UNIVERSIDADE
BEIRA INTERIOR

Effects of bout duration on players internal and external loads during small-sided games in soccer

Luís Filipe Cardoso Branquinho

Tese para obtenção do Grau de Doutor em
Ciências do Desporto
(3º ciclo de estudos)

Orientador: Prof. Doutor Mário António Cardoso Marques
Co-orientador: Prof. Doutor Ricardo Manuel Pires Ferraz

7 de junho de 2021

Provas publicas de defesa de Doutoramento realizadas a 31 de maio de 2021 na Universidade da Beira Interior, Covilhã, Portugal

Presidente do Júri:
Professor Doutor Mário António Cardoso Marques

Arguentes:
Professor Doutor Francisco José Bessone Ferreira Alves
Professor Doutor António José Barata Figueiredo
Professor Doutor Júlio Manuel Garganta da Silva
Professor Doutor Daniel Almeida Marinho
Professor Doutor Ricardo Manuel Pires Ferraz

“Clear eyes, full hearts, can't lose”
To my parents José Luis e Jacinta,
my brother Diogo and my fiancée Ana

Academic thesis submitted with the purpose of obtaining a doctoral degree in Sport Sciences according to the provisions of Portuguese Decree-Law 107/2008 of 25 June.

Acknowledgments

It was five years of an adventure of self-discovery and growth, on a personal and professional level. It was a motivating journey, and perhaps the biggest challenge I faced. I reach the end of this journey, with the full certainty that the best is yet to come, but I can not fail to thank and acknowledge the importance of all those who contributed to the conclusion of this doctoral thesis, special thanks to:

Professor Mário C. Marques, for supervision, guidance, counseling and all the support. Thank you for all the shared knowledge, patience, understanding, trust and friendship over the past 13 years. Much of what I am today I owe you! Thank you, Great Master!

Professor Ricardo Ferraz, for supervision, guidance, counseling and all the support. None of this would have been possible without you, thank you for all the sharing moments, for always being available at all hours, for the constant encouragement, friendship and for believing in me.

To all my co-authors for their help and collaboration.

To the clubs, coaches and players for having participated in the experimental procedures.

To my friends, for always encouraging me!

To my parents, José Luís and Jacinta, for having made it possible for me to get so far, for being my support, for always encouraging me, you are my pride. I can never thank you enough!!

To my brother Diogo, for all the support, encouragement and for always being there when needed. We are together!!

To my beautiful wife, for her tireless support, for being what I need, for encouragement and for your understanding at all times. You are the best!

List of Publications

This Doctoral Thesis is supported by the following papers:

- **Branquinho, L.,** Ferraz, R. & Marques, M.C (2020). The continuous and fractionated game format on the training load in Small Sided Games in soccer. *The Open Sports Science Journal,* 13(1),81-85. doi: 10.2174/1875399X02013010081

- **Branquinho, L**., Ferraz, R., Travassos, B., & Marques, M.C (2020). Comparison between Continuous and Fractionated Game Format on Internal and External Load in Small-Sided Games in Soccer. *International journal of environmental research and public health*, *17*(2), 405. https://doi.org/10.3390/ijerph17020405.

- **Branquinho, L**., Ferraz, R., Travassos, B., Marinho, D.A, & Marques, M.C (2020). Comparison between different recovery times on internal and external load in small-sided games in soccer. *Sports Health*. doi: 10.1177/1941738121995469

- **Branquinho, L**., Ferraz, R., & Marques, M.C (2020). The role of 5-a-side game format in soccer training: Theoretical concerns and practical applications. *Strength and Conditioning Journal*. doi:10.1519/SSC.0000000000000629

Beyond these papers, some presentations conducted as a preliminary approach to soccer performance:

- **Branquinho, L.,** Ferraz, R., Travassos, B., & Marques, M.C (2019). Prescription and monitoring of internal and external load in SSG's: A comparison between the continuous method and fractional method. Revista Motricidade 15(s1), 97. http://dx.doi.org/10 6063/motricidade.16967. CIDESD 2019 Internacional Congress. Instituto Universitário da Maia (ISMAI). Oral Presentation

- **Branquinho, L.,** Ferraz, R., Marinho, D.A, & Marques, M.C (2020). Comparison between different recovery times on internal and external load in small-sided games in soccer. *Research in sports science inside the social sciences framework*. Costa Blanca Sports Science Events – Summer Event. Alicante, Spain. (E-poster)

