitored for an 8-week period two times per week. Subjects performed a standardized warmup prior to completing various formats of SSG lasting 4 x 2 minutes interspersed with 2 minutes rest in a randomized order. All players were equipped with a player tracking device (OptimEye S5, Catapult Sports, Australia) consisting of both a GPS-TD collecting data at 10 Hz and an IMU measurement unit collecting data at 100 Hz. Selected measurements include Playerload™ (accelerometer-based measurement of external training load), Playerload™ 2D (excluding vertical axis) High intensity events (HIE) which is the combined measurement of accelerations, decelerations, and changes of direction, Total distance (TD), Meter per minute and Low intensity running (LIER) which is running performed at speeds lower than 11.0 km/h

RESULTS: Significant variation ($p < 0.05$) in intensity was observed for within-athlete variation when Playerload™, Playerload™ 2D, HIE total and LIER when 3 vs. 3 were compared to 6 vs. 6. A larger variation in intensity between-athlete was observed for Playerload™, Playerload™ 2D, TD, Meter per minute and LIER when 3 vs. 3 was compared to 6 vs. 6. 6 vs. 6 demonstrated a larger variation for HIE med, high and total when compared to 3 vs. 3.

CONCLUSION: During various formats of SSG training drills 3 vs. 3 demonstrates larger variation in intensity when compared to 6 vs.6. A higher number of accelerations, decelerations and changes of direction is likely to occur during 3 vs. 3

KEY WORDS: Young male footballers, GPS-tracking devices, Small-sided games, training drills, training intensity

INTRODUCTION

Football is a complex team sport with a large amount of different movement patterns performed at various intensities.[1] These movements can be classified as either locomotive movements such as running, walking, sprinting[2-4] and higher intensity movements such as accelerations, decelerations and changes of direction.[5] The measurement and interpretation of such movements relies today heavily on tracking devices using global positioning systems (GPS) often integrated with inertial measurement units (IMU).[6,7] GPS tracking devices (GPS-TD) have demonstrated good reliability to track movement patterns occurring at lower speeds and over longer durations, with decreased validity as movement intensity increases and is performed over short distances.[8,9] GPS-TD are acceleration dependent, demonstrating reduced validity and reliability when measuring accelerations over 4 ms_{-2}[6] and at higher velocities (>20 km/h).[8] IMUs have demonstrated good reliability to measure physical activity in team sports (<2% CV), especially when high intensity movements are considered, as such the combined use of traditional GPS and IMU data has increased to provide an accurate measurement of workload and exercise intensity during training and competitive matches.[10,11]

Small-sided games (SSG) have been developed to concurrently develop fitness, technical and tactical skills in football.[12] SSG are regarded to be suitable for developing physical characteristics necessary to perform under pressure and fatigue and to replicate movement patterns typically encountered during competitive games.[3,13] SSG are played on reduced pitch areas with modified rules and containing fewer players than traditional competitive football games.[14] It is important to gain a better understanding of the intensity occurring during SSG and how the various modification to traditional football rules impacts the intensity when combined or on their own.[14] Furthermore, limited studies have investigated the within-athlete variation during SSG training drills. To our knowledge, no previous studies have investigated the between-athlete intensity during SSG training drills. This will therefore be a new contribution to the field.

As such the present study aims to investigate the variation in intensity occurring during the various SSG formats in order to provide a more accurate and detailed picture of their relevance in soccer specific drills. This study will investigate the variation in intensity for each session, both for the within-athlete and between-athlete variation in two various SSG formats (3 vs. 3, 6 vs. 6). It is postulated that the format containing the largest pitch area and the largest number of players will demonstrate the highest variation in intensity.

METHODS

SUBJECTS

Twenty male youth football players were recruited to participate in the current study. All played for the same local team competing at a regional level and participants were recreational football players training three football specific group practices per week. Participation in the research project was voluntarily and was approved by the local ethical committee at the University of Agder and carried out in accordance with the Helsinki declaration of 1975.[15] From the initially recruited participants, 19 (age: 14.0 ± 1.0 y, height: 1.6 ± 7.4 m, body mass: 54.5 ± 7.5 kg) participants meet the inclusion criteria of a minimum of 1 monitored training sessions and were included in the data analysis. No fitness tests were performed nor any other measurement of the players physical characteristics.

DESIGN

The current study was carried out as an observational study where players were monitored for 8 weeks, this included a 2-week familiarization phase and 6 weeks of research monitoring. Two sessions were monitored each week. After completing a standardized warm up lasting for approximately 20 minutes, participants completed two formats of SSG (3 vs. 3 and 6 vs. 6) with a duration of 2 x 4 minutes interspersed with 3 minutes rest for each format. The areal for each SSG was determined by previous research[14] and were as follows 20 x 15 m for 3.vs 3 and 32 x 24 m for 6 vs. 6. The SSG formats were played with no offside rules, with small goals (6x4 m) and no goalkeepers and with fast ball availability. This meant that balls were positioned around the pitch so when the ball went out of play it was immediately replaced with a new one. If a foul was awarded, the team which the player belonged to would receive the ball back without any freekick in order to reduce stoppage in play. Coaches were instructed to encourage and instruct players similarly to what they normally did.