Abstract

The evolution observed in soccer over the last years has led to an increase in the physical and metabolic demands required during a game. To prepare players for these demands, coaches must prescribe high-intensity training stimuli, which follow the modern competition's requirements. Thus, selecting the appropriate form, duration, and recovery time of exercises, with the objective of controlling training load, is regarded as a task of vital importance for the enhancement and development of capacities during the training process. Therefore, the general objective of this thesis was to identify which form, duration, and recovery time of a specific training exercise allowed male soccer players to reach and maintain higher training loads. To achieve the proposed objectives, the following sequence of work was conducted: (i) review of the literature on the proposed theme, (ii) comparison between the use of the continuous method or the fractionated method in the training load during the performance of small-sided games, and (iii) assessment of the impact of different recovery times on training load during small-sided games. The main evidence suggests that (i) exercises performed by the fractionated training method induce greater responses at the level of external load when compared to exercises performed by the continuous method; (ii) during the performance of small-sided games, the increase in the number of repetitions of the exercise (fractionated method) induces increases in the external load variables compared to the use of the continuous method; (iii) different recovery times for the same total exercise duration, induced differences in internal and external loads; iv) short recovery periods (i.e. 30 s) were sufficient to maintain high training loads compared to longer recovery periods (i.e. 1-2 min) during the performance of 5-a-side small-sided games v) the fractionated method should be used if the trainer aims to induce high training loads during 5-a-side small-sided games, since the continuous method seems to have caused a decrease in the players physical and physiological responses. This thesis also allows the development of guidelines for the prescription and monitoring of training load in soccer, using small-side games.

Keywords

Soccer;training load;external load;internal load;continuous method;fractionated method;recovery time;fatigue;small-sided games manipulation.

Resumo

A evolução verificada durante os últimos anos no futebol, levou ao aumento das solicitações físicas e metabólicas requeridas durante um jogo. De modo a prepararem as equipas para estas exigências, os treinadores devem prescrever estímulos de treino de alta intensidade, que acompanhem a exigência da competição. Assim, a escolha adequada da forma, duração e tempo de recuperação do exercício, com o objetivo de controlar a carga de treino, assumem-se como tarefas de vital importância para a potenciação e desenvolvimento das capacidades durante o processo de treino. Consequentemente, o objetivo geral desta tese foi identificar de que forma, a duração e o tempo de recuperação de um exercício específico de treino permitem atingir e manter cargas de treino mais elevadas em jogadores de futebol masculino. De modo atingir os objetivos propostos foi utilizada a seguinte sequência de trabalho: (i) revisão da literatura sobre o tema proposto, (ii) comparação entre a utilização do método continuo ou do método fracionado na carga de treino durante a realização de jogos reduzidos, (iii) impacto de diferentes tempos de recuperação na carga de treino durante a realização de jogos reduzidos. As principais evidências sugerem que: (i) exercícios realizados pelo método de treino fracionado induziram maiores respostas ao nível da carga externa quando comparados aos exercícios realizados pelo método contínuo; (ii) distintos tempos de recuperação para a mesma duração total do exercício, induziram diferenças nas respostas de cargas interna e externa de treino; iii) períodos curtos de recuperação (i.e., 30 s) foram suficientes para manter elevadas as cargas de treino em comparação com períodos de recuperação mais longos (i.e., 1-2 min) durante o desempenho de jogos reduzidos no formato 5 contra cinco iv) o método fracionado deve ser usado se o treinador tiver como objetivo induzir elevadas cargas de treino durante jogos reduzidos de 5 contra 5. Esta tese permite, igualmente, o desenvolvimento de diretrizes para a prescrição e monitorização da carga de treino no futebol através do uso de jogos reduzidos.

Palavras-Chave

Futebol;carga de treino;carga externa;carga interna;método continuo;método fracionado;tempo de recuperação;fadiga;manipulação de jogos reduzidos.

Resumen

La evolución observada durante los últimos años en el fútbol ha llevado a un aumento en las demandas físicas y metabólicas requeridas durante una partida. Para preparar a los equipos para estas demandas, los entrenadores deben prescribir estímulos de entrenamiento de alta intensidad, que acompañan el requisito de la competición. Así, la elección adecuada de la forma, duración y tiempo de recuperación del ejercicio, con el objetivo de controlar la carga de entrenamiento, se asume como misión de vital importancia para la potenciación y desarrollo de las capacidades durante el proceso de entrenamiento-. Así, el objetivo general de esta tesis fue identificar qué forma, duración y tiempo de recuperación de un ejercicio de entrenamiento específico permitió alcanzar y mantener cargas de entrenamiento más altas en jugadores de fútbol masculino. Para lograr los objetivos propuestos, se utilizó la siguiente secuencia de trabajo: (i) revisión de la literatura sobre el tema propuesto, (ii) comparación entre el uso del método continuo o el método fraccional en la carga de entrenamiento durante la ejecución de juegos reducidos, (iii) impacto de diferentes tiempos de recuperación en la carga de entrenamiento durante juegos reducidos. La evidencia principal sugiere que: (i) los ejercicios realizados por el método de entrenamiento fraccionado inducen mayores respuestas a nivel de carga externa en comparación con los ejercicios realizados por el método continuo; (ii) diferentes tiempos de recuperación para la misma duración total del ejercicio, indujeron diferencias en las cargas internas y externas; iii) los períodos de recuperación cortos (i.e., 30 s) fueron suficientes para mantener altas cargas de entrenamiento en comparación con los períodos de recuperación más largos (i.e., 1-2 min) durante la ejecución de juegos de 5 contra 5 en espacios reducidos iv) se debe utilizar el método fraccionado si el entrenador tiene como objetivo inducir cargas elevadas de entrenamiento durante el juego de 5 contra 5 en espacios reducidos. Esta tesis también permite el desarrollo de pautas para la prescripción y monitoreo de la carga de entrenamiento en el fútbol mediante el uso de juegos reducidos.

Palabras-clave

Fútbol;carga de entrenamiento;carga externa;carga interna;método continuo;método fraccional;tiempo de recuperación;fatiga;manipulación de juegos reducidos.

Table of Contents

Index of Figures

Chapter 3 Study 2.

Chapter 3. Study 3.

Chapter 3. Study 4.

Index of Tables

List of Abbreviations

ATP	Adenosine Triphosphate
Av. HR	Average heart rate
CL	Confidence limits
GPS	Global position system
GR	Goal Keeper
H^+	Hydrogen ions
HIT	High-intensity interval training
HR	Heart Rate
HR_{max}	Maximal heart rate
Max. HR	Maximal heart rate
Min	Minutes
PCr	Phosphocreatine
REST-Q	The recovery stress questionnaire for athletes
RPE	Rate perceived exertion
S	Seconds
SSG	Small-sided soccer games
SSGs	Small-Sided games
WIMUs	Wireless Inertial Motion Analysis Devices
VAS	Visual analogue scale
$VO_{2\ max}$	Maximum oxygen uptake

Chapter 1

General Introduction

Sports training is a long-term process that demonstrates a cause-effect relationship between load and adaptation (Smith, 2003). In particular, load priority for the preparation of soccer players should target the improvement of both individual and collective skills so that the team is more competitive; hence, one major goal of the coach is to improve the quality of the team's game simultaneously with the development of the team's physical condition (Reilly, 2005) since competitive soccer requires the execution of technical and tactical skills under great physical stress (Lago-Peñas et al., 2010).

Soccer players much achieve a high level of physical fitness through efficient training structures (Iaia et al., 2009), which allow the specific development of several physical qualities such as speed and endurance (Desgorces et al., 2007) to overcome the physical and physiological demands of the competition.

Soccer is an intermittent sport (Bangsbo, 1994) that involves multiple actions with high unpredictability. Each player must be prepared to react rapidly and efficiently throughout the match (Hazir, 2010). Furthermore, the majority of actions performed during the game are at a submaximal intensity, and the main metabolic pathway used is the aerobic system (Mohr et al., 2003; Reilly, 1997; Stølen et al., 2005). Although most actions are performed at a low-intensity pattern, players must also have a good anaerobic capacity for high-intensity movements, such as sprinting, sudden changes in direction, and constant accelerations or decelerations over small distances (Hoff et al., 2002). It is therefore relevant for soccer training to recreate the unstable, unpredictable, and dynamic nature of the game that is also representative of all competition requirements (Davids et al., 2013). According to the most recent literature, these standards can be achieved using small-sided games (SSGs) (Hill-Haas et al., 2011; Köklü, 2012).

The SSG is characterized as a modified game played in small areas, with adapted rules, and generally involves a small number of players (Hill-Haas et al., 2011). It allows the simultaneous enhancement of technical and tactical development with specific fitness capacities, such as endurance (aerobic and anaerobic), strength, and agility (Hill-Haas et al., 2009). It has been considered the best resource for building team play and one of the essential ways to improve all components of the game (Hammami et al., 2018; Hill-Haas et al., 2011).

In addition to replicating combinations of players' technical, tactical, and physical abilities as observed in full-sized matches (Bujalance-Moreno et al., 2019; Hill-Haas et al., 2011), several studies have shown that the manipulation of some variables during SSGs, like duration and the recovery periods between repetitions (i.e., the use of continuous or fractionated methods) (Hill-Haas et al., 2009; Köklü, Alemdaroğlu, Cihan, & Wong, 2017), previous information about duration (Ferraz, Gonçalves, Coutinho, et al., 2018; Ferraz, Gonçalves, Van Den Tillaar, et al., 2018), pitch size, number of players, coach encouragement, rules or the use of goalkeepers, and the knowledge of the duration of the exercise enable different intensities and different technical/tactical adaptations (Clemente et al., 2014; Ferraz, Gonçalves, Van Den Tillaar, et al., 2018; Köklü, Alemdaroğlu, Cihan, & Wong, 2017).

Regarding the manipulation of the number of players during SSGs, recent studies have shown that SSG formats with a different number of players induce distinct physiological, preceptive, and time movement requests (Hill-Haas et al., 2009; Katis & Kellis, 2009; Sampaio et al., 2007). Previous research has also shown (Hill-Haas et al., 2009; Katis & Kellis, 2009; Owen et al., 2004; Rampinini et al., 2007) that formats with a reduced number of players can induce higher heart rate (HR) responses compared to larger formats. The results of Clemente et al., (2014) indicate that the five-a-side format seems to be a viable option for high-intensity training similar to or greater than that required during the game. These researchers add that the five-a-side format is a good choice to induce important physiological responses similar to a real game situation (85% to 93% Maximal heart rate (max.HR). This idea is supported by other studies (Clemente et al., 2014; Little, 2009; Owen et al., 2004), which suggests that the five-a-side format can be used for high-intensity aerobic training involving repetitions of 4-6 min with 3-4 bouts. In addition, this format can be used to increase perceived exertion values compared to other formats (e.g., four-a-side and six-a-side formats) (Sampaio et al., 2014).