METHODOLOGY

All players were equipped with a player tracking device (OptimEye S5, Catapult Sports, Australia) consisting of both a GPS-TD collecting data at 10 Hz and an IMU measurement unit integrated with a tri-axial accelerometer, a gyroscope and magnetometer able to collect data at

100 Hz. The device was worn in a padded pouch located on the upper back between the shoulder blades in a custom-made vest from Catapult Sports. The researcher was located on the side of the pitch, tracking player movement live with the use of Catapult Openfield software (Catapult Sports, Australia), an antenna used to improve the signals from the device were connected to the computer which held the Openfield software. After performing the standardized warmup, players performed the SSG as described above, however the SSG were performed in a randomized order for each session. During SSG play, the coach had the responsibility of starting and ending the sessions, while the researcher kept track of time and would signal the coach when to start and when to allow the players to rest. After the SSG player monitoring was concluded, the remainder of the session was carried out as preferred by the coach. The GPS-TD were turned on 15 minutes prior to monitoring the SSG in order to obtain GPS signals from the satellites. All research was conducted on the players home ground.

STATISTICAL ANALYSIS

Prior to extracting the data from the Catapult software, each format was split into two periods which provided us with four different periods per session. Within Microsoft excel (2019) the mean, coefficient of variation (CV) and standard deviation (SD) was calculated for all the variables. Variables extracted from the OpenField Cloud software includes Playerload^{TM} and Playerload^{TM} 2D. Playerload^{TM} is an accelerometer-based measurement of external load in team sport that measures movements in all three axes (vertical, horizontal and forward), whereas Playerload^{TM} 2D excludes the vertical axis. High intensity events (HIE) is the combination of acceleration, decelerations and change of direction performed at various intensities. Locomotive measurements include Total distance (TD) i.e. the total distance ran during the measured period, Meter per minute which is an average of meters ran per minute and Low intensity running (LIER) i.e. running performed at intensity lower than (11.0 km/).

In order to assess the equality of variances within the data set, a Levens test was performed. A Levens test is used to determine the variation within a set of data, statistical significance is set to $p < 0.05$ where a significant result would indicate that there is a significant difference in the variation between the two variables[16]. It is important to highlight that a Levens test has been performed on all the measurements, and that there has been used no other statistical analysis on any of the other variables, i.e. comparison of the mean, SD or CV.

Data has been presented for the entire team, for the individual athletes during 3 vs. 3 and 6 vs. 6. Furthermore, the dataset has been divided to demonstrate the intensity occurring during the various formats based on the order that they were performed in during a training session. During this process some of the athletes had too few sessions measured and couldn't be included in the data set. As such when data are presented for the various formats in session order, it includes two less athletes compared to when its presented either individually or for the entire team.

RESULTS

Playerload^{TM}, Playerload^{TM} 2D, HIE total and LIER all demonstrated significant variance in intensity when 3 vs. 3 and 6 vs. 6 was compared (table 1). There was a tendency towards that 3 vs. 3 demonstrated a higher variation in intensity when compared to 6 vs. 6 (table 1). All the HIE variables demonstrated a high coefficient of variation (CV) compared to Playerload^{TM}, Playerload^{TM} 2D, TD, Meter per minute and LIER.

Table 1: *Mean coefficient of variation for all athletes during 3 vs. 3 and 6 vs. 6 with the p value obtained from the Levens test when 3 vs. 3 and 6.vs 6 were compared towards each other.*

	CV		p value
	6 vs 6	3 vs 3	
Playerload^{TM} (AU)	12,5	15,9	0.01
Playerload^{TM} 2D (AU)	12,8	16,2	0.02
HIE Low (M)	28,5	28,2	0.01
HIE Medium (M)	45,5	42,0	0.40
HIE High (M)	99,0	79,8	0.49
HIE Total (M)	25,7	25,1	0.01
Total distance (M)	10,7	13,5	0.21
Meter / Min	10,7	13,5	0.21
LIER (M)	10,2	13,3	0.05