Regarding the duration of the exercise, the literature described that SSG performance for different periods of time using continuous or fractionated methods causes distinct changes in the training load (Köklü, Alemdaroğlu, Cihan, & Wong, 2017), particularly due to the changes that occur in the intensity distribution during the different performance periods (Fanchini et al., 2011).

The use of SSGs also allows the development of players' decision making under pressure and fatigue (Gabbett & Mulvey, 2008). Indeed, fatigue can significantly affect motor and perceptual processing (Akenhead & Nassis, 2016; Kellis et al., 2006; Mohr et al., 2003; Thorpe et al., 2017), which has a direct relationship with physiological and metabolic failures during SSGs. Fatigue can translate into a substantial reduction in muscular strength and coordination and a decrease in performance for different periods of time (Kellis et al., 2006; Mohr et al., 2003, 2005). In addition, mental fatigue also influences the perception of effort during exercise, resulting in impairment of resistance-based physical activity (Alghannam, 2012), yet it does not affect neuromuscular function and therefore has a minimal impact on high-intensity exercise and short durations (Waldron & Highton, 2014). Moreover, previous studies (Boksem et al., 2006) also revealed that decreased motivation is associated with mental fatigue and can affect the level of effort one is willing to exert on a task (Brehm & Self, 1989). Ultimately, correct control and monitoring of training load is essential for ensuring that the level of fatigue does not limit the objectives to be achieved (Halson, 2014), or that the technical and tactical objectives of the exercise are marked out according to the physical objectives (Dellal et al., 2011).

Training load has been described as the training variable that can be manipulated to elicit the desired training response (Coutts et al., 2017). Monitoring the training load is essential to determine players' individual adaptations, responses, fatigue, and needs for recovery in addition to minimizing the risk of overreaching and consequent injury or illness (Bourdon et al., 2017). On this, training load can be classified as internal or external and reflects the requirements imposed on athletes (Bourdon et al., 2017; Lambert & Borresen, 2010). The external training load is an objective measure of the work that the athlete performs during training or competitions and is important to understand the athlete's real capabilities relative to his performance (Halson, 2014). Typically, it describes the demands of the athlete's own movement (distance covered, accelerations, changes of direction, and power output) (Burgess, 2017). The internal training load is defined as the biological requirement (physiological or psychological) that the work performed imposes on the athletes' structures (Bourdon et al., 2017; Burgess, 2017; Halson, 2014).

Several studies (Bujalance-Moreno et al., 2019; Casamichana et al., 2013; Hill-Haas et al., 2009; Köklü et al., 2017) have been conducted to monitor internal and external training loads during SSGs. The results highlight the extended potential of SSGs as they not only increase the motivation of the players but also promote specific physical conditions and technical/tactical capacities in soccer (Hammami et al., 2018a; Little, 2009; Los Arcos et al., 2015). Generally, SSGs are performed in a continuous or fractionated format (Casamichana, Castellano, & Dellal, 2013; Köklü, 2012; Yücesoy et al., 2019), and both methods must contemplate, (i) intensity and duration of the work; (ii) type of recovery (rest/active recovery) and duration of the recovery; and (iii) total duration of work (number of interval of work × duration of work) (Halouani et al., 2014).

A previous study (Laursen, 2010) highlighted the potential of the fractionated format in trained athletes using repeated short or long periods of high-intensity exercise interspersed with recovery periods (Billat, 2001). Greater cardiovascular and peripheral adaptations have been reported in athletes who performed several fractionated exercises at high intensities interspersed with resting periods (Billat, 2001; Faude et al., 2013; Laursen & Jenkins, 2002); however, it remains unclear the precise influence of the continuous and fractionated methods in the training load response under various conditions.

Data suggests that the duration of recovery during exercises using the fractionated method can be an important factor in training load (Hill-Haas et al., 2009; Köklü et al., 2017) since the ability to maintain high exercise intensity across several training sessions depends significantly on the duration of exercise and recovery (Balsom et al., 1992). During the recovery period, oxygen consumption remains elevated to replenish the intramuscular high-energy phosphates required to perform high-intensity exercise to pre-exercise levels (Balsom et al., 1992). In accordance with the objectives of the physical efforts defined for the exercises, the correct manipulation of exercise duration and recovery periods between repetitions must therefore be ensured by coaches; however, knowledge about the influence of the duration of each repetition on training load during SSGs has been inconclusive, and further research is needed. Furthermore, psychological aspects should also be considered from the psychophysiological integrated perspective. As stated before, previous studies (Boksem et al., 2006) revealed that decreased motivation is associated with mental fatigue and can affect the level of effort required to exercise a task, thus the recovery period can help to regulate physiological and psychological stress, allowing players to achieve optimal levels of arousal and subsequent attentional levels necessary to maintain high internal and external load indicators during exercise (McMorris & Graydon, 1996).