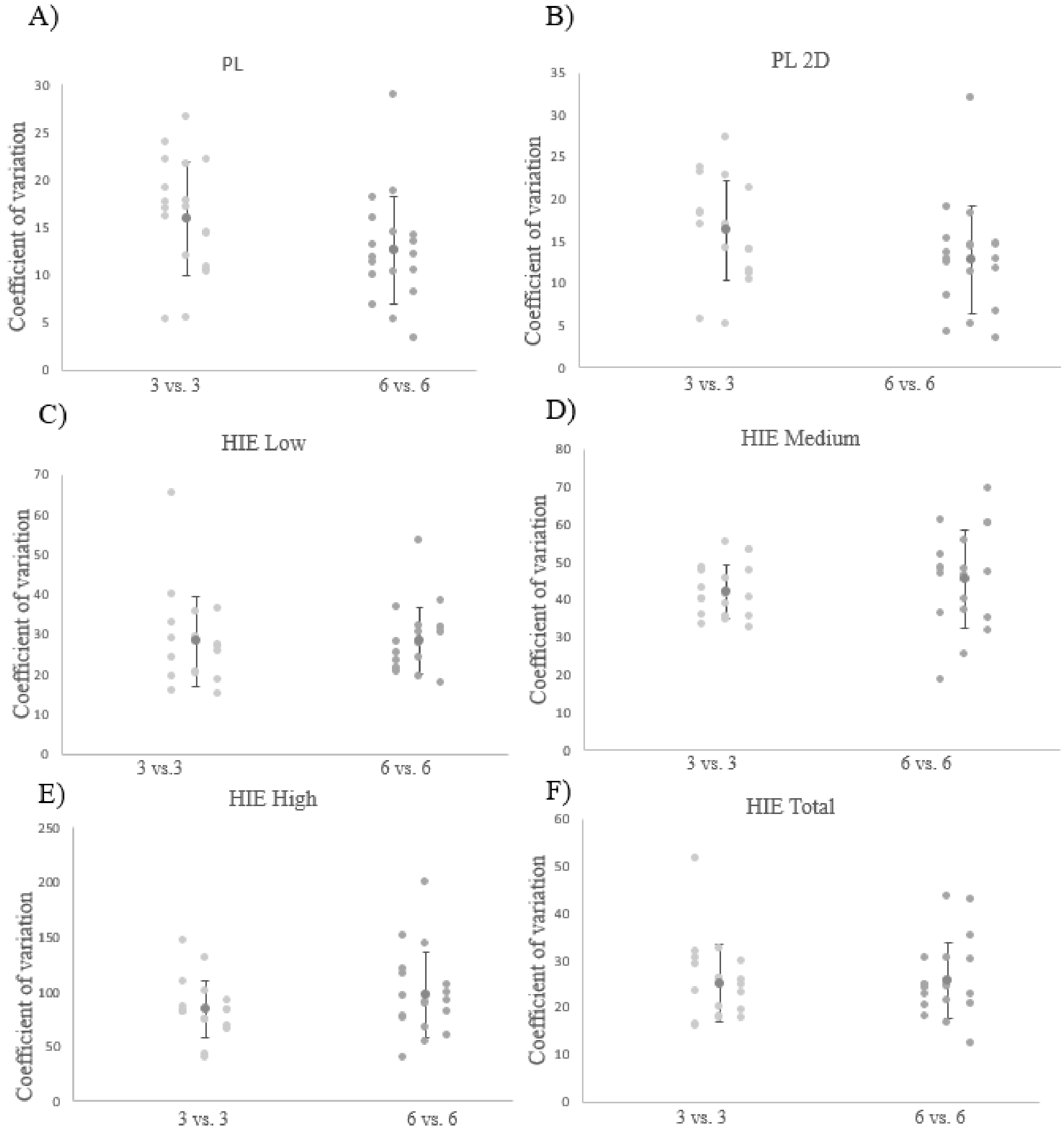
Small changes were observed for Playerload^{TM} and Playerload^{TM} 2D during the two formats, where the highest percent change was observed for the HIE measurements (table 2). It is therefore likely that 3 vs.3 consists of a higher number of accelerations, decelerations and changes of direction compared to 6 vs. 6. Furthermore, players seem to cover longer distances during 6 vs.6 when compared to 3 vs. 3 and spend more time at lower intensities during 6 vs.6 compared to 3 vs.3 (table 2).

Table 2: *Mean and standard deviation for all athletes during 3 vs.3 and 6 vs. 6 and the percentage of change in intensity for 3 vs. 3 and 6 vs. 6.*

	Mean + SD		% change
	6 vs 6	3 vs 3	
Playerload^{TM}	35.5± 4.4	37.0± 5.7	4 %
Playerload^{TM} 2D	23.0± 2.9	24.4± 3.0	6 %
HIE Low (M)	21.9± 6.1	30.2± 7.3	27 %
HIE Medium (M)	4.4± 1.9	5.2± 2.7	17 %
HIE High (M)	1.2± 1.1	1.5± 1.1	19 %
HIE Total (M)	27.5± 6.8	37.1± 7.7	26 %
Total distance (M)	308.8± 32.6	285.9± 36.8	8 %
Meter / Min	77.2± 8.1	71.4± 9.2	8 %
LIER (M)	299.2± 29.9	281.3± 36.2	6 %

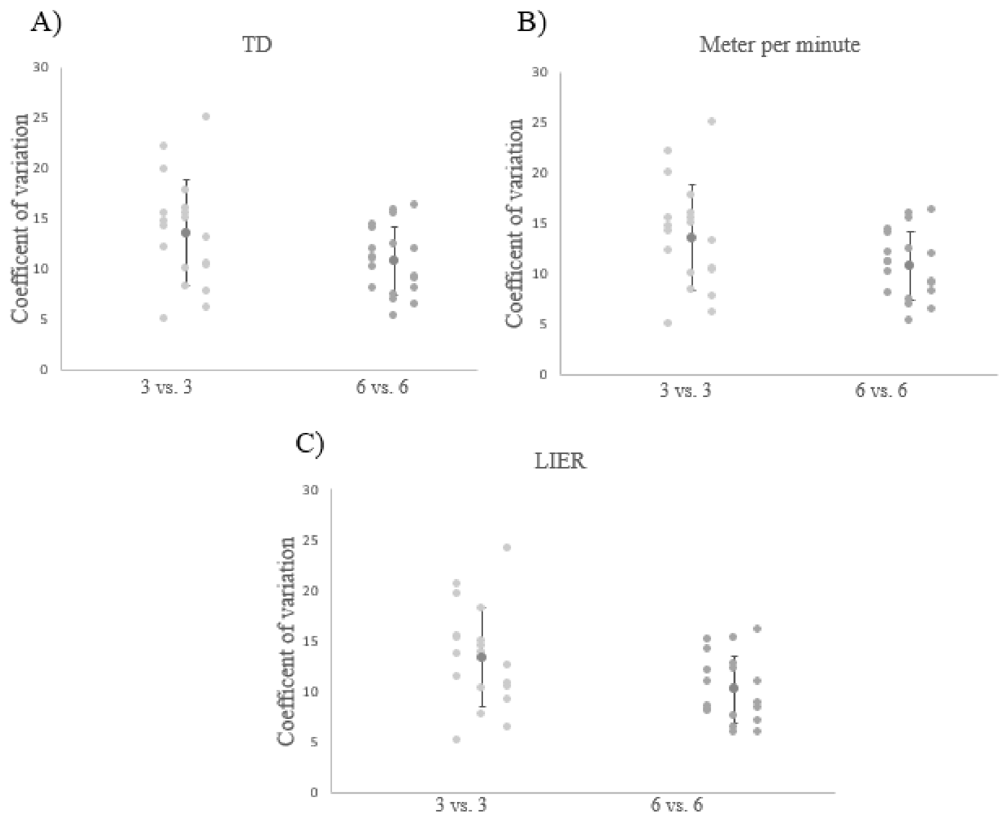
When Playerload^{TM} and Playerload^{TM} 2D are considered there was a tendency towards a larger individual variation in intensity for 3 vs. 3 compared to 6 vs. 6 (figure 1a,b) Furthermore, the intensity demonstrated in HIE low seems to be more evenly distributed across both formats (figure 1c). 6 vs. 6 demonstrated a larger variation in intensity for the