Overall, we conclude that the results of previous studies have allowed coaches better control of training load during SSGs; however, some questions remain unanswered, such as those relating to the use of the continuous and fractional methods as well as the manipulation of three critical variables related to the SSG prescription: time duration, interval of rest, and number of repetitions. The current data highlight some lack of consensus in the use of both methods and remain inconclusive regarding the effects of manipulation on the variables identified. Further studies are needed to clarify the topic due to its importance for training manipulation and control. According to the literature gap, it may also be relevant to study the effects of the fractionated method in SSGs when considering the same total duration of exercise (total and in each repetition) and manipulating different recovery times.

Thus, the present work aimed to identify the effects on internal and external loads resulting from the application of the continuous and fractionated methods in SSGs in soccer training and the effects of different recovery durations between repetitions of a five-sided SSG in training load in soccer players. Three hypotheses were raised:

1) The fractionated method, characterized by same total duration and same interval rest but with different recovery times, induces a higher internal and external load;
2) The increase in the number of repetitions in the fractionated method raises the internal and external load compared to the continuous method;
3) Increasing recovery time will decrease the internal load and increase the external load of the exercise and lead to a higher physical impact of exercise (higher indicators of training load).

The thesis was developed according to the following sequence:

- Chapter 2 presents a descriptive review based on the early studies regarding training load during SSG and a review study developed to accomplish the main aim of this thesis:
    - Study 1. The effect of the continuous and fractionated game format on the training load in Small Sided Games in soccer.

- Chapter 3 shows the experimental studies developed to accomplish the main aim of this thesis:

    - Study 2. Comparison Between Continuous and Fractionated Game Format on Internal and External Load in Small-Sided Games in Soccer.

    - Study 3. Effects of different recovery times on internal and external load during small-sided games in soccer.

- Chapter 4 shows practical recommendations considering a specific game format:

    - Study 4. 5-a-side Game as a Tool for the Coach in Soccer Training

After the studies presentation, a general discussion of the results is provided (Chapter 5), followed by the main conclusions (Chapter 6) and some suggestions for future research (Chapter 7).

Chapter 2

Literature review

Features and capabilities of the soccer players

Soccer is characterized by intermittent efforts that alternate brief moments of high intensity and longer periods of low-intensity exercise (Mohr et al., 2003; Rampinini et al., 2007). Although the aerobic system mostly dominates the energy supply, elite soccer players perform around 1,000-1,400 short-term actions that vary randomly every 3-5 s, including kicks, dribbles, tackles, direction changes, running at different velocities, accelerations, decelerations, jumps, running backwards and sideways, and disputes (Bishop et al., 2018; Gonzalo-Skok et al., 2017; Mohr et al., 2003; Reilly et al., 2000). This means that there are high anaerobic demands during intense periods throughout a game (Bangsbo, 1994) and therefore, it is critical to ensure that players have the ability to maintain high levels of activity through well-developed aerobic and anaerobic endurance, which mediates the onset of fatigue (Buchheit & Laursen, 2013; Yusuf Köklü et al., 2015). In this sense, high-intensity intermittent training has been described as beneficial for improving aerobic capacity and the ability to perform high-intensity actions (Billat et al., 2002; Buchheit & Laursen, 2013; Dellal et al., 2010). In high-performance sports, it has been well documented over the years that maximum benefits are achieved when training stimuli are similar to competitive demands (Giménez et al., 2020; Kelly et al., 2020).

The demands imposed by the game cause constant physical and physiological adaptations to the organism (Hevilla-Merino & Castillo-Rodríguez, 2018). In order to achieve excellent performances, it is essential that soccer training programs include successive, intermittent, high-intensity requests without forgetting that the tasks should be representative of the game (Reilly, 2006).

Thus, we can conclude that aerobic metabolism stands out as the main source of energy for muscle activity and is useful in the recovery between decisive periods of intense activity, where anaerobic metabolism is highlighted (Baker et al., 2010; Buchheit & Laursen, 2013; Rodríguez-Fernández et al., 2019). Taking into account the multilinear character of movement during a game, it is imperative that all the elements required during a game are considered in the training programs, which have as their main objective the reduction of fatigue associated with the task and the increase in sports performance (Impellizzeri et al., 2005).

Physical and physiological demands of soccer

It is estimated that a professional soccer player covers a total distance between 9-14 km during a soccer match (Bradley et al., 2013); however, recent studies showed that most of this distance is covered at a low intensity, with only 7-12% performed at a high intensity and 1-4% in sprint (Bush et al., 2015). Although the aerobic system primarily dominates the energy supply, elite senior players perform an average of 250 brief high-intensity actions during a match. Furthermore, during a game, the maximum oxygen uptake of soccer players (VO_{2max}) ranges from 55-70 mL/kg·min^{-1}, with individual values above 70 mL/kg·min^{-1} (Reilly et al., 2000), and the anaerobic threshold of the elite players is defined as 80-85% of VO_{2max} and 80-90% of maximal heart rate (Helgerud et al., 2001). Regarding this information, a study by Bradley et al. (2016) notes that the physical and physiological demands of players has been subject to changes in the last few years. These changes are related to several variables such as the location of the competition, competitive category, style of play, tactical system, level of the opponent, time with and without the ball, and the nationality of the players, all of which have a conditioning effect on the duration and intensity of the efforts required during competitions (Casamichana & Castellano, 2014; Castellano et al., 2011; da Mota et al., 2016; Di Salvo et al., 2013; Folgado et al., 2014; Morgans et al., 2014; Tierney et al., 2016).