***Figure 1**: The individual coefficient of variation for Playerload^{TM}, Playerload^{TM} 2D, HIE low, HIE Medium, HIE high and HIE total for all athletes during 3 vs. 3 and 6 vs. 6.*



individual athletes when 6 vs. 6 is compared to 3 vs. 3 for HIE medium, HIE high and HIE total with the largest variation demonstrated for HIE medium (Figure 1d, e, f). 3 vs. 3 demonstrated a larger variation in intensity for the individual athletes when compared with 6 vs. 6 for Total distance (TD), Meter per minute and LIER (figure 2a, b, c). The variation showed a tendency towards similarity for all three variables.

Figure 2: *The individual coefficient of variation for TD, Meter per minute and LIER for all athletes during 3 vs. 3 and 6 vs. 6.*



A significant difference is observed for Playerload^{TM} and Playerload^{TM} 2D for 6 vs.6 when period 1 is compared to period 4 which demonstrated a higher variation in intensity for period 1 (table 3). LIER demonstrated a significant difference in variation for both 6 vs. 6 and 3 vs. 3 when period 1 is compared to period 4 (table 3). When 6 vs.6 is considered the variation is demonstrated as less during period 4 whereas for 3 vs. 3 there was a higher variation during period 4 (table 3). Furthermore, there was a tendency towards a larger variation in intensity for period 1 vs 4 during 3 vs. 3 based on observations made for Playerload^{TM}, HIE high, HIE total, TD and LIER (table 3).

Exercise intensity demonstrated a tendency towards being maintained across all four periods

***Table 3**: The coefficient of variation for all athlete during period 1,2,3 and 4 for both 3 vs.3 and 6 vs. 6 with the significant results from levens test demonstrated as x^{*x}.*

	6vs6				3vs3			
Period	1	2	3	4	1	2	3	4
Playerload^{TM} (AU)	12.3^{*4}	9.8	12.0	7.9^{*1}	9.9	9.3	18.6	16.2
Playerload^{TM} 2D (AU)	23.7^{*4}	24.2	22.8	23.1^{*1}	24.4	25.2	24.8	24.6
HIE Low (M)	23.2	23.0	20.6	21.7	18.0	17.6	13.6	25.1
HIE Medium (M)	39.5	25.8	35.4	33.7	39.6	22.1	27.9	28.3
HIE High (M)	63.6	70.2	88.7	80.7	62.4	55.2	72.2	75.8
HIE Total (M)	20.0	13.7	23.5	18.7	14.9	14.3	25.2	24.2
Total distance (M)	82.7	75.8	77.0	49.6	64.0	9.8	61.8	84.3
Meter / Min	9.3	8.3	8.5	6.9	9.6	9.8	9.9	12.8
LIER (M)	10.2^{*4}	8.3	10.9	8.0^{*1}	10.0^{*4}	14.1	14.1	14.7^{*1}

during 3 vs. 3, this was mainly demonstrated through the mean of each variable having almost the same average result from each period with modest changes from period to period (table 4). A different tendency was demonstrated for 6 vs. 6, most variables demonstrated a decreased in intensity when the mean from each variable was accounted for. It is therefore likely that there is a tendency towards that players were able to better maintain exercise intensity during 3 vs.3 when compared to 6 vs. 6 (table 4).

***Table 4:** Mean and standard deviation for all athletes during period 1,2,3 and 4 for both 3 vs. 3 and 6 vs. 6.*

	6vs6				3vs3			
Period	1	2	3	4	1	2	3	4
Playerload^{TM} (AU)	36.7±4.8	37.0±3.9	35.3±5.9	31.8±3.5	36.9±4.6	38.3±4.5	37.4±7.5	37.1±5.8
Playerload^{TM} 2D (AU)	23.7±3.31	24.1±2.7	22.8±3.7	20.5±2.1	24.4±3.0	25.1±2.8	24.8±5.1	24.6±3.9
HIE Low (M)	23.2±5.72	22.3±4.4	20.6±4.4	19.5±5.1	31.2±7.3	32.0±6.7	30.3±7.1	29.8±8.4
HIE Medium(M)	4.6±1,95	4.7±1.9	4.5±4.4	3.4±1.6	5.4±2.7	5.4±1.6	5.3±1.8	7.0±2.2
HIE High (M)	1.7±1.05	1.1±0.5	1.2±1.0	1.0±0.8	1.5±1.1	1.5±1.1	1.5±0.8	1.7±1.1
HIE Total (M)	29.5±6.41	28.7±4.7	26.2±7.6	24.5±6.0	38.1±7.7	38.9±7.0	37.0±9.7	36.9±10.1
Total distance (M)	308.7±32.97	322.1±29.9	322.0±30.4	278.1±27.3	277.9±36.8	294.4±36.4	293.5±36.8	285.5±37.0
Meter / Min	77.2±8.24	80.5±7.4	80.5±7.6	69.5±6.8	69.5±9.2	73.6±9.1	73.4±9.2	71.4±9.3
LIER (M)	300.3±34.12	293.9±31.9	293.9±31.9	268.6±32.2	273.2±36.2	283.5±44.3	283.5±44.3	281.4±45.2

DISCUSSION

This study aimed to investigate the variation in intensity during various formats of SSG in youth footballers measured via GPS-TD. The main findings of the current study indicate that the variation demonstrated during 3 vs. 3 is larger when compared to 6 vs. 6 for both the within-athlete and between-athlete comparisons. This is mainly demonstrated through a significant variation in Playerload™, Playerload™ 2D, HIE total and LIER for within-athlete and via a larger observed between-athlete variation for Playerload™, Playerload™ 2D. The findings for within-athlete data are expected and are similar to findings indicating that a lower player number will demonstrate higher intensity during SSG.[12,14,17] It is however in contrast with research suggesting that increasing individual pitch area will increase intensity, primarily demonstrated through higher blood lactate concentration, heart rate and RPE.[18,19] Furthermore, one of the studies also demonstrated increased TD covered at low (7.0-12.9 km/h), medium (13.0-17.9 km/h) and high intensity running (>18 km/h)[19] and more time spent stationary/walking (0.0-6.9 km/h) during the smaller formats of SSG.[19] In our study the individual pitch area per player were 50 m^2 for 3 vs.3 and 64 m^2 for 6 vs.6, suggesting that intensity should have been higher for 6 vs.6 based on the individual pitch area. We believe that this is likely because 3 vs.3 consisted of a larger number of accelerations, decelerations and changes of direction compared to 6 vs. 6, and that players spend more time running longer distances at lower speeds when playing 6 vs. 6. Previous research has indicated that acceleration, deceleration and changes of direction elicit high metabolic demands even at low intensities and that these movements contributes considerably towards the total load of players.[1,5] Furthermore, the studies indicating higher intensity with increased pitch area per player did not have their players equipped with IMU units.[18,19] This can potentially explain our contrary findings, due to the fact that IMU units are more suitable for measuring sport specific movements at high intensities,[10,11] which can further explain why players spent more time walking/stationary in the investigated study.[19]

It is however important to note that our data indicated that the intensity during SSG demonstrated large variation when accelerations, decelerations and changes of directions are considered, this were demonstrated through a high CV for all HIE variables. Similar findings have been demonstrated where a lower mean for HIE has been observed compared to Playerload™. [7] This can be partially explained trough players being fatigued,[7] which could also explain why the current study demonstrated larger variation for HIE during all SSG formats, especially considering that the athletes were young recreational athletes, thus not able to maintain the same intensities as young professionals or adult professionals.

For within-athlete data a significant variation in intensity were observed for Playerload™ and Playerload™ 2D during 6 vs.6 when period 1 were compared to period 4 with a greater variation demonstrated during period 1. LIER also demonstrated a significant variation, with a lower variation during period 4 compared to period 1. This is in contrast to a study that demonstrated a decrease in intensity from period 1 to 4 when TD, TD in very high and high intensity were measured during 2 vs. 2, 3 vs. 3 and 4 vs. 4.[20] Furthermore, LIER demonstrated a significant variation during 3 vs.3 when period 1 is compared to period 4, with a lower variation observed during period 4.

Based on observations made in this study (table 4), it seems that players were able to maintain the intensity across periods during 3 vs. 3. This is in contrast to similar studies which indicated that intensity is reduced from period 1 to 4 during SSG (5 vs. 5) when frequency of sprints, metabolic power, TD, accelerations and decelerations were considered.[21] This is also similar to our findings for 6 vs. 6, where a reduction in intensity were observed from period 1 to 4 for all variables measured (table 4). Based on our findings and previous research, it is likely that player number is a determining factor in regulating both intensity during SSG and observed variation between sessions.[20] It is likely that player number is able to influence factors such as frequency of HIE, rest period between HIE, number of ball possessions and technical actions resulting in higher physical demands.[14,20,22]

The between-athlete variation was as previously stated higher for 3 vs. 3 when Playerload™, Playerload™ 2D, TD, Meter per minute and LIER were compared to 6 vs.6. However, the variation demonstrated for HIE, HIE High, and HIE total were higher during 6 vs. 6 compared to 3 vs.3 whereas HIE low seemed to be evenly distributed across both formats.
A higher variation in all HIE variables apart from HIE low during 6 vs.6 might suggest that players more often performed a more evenly distributed number of accelerations, decelerations and change of direction during 3 vs. 3 compared to 6 vs.6. Furthermore, the higher between-athlete variation observed during 3 vs.3 may suggest that players demonstrated different capabilities to maintain intensity during 3 vs.3 compared to 6 vs. 6. As 3 vs. 3 varied more when Playerload™, Playerload™ 2D, TD, Meter per minute and LIER was considered one could argue that the total variation in training load during 3 vs. 3 might be higher when

compared to 6 vs. 6. However, to our knowledge this is the first study investigating the between-athlete variation and clearly more research is needed in the area.

The main function of SSG within practice drills is to improve tactical and physiological components related to match specific activity within football.[14,23] During competitive games accelerations, deceleration and changes of directions plays a large impact towards the total load of players (15-17% of total load)[1]. As such our findings indicates that if the main goal is to develop increased ability to perform accelerations, decelerations and changes of direction 3 vs. 3 might be a suitable option. Interestingly, players were unable to achieve sprint speeds higher than 15 km/h during the current study in any of the formats. As the ability to perform sprints, repeated sprints and high intensity running is believed to be important in order to achieve optimal performance[24] our findings indicate that SSG are not suitable if this is the goal for the session for the investigated age group.