According to a previous study (Hoff & Helgerud, 2004), to maintain the best performance during a competition, it is necessary that players have high aerobic training, speed, and strength. The acyclical character of movements, frequently changing situations, and playing pace in soccer require players to generate energy from different sources through aerobic and anaerobic metabolism (Duk et al., 2011; Reilly & Williams, 2003). During a soccer game, short exercises performed by players at maximal and high intensities (sprinting) are dominated by anaerobic energy processes and are intertwined with activities of moderate and low intensity (walking and jogging) characterized by aerobic energy processes; however, match playing time, exercise intensity, and the percentage of time devoted to the performance of various activities indicate that match performance is dominated by aerobic metabolism (Andrzejewski et al., 2013; Bangsbo, 1994). Furthermore, low-intensity exercise and rest periods during a match, lasting from a few to more than 10 s, are necessary for muscle relaxation, body recovery, and lactate utilization (Spencer et al., 2005). In addition, a high level of aerobic fitness (VO_{2max}) in players enhances all these reactions and physiological-biochemical processes (Gharbi et al., 2015).

Collectively, these data suggest that relevant adaptations (i.e., total duration, number of repetitions, and recovery time) performed during the training process by the exercises are needed to guarantee that the quality of the training process allows the optimized performance of players, preparing them for the demands of soccer games.

Small Sided Games a powerful tool for training process

SSGs are implemented in a more open and random environment than traditional methods of physical training, allowing greater variability in exercise intensity (Gamble, 2004). During these games, players can experience multiple situations and constraints that are similar to the competition (Owen et al., 2004). The game demands justify the use of these types of exercises (Reilly et al., 2009) and therefore, SSGs are considered ideal for the development of specific physical characteristics required during the game (Impellizzeri et al., 2006; Köklü, 2012). Ultimately, weekly soccer training programs need to represent the dynamic, unpredictable, and unstable nature of the game (Davids et al., 2013).

The use of SSGs (Hill-Haas et al., 2009; Katis & Kellis, 2009) has been proposed as a tool for developing such capabilities in the context of performance, highlighting similar combinations of players' technical, tactical, and physical abilities as observed in full-sized matches (Aguiar et al., 2008; Clemente et al., 2014; Katis & Kellis, 2009). SSGs are also referred to as skill-based conditioned games (Gabbett, 2006) or game-based training (Gabbett et al., 2009) and are played with a smaller number of players compared to a formal 11-a-side game. In addition, the field sizes, can range from 10m x 5m to 60m x 50m (Hill-Haas et al., 2011). SSGs are also characterized by their variability in changing the physical, physiological, and technical-tactical requirements of training based on the manipulation of numerous variables, such as field dimensions (Kelly & Drust, 2009; Rampinini et al., 2007), number of players (Little & Williams, 2006; Rampinini et al., 2007), rules or restrictions (Hill-Haas et al., 2009), inclusion of a goalkeeper (GR), (Little, 2009; Sassi et al., 2005), the presence of a coach's verbal encouragement (Rampinini et al., 2007), number of repetitions and effort/recovery ratio (Fanchini et al., 2011; Rampinini et al., 2007), or previous information about exercise duration (Ferraz et al., 2017; Ferraz, Gonçalves, Coutinho, et al., 2018; Ferraz, Gonçalves, Van Den Tillaar, et al., 2018).

Due to the high number of variables involved, to our best knowledge, there are no studies that cover all possible combinations of them, and it is very difficult to reach a consensus even in studies that use similar variables. Therefore, more research is required to promote an accurate and reliable monitoring tool to ensure that there is an effective improvement of the player's physical abilities.

The literature indicates that the number of players can influence physical, physiological, and time motion patterns during SSGs (Aroso et al., 2004; Hill-Haas et al., 2010; Katis & Kellis, 2009; Owen et al., 2004). Some studies have shown that SSGs performed with a reduced number of players induce greater heart rate (HR) responses when compared to larger formats (Hill-Haas et al., 2009; Impellizzeri et al., 2006). In this respect, studies have failed to observe differences in HR responses between different SSG formats (Aroso et al., 2004; Dellal et al., 2008; Jones & Drust, 2007) and the literature also report no significant differences in variables such as the entire distance covered and distances covered at different intensities (Hill-Haas et al., 2009, 2010; Jones & Drust, 2007); however, for high-intensity efforts, different conclusions have been reported (Hill-Haas et al., 2009), noting that the sprint distance and duration increase progressively with an increasing number of players in the exercise. Some studies (Hill-Haas et al., 2010) do not observe significant differences related to the number of players used during the exercise. Contrary to the results that have been previously reported, Drust et al. (2000) reported that a reduction in the number of players increases the exercise intensity.