LIMITATIONS

The subjects used in the current study were recreational athletes, it is therefore likely that they are not able to display similar physical characteristics when compared to professional athletes.[25] Furthermore, we did not perform any physiological measurement of the players physical capabilities, as such we are not able to determine their level of physical ability. The technical and tactical abilities of the players in the current study also varied considerably which led to some subjects being more involved in the session compared to others. However, we believe that this would be natural for the current subject group. The monitored session per athlete also varied considerably, with the lowest monitored periods being four and the highest being fourteen giving us an average of 8 ± 3. This has led to certain athletes contributing more to the data set compared to others, which potentially can affect the results.

PRACTICAL IMPLICATIONS

Coaches and support staff should be aware that 3 vs. 3 demonstrates larger variation in intensity when compared to 6 vs. 6. As such it would possibly be harder to manage and control training load/ training intensity when utilizing 3 vs. 3 within training drills compared to 6 vs. 6. If the main goal is to improve players ability to successfully perform accelerations, deceleration and changes of direction one should incorporate 3 vs. 3 as a SSG format within training drills, if the main desire is to spend more time at lower intensities over longer distance 6 vs. 6 is the most suitable option. It is likely that 3 vs. 3 is more physical demanding to perform for players and will impose a larger amount of fatigue. Player number and pitch area are likely to be the factors which influences intensity during SSG the most and should be controlled for when planning a training session. Previous research has highlighted the impact rules changes have on intensity, often demonstrated via higher intensity during possession play, playing without goals and goalkeepers and through other various rules within SSG training drills.[17,26] Based on our findings and previous research we recommend that future research should investigate how various rule changes impact the variation in intensity when player number and pitch area is held constant.

CONCLUSION

During various formats of SSG training drills 3 vs. 3 demonstrates larger variation in intensity when compared to 6 vs.6. Furthermore, 3 vs. 3 is likely to contain a larger number of accelerations, deceleration and changes of direction contributing to a larger physical demand compared to 6 vs. 6. More research is needed regarding the influence rule changes have on intensity during SSG. Furthermore, the between-athlete variation in intensity clearly needs more investigation, as there is a current lack in the field when this is considered.

ACKNOWLEDGEMENTS

The authors would like to extend their gratitude towards all the people involved in the research project, especially the subjects for their time and effort. The authors have no conflict of interests.

REFERENCES:

1. Dalen T, Jørgen I, Gertjan E, Havard HG, Ulrik W. Player load, acceleration, and deceleration during forty-five competitive matches of elite soccer. *The Journal of Strength & Conditioning Research.* 2016;30(2):351-359.
2. Bradley PS, Di Mascio M, Peart D, Olsen P, Sheldon B. High-intensity activity profiles of elite soccer players at different performance levels. *The journal of strength & conditioning research.* 2010;24(9):2343-2351.
3. Gabbett TJ, Mulvey MJ. Time-motion analysis of small-sided training games and competition in elite women soccer players. *The Journal of Strength & Conditioning Research.* 2008;22(2):543-552.

4. Scott BR, Lockie RG, Knight TJ, Clark AC, de Jonge XAJ. A comparison of methods to quantify the in-season training load of professional soccer players. *International journal of sports physiology and performance.* 2013;8(2):195-202.
5. Osgnach C, Poser S, Bernardini R, Rinaldo R, Di Prampero PE. Energy cost and metabolic power in elite soccer: a new match analysis approach. *Med Sci Sports Exerc.* 2010;42(1):170-178.
6. Akenhead R, French D, Thompson KG, Hayes PR. The acceleration dependent validity and reliability of 10 Hz GPS. *Journal of Science and Medicine in Sport.* 2014;17(5):562-566.
7. Luteberget LS, Trollerud HP, Spencer M. Physical demands of game-based training drills in women's team handball. *Journal of sports sciences.* 2018;36(5):592-598.
8. Cummins C, Orr R, O'Connor H, West C. Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports medicine.* 2013;43(10):1025-1042.
9. Jennings D, Cormack S, Coutts AJ, Boyd L, Aughey RJ. The validity and reliability of GPS units for measuring distance in team sport specific running patterns. *International journal of sports physiology and performance.* 2010;5(3):328-341.
10. Boyd LJ, Ball K, Aughey RJ. The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *International journal of sports physiology and performance.* 2011;6(3):311-321.
11. Malone JJ, Barrett S, Barnes C, Twist C, Drust B. To infinity and beyond: the use of GPS devices within the football codes. *Science and Medicine in Football.* 2019:1-3.
12. Hill-Haas SV, Dawson BT, Coutts AJ, Rowsell GJ. Physiological responses and time–motion characteristics of various small-sided soccer games in youth players. *Journal of sports sciences.* 2009;27(1):1-8.
13. Dellal A, Owen A, Wong DP, Krustrup P, van Exsel M, Mallo J. Technical and physical demands of small vs. large sided games in relation to playing position in elite soccer. *Human movement science.* 2012;31(4):957-969.
14. Hill-Haas SV, Dawson B, Impellizzeri FM, Coutts AJ. Physiology of small-sided games training in football. *Sports medicine.* 2011;41(3):199-220.
15. Declaration H. The Final Act of the Conference on Security and Cooperation in Europe. 1975.

16. Vorapongsathorn T, Taejaroenkul S, Viwatwongkasem C. A comparison of type I error and power of Bartlett's test, Levene's test and Cochran's test under violation of assumptions. *Songklanakarin J Sci Technol.* 2004;26(4):537-547.
17. Castellano J, Casamichana D, Dellal A. Influence of game format and number of players on heart rate responses and physical demands in small-sided soccer games. *The Journal of Strength & Conditioning Research.* 2013;27(5):1295-1303.
18. Rampinini E, Impellizzeri FM, Castagna C, et al. Factors influencing physiological responses to small-sided soccer games. *Journal of sports sciences.* 2007;25(6):659-666.
19. Casamichana D, Castellano J. Time–motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *Journal of sports sciences.* 2010;28(14):1615-1623.
20. Dellal A, Drust B, Lago-Penas C. Variation of activity demands in small-sided soccer games. *International journal of sports medicine.* 2012;33(05):370-375.
21. Moreira A, Aoki MS, Carling C, et al. Temporal changes in technical and physical performances during a small-sided game in elite youth soccer players. *Asian journal of sports medicine.* 2016;7(4).
22. Dellal A, Hill-Haas S, Lago-Penas C, Chamari K. Small-sided games in soccer: amateur vs. professional players' physiological responses, physical, and technical activities. *The Journal of Strength & Conditioning Research.* 2011;25(9):2371-2381.
23. Halouani J, Chtourou H, Dellal A, Chaouachi A, Chamari K. The effects of game types on intensity of small-sided games among pre-adolescent youth football players. *Biology of sport.* 2017;34(2):157.
24. Haugen TA, Tønnessen E, Seiler S. Anaerobic performance testing of professional soccer players 1995–2010. *International Journal of Sports Physiology and Performance.* 2013;8(2):148-156.
25. Gissis I, Papadopoulos C, Kalapotharakos VI, Sotiropoulos A, Komsis G, Manolopoulos E. Strength and speed characteristics of elite, subelite, and recreational young soccer players. *Research in sports Medicine.* 2006;14(3):205-214.
26. Köklü Y, Sert Ö, Alemdaroglu U, Arslan Y. Comparison of the physiological responses and time-motion characteristics of young soccer players in small-sided games: The effect of goalkeeper. *The Journal of Strength & Conditioning Research.* 2015;29(4):964-971

PART 3:

Appendices

Espen Gabrielsen Johnsen

University of Agder

APPENDIX 1: Participation letter

Vil du delta i forskningsprosjektet?
Økt forståelse av sammenhengen mellom Lokomotiv og akselerasjons målingers evne til og måle arbeidsbelastning

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å øke forståelsen av sammenhengen mellom tradisjonelle lokomotive målinger fra GPS og akselerasjons målingers samlet inn fra akselerometer, gyroskoper og magnetometer, samt deres evne til og måle og kontrollere arbeidsbelastning. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg

Formål:
I dag bruker flere og flere profesjonelle idrettsklubber måleinstrumenter som blir brukt analysere og overvåke arbeidsbelastning til spillere i form av lokomotiv data som antall total distanse løpt, total distanse løpt under ulike hastigheter og gjennomsnitts hastighet samt måler som akselerasjoner/deselerasjon, retningsforandringer.
Målet med monitorering av arbeidsbelastning er å kunne bistå trenere og andre personer tilknyttet til trener staben til og ytterligere forstå den totale treningsbelastningen til spillere samt deres tilgjengelighet rundt trening og kamper. Tidligere forskning har funnet at spillere blir utsatt for økt intensitet under småspill i firkanter der de spiller 3 mot 3 sammenlignet med 6 mot 6 eller 11 mot 11, noe som indikerer at intensiteten økes ved småspill der det er færre deltakere enn ved flere deltakere. Hensikten med småspill er først og fremst å simulere de mest intense periodene som forekommer under kamp, det finnes også noe indikasjoner på at småspill med begrenset område og få deltakere øker tekniske ferdigheter grunnet økt eksponeringstid med ballen. Det ser ut til at størrelsen på området spillerne har indikerer enten økt eller redusert intensitet. Hensikten med studiet er å utforske to ulike måleinstrumenters evne samt relasjonen mellom disse to måleinstrumentenes evne til og fange opp og måle arbeidsbelastning. De to måleinstrumentene er en GPS-måleenhet og en innebygd sensor i målenheten. Dette er en Mastergradsoppgave ved Universitet i Agder.

Hvem er ansvarlig for forskningsprosjektet?

Universitet i Agder er ansvarlig for prosjektet, prosjektet utføres av:
Espen Johnsen (Mastergrad student)
Matthew Spencer (Professor)

Hvorfor får du spørsmål om å delta?
Du får spørsmål om å delta ettersom du er i den aktuelle aldersgruppen vi ønsker og utforske (ungdommer). Du og dine lagkamerater ble først og fremst invitert og delta ettersom Universitet har kontakter rundt laget som gjorde dette samarbeidet mulig.

Hva innebærer det for deg å delta?
Deltakerne vil bli utstyrt med en tettsittende vest utstyrt med måleinstrumentet som de skal ha på seg under treningsdrakten hvor måleinstrumentet vil bli festet. Under hele testingen skal deltakerne ha på seg denne vesten som sender signaler til en pc utstyrt med programvaren fra leverandøren av disse vestene og måleinstrumentet.

10-12 treningsøkter vil bli monitorert av kvalifisert forskningspersonell, deltakerne vil bli eksponert for en variant av småspill som vil ha ett begrenset område som deltakerne kan bevege seg på. Deltakerne vil utføre en standardisert oppvarming hver gang som vil si at den samme oppvarmingen vil bli brukt for alle 10 treningsøkten. Forskningspersonellet vil også være til stedet under 3-4 kamper hvor deltakerne vil bruke de samme vestene og arbeidsbelastning vil bli målt ved hjelp av måleinstrumentene. Reglene for småspill formatet vil være likt som under kamp, å trenere vil bli oppfordret til og heie og instruere spillere akkurat slik de ville gjort normalt under både trening og kamp.