Moreover, a study conducted by Hill-Haas et al. (2009) that examined the variation in physiological and perceptual responses and time-motion profiles in SSGs formats (three-a-side; four-a-side; six-a-side) based on the fractionated (4 x 6min) and continuous methods (24min) concluded that, with the exception of lactate concentration, changes in format (interval or continuous) do not appear to affect the variability between physiological or preceptive response sessions. In addition, intensity measurements in continuous training are less variable than interval training sessions. The divergent conclusions drawn from these studies can be justified by the variability in the sample used, experimental design, and especially the field size.

Regarding the field size, previous investigations have shown that different sizes can induce different physical and physiological responses (Aslan, 2013; Casamichana & Castellano, 2010; Clemente et al., 2014) Corroborating these data, several studies (Casamichana & Castellano, 2010; Rampinini et al., 2007) could observed significant differences in the internal load indicators, specifically in HR, with changes in the size of the playing field. Fields with larger dimensions induced higher HR values in comparison to medium and small fields (Aguiar et al., 2015) which suggests that changing the field size may help coaches in intensity regulation during SSGs. In addition, previous experiments observed that increasing the playing area can promote exercise intensity enhancement (Rampinini et al., 2007) likely due to the increase in the area that needs to be covered by each player. As an example, Balsom et al. (1999), reported that intensities observed in a three-a-side game can be achieved in a four-a-side scenario based on the increase in the field size, and yet most research indicates that HR increases with an increasing field size (Casamichana & Castellano, 2010; Owen et al., 2004).

During the last years, SSG studies indicated that players increased their motivation with the completion of SSGs since they develop greater physical enjoyment (Hammami et al., 2018; Hill-Haas et al., 2010; Los Arcos et al., 2015; Selmi et al., 2018). In addition, physical enjoyment has been associated with positive psychometric responses to activity, which is one of the main reasons leading athletes to adhere to prescribed training (Carraro et al., 2014). From the same perspective, a study conducted on professional soccer players (Selmi et al., 2018) concluded that high-intensity interval training produced a mood disorder, while the use of SSGs help achieved the balance of mood (Los Arcos et al., 2015).

Training Load

Training load is understood as a quantitative measure of the physical and physiological work performed during the exercise period (Halson, 2014) and can be categorized as internal or external (Malone et al., 2015). Internal load is a measure of perception of effort by the athlete themselves (e.g., rate of perceived exertion or HR response to the stimulus). In contrast, external load is the quantification of some external variables (e.g., speed and total distance covered) (Drew & Finch, 2016). The internal load is also defined as the internal indicator to the external load, can be subject to variations, and does not always follow the trend of external load (Köklü, 2012; Köklü, Alemdaroğlu, Cihan, & Wong, 2017).

Training load is relevant to the player's physical state since performance optimization is only achieved from post-training and competition recovery periods. It is necessary to consider an optimum balance between stress resulting from the stimulus and adequate recovery intervals (Kellmann, 2002); therefore, exercise variables such as duration, recovery, and intensity are the predominant vectors of the training load (Brink et al., 2010).

To increase or decrease fatigue, training loads can be adjusted during a training cycle. Depending on the training period (pre-season, in-season, or detraining phase), the objectives and other variables can be manipulated to control the intensity of the SSG. Among these variables are size of playing field, number of players, coaching, game rules, content focus of the game, goal size, number of goals, presence of goalkeepers, dosing of load interval, rest interval, knowledge about exercise duration, match status, and training method (Christopher et al., 2016; Clemente et al., 2017; Halouani et al., 2014; Köklü et al., 2015; Los Arcos et al., 2015; Yücesoy et al., 2019). Monitoring fatigue across training load indicators can provide a scientific explanation for changes in performance. In order to analyze training load, several variables can be quantified (Table 1).

Monitoring fatigue across training load indicators, can provide a scientific explanation for changes in performance. In order to analyze the training load, several variables can be quantified (Table 1).

Table 1. Variables that can be used to monitor training load

Variable	**Units/descriptors**
Frequency	Sessions per day; Week; Month
Time	Seconds; Minutes; Hours
Intensity	Absolute; Relative
Type	Modality; Environment
Maximal effort	Maximum mean power; Jump height
Repeat effort	Number of efforts; Quality of efforts
Training volume	Time; Intensity
Perception of effort	Rpe
Perception of fatigue and recovery	Questionnaires; REST-Q; VAS
Illness	Incidence; Duration

Biochemistry and hormone analysis	Baseline; Response to exercise
Technique	Movement deviations
Body composition	Total body weight; Fat mass; Fat-free mass
Sleep	Quality; Quantity; Routine
Psychology Sensations Hopeful	Stress; Anxiety; Motivation Sensations Hopeful

Note: : REST-Q=The recovery stress questionnaire for athletes ; VAS= Visual Analogue scale

External and Internal load during Small Sided Games

Participating in SSGs could induce various responses in the external load (Köklü, 2012; Köklü, Alemdaroğlu, Cihan, Wong, et al., 2017). A previous study which compared the SSG and a regular game performance concluded that the level of intensity during the regular soccer game was higher compared to the SSG, although the distance covered per minute was greater during the SSG (Castellano et al., 2012). Another study (Aguiar et al., 2012) observed that a reduction in the number of players participating in the SSG caused a decrease in the distance covered and the number of sprints performed. Other investigations (Aasgaard & Kilding, 2018; Cihan, 2015) reported that the inclusion of defensive strategies (e.g., man-to-man marking) by the coach promotes an increase in the total distance covered, namely at high intensities, while the inclusion of goalkeepers caused an increase in the number of accelerations (Castellano et al., 2013).