Dataen som forskningspersonellet innhenter vil brukt til og besvare hensikten med studiet og vil kun bli brukt i denne sammenhengen. Videre vil resultatene av studien kunne bidra til at trenere, forskere samt utøvere vil kunne få en økt forståelse av måleinstrumentenes evne til å måle arbeidsbelastning samt øke forståelsen av hvordan en kan optimalisere bruken av dem. Dette vil videre kunne gi en økt kunnskap om optimalisering av treningsbelastning for å potensielt øke prestasjon under kamp samt forebygge eventuelle belastningsskader.

Studien innebærer at deltakeren møter opp som normalt til trening, treningen vil bli planlagt av forskere og trenere for at det skal bli litt mer kontrollert, men vil tilnærmet lik den normale treningen. Videre må deltakerne ha på seg vesten under trening samt mota instruksjoner fra forskningspersonellet.

Fordeler ved deltakelse

Trener og utøver vil dersom ønskelig få tilgang til forskningsresultatene når disse er klare. Dette vil kunne gi både trener og utøver en bedre forståelse av den totale arbeidsbelastningen relatert til kamp og trening både individuelt og posisjon spesifikt. Dette vil kunne optimalisere fysisk prestasjon og forebygge eventuelle skader.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om deg vil da bli avidentifisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Dine opplysning kun bli brukt slik som den står beskrevet i hensikten til studiet. All informasjon vil bli avidentifisert i form av at deltakeren får oppgitt et nr istedenfor navn og ingen personlig informasjon vil bli oppgitt når forskningsprosjektet ferdigstilles og blir publisert for befolkningen. Det vil kun være forskningspersonellet som kjenner til deltakerens identitet og all informasjon vil bli lagret på en trygg plass som er passord beskyttet og kun personer involvert i prosjektet vil ha tilgang til den personlige informasjonen. En koblingsnøkkel vil bli brukt slik at forskningspersonellet kan identifisere personer i forskningsprosjektet. Så lenge du kan identifiseres i datamaterialet har du rett på følgende: Innsyn i hvilke personopplysninger som er registrert om deg, å få rettet personopplysninger om deg, få slettet personopplysninger om deg, få utlevert en kopi av dine personopplysninger samt sende klage til personvernombudet eller datatilsynet om behandlingen av dine personopplysninger. Prosjektet er meldt til personvernombudet for forskning, norsk senter for forskningsdata. Avidentifisert data som er innhentet i studien vil i hovedsak bli benyttet i vitenskapelige artikler, men vil også kunne bli presentert på nasjonale og internasjonale konferanser og seminarer. Det er viktig og presisere at det vil aldri bli publisert personlig informasjon i verken vitenskapelig artikler eller på konferanser eller seminarer. Det vil kun være forskningspersonellet som vil vite din identitet.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Koblingsnøkkelen vil bli slettet ved prosjektslutt som er estimert til og være Mai 2020.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

Espen Johnsen (Mastergrad student), Universitet i Agder: espegj13@uia.no, Tel: 90251616

Matthew Spencer (Professor), Universitetet i Agder: matthew.spencer@uia.no, Tel:98404378

Ina Danielsen (vårt personvernombud), Universitetet i Agder: ina.danielsen@uia.no, Tel: 452 54 401

NSD – Norsk senter for forskningsdata AS, på e-post personverntjenester@nsd.no eller Tel: 55 58 21 17

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *[Relationship between traditional locomotive and inertial sensor variables of GPS tracking devices in typical training drills and match data in youth football players]*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i *Forskningsprosjektet*
- ☐ å delta i *Observasjon og monitorering av arbeidsbelastning hvor det brukes GPS sporings enheter integrert med gyroskoper, magnetometre og akselerometre.*

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet, ca. *2020-2021*

(Signert av prosjektdeltaker/foresatte, dato)

APPENDIX 2: NSD APPROVAL

NORSK SENTER FOR FORSKNINGSDATA

NSD's assessment

Project title

Relationship between traditional locomotive and inertial sensor variables of GPS tracking devices in typical training drills and match data in youth football players.

Reference number

530736

Registered

03.09.2019 av Matthew Ronald Spencer - matthew.spencer@uia.no

Data controller (institution responsible for the project)

Universitetet i Agder / Fakultet for helse- og idrettsvitenskap / Institutt for folkehelse, idrett og ernæring

Project leader (academic employee/supervisor or PhD candidate)

Matthew Spencer, matthew.spencer@uia.no, tlf: 98404378

Type of project

Student project, Master’s thesis

Contact information, student

Espen Gabrielsen Johnsen, espegj13@student.uia.no, tlf: 90251616

Project period

14.10.2019 - 31.05.2020

Status

18.09.2019 - Assessed

Assessment (1)

18.09.2019 - Assessed

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet

med vedlegg den 18.09.2019, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde:

https://nsd.no/personvernombud/meld_prosjekt/meld_endringer.html

Du må vente på svar fra NSD før endringen gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 31.05.2020.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake. Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke behandles til nye, uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).

NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

Catapult Sports er databehandler i prosjektet. NSD legger til grunn at behandlingen oppfyller kravene til bruk av databehandler, jf. art 28 og 29.

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og/eller rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Kontaktperson hos NSD: Karin Lillevold
Tlf. Personverntjenester: 55 58 21 17 (tast 1)