Regarding internal load, previous studies have reported that increasing the size of the playing field induces increases in HR responses (Casamichana et al., 2013; Owen et al., 2004). In contrast, another investigation (Rampinini et al., 2007) found that the increase in the number of players in the exercise induced an intensity enhancement, and consequently, higher HR responses. More recently, a study by Dellal el al. (2012), found that HR responses were higher in SSGs regardless of the method by which they were performed when compared to friendly games. In addition, the duration of repetition may be a determining factor that should be considered, as shorter and successively shorter repetitions appear to cause a lower % max.HR compared to longer repetitions (Bujalance-Moreno et al., 2019; Hill-Haas et al., 2009; Köklü, 2012). Contrary to this evidence, a study comparing the use of longer and shorter repetitions found that the physiological responses were similar (Köklü, 2012).

Continuous *vs*. fractionated training method during Small Sided Games

During SSGs, the rate rest at work can be a determining variable that influences physiological responses (Casamichana, Castellano, & Dellal, 2013; Köklü, 2012), and therefore, the organization and prescription of these games should be based on three vectors (Halouani et al., 2014): 1) work intensity and duration; 2) recovery type (passive/active) and duration; and 3) total duration of work (number of the interval of work x duration of work). Although most studies on SSGs use the fractionated method, it is extremely important to verify the differences derived from the use of the continuous (i.e., without repetitions or rest intervals during the exercise) and fractionated methods (i.e., exercises performed repeatedly, with intervals between repetitions) and the possible types of manipulations to ensure the desired training loads. Unfortunately, there are few studies that have investigated how SSG training load can be manipulated to change training stimuli based on the choice of training method (Fanchini et al., 2011; Hill-Haas et al., 2009).

The continuous method is characterized by a large volume of work without interruptions, where the main objective is to improve the aerobic capacity of players (Bompa, 2009). Its use during SSGs essentially aims at the development of basic resistance during the preparatory periods of the season (Hill-Haas et al., 2011). The continuous method can be categorized as uniform or varied. The first is characterized by the maintenance of effort over a period of time, while the second consists of the performance of prolonged efforts with significant variations in intensity but without having to effectively cease the activity (Alves et al., 2006).

The literature also describes that the performance of the exercise using the continuous or fractionated methods can cause changes in the training load (Köklü, Alemdaroğlu, Cihan, Wong, et al., 2017), especially due to the changes that are verified in the intensity distribution during the different periods of performance (Fanchini et al., 2011); however, the differences resulting from its application are still unclear (Fanchini et al., 2011; Impellizzeri et al., 2019; Köklü, Alemdaroğlu, Cihan, Wong, et al., 2017; Yücesoy et al., 2019). Regarding peripheral and central adaptations, some results reveal that there are no differences between the methods (Edge et al., 2006; Seiler & Tønnessen, 2009), but there are reports suggesting that the continuous method performed at submaximal intensities promotes better peripheral adaptations, while the fractionated method promotes better central adaptations (Helgerud et al., 2007). In addition, another study Reilly (2006) observed significant differences in the recruitment of the type of muscle fiber between 18 protocols of continuous and fractionated exercise. Slow contraction fibers were predominantly activated during continuous exercise, whereas both the quick and slow contraction fibers were requested during the fractionated exercise.

Usually, SSGs are prescribed with the fractionated method (Harrison et al., 2014) although the continuous method is more similar to the demands of real games (Aguiar et al., 2012). One of the aforementioned studies (Fanchini et al., 2011) concluded that with the total duration of the SSG, the value of HR is smaller with shorter repetitions (e.g., 2 min) compared to longer repetitions (e.g., 6 min). Thus, these results may suggest that the continuous method induces higher HR responses compared to the fractionated method with shorter repetitions, considering the total duration of the SSG. Some possible justifications for these results have been noted, such as the additional rest between repetitions that causes decreases in HR (Aguiar et al., 2012) and a pacing effect that can induce players to set the pace of the game (Carling et al., 2008). Finally, some studies have also suggested that SSGs performed under the continuous or fractionated formats display identical physiological responses for both training regimes (Köklü, 2012; Yücesoy et al., 2019). Similarly, (Christopher et al., 2016) also observed no differences for physiological indicators when comparing both training methods. These results suggest that both regimes can be used for physiological adaptations and match-specific conditioning. Taking into account the vast number of variables that can be manipulated in SSGs and the different possible objectives, which can influence internal and external load indicators, it is clear that more research is needed that explore the real impact of using the continuous or fractionated methods on training load during SSGs and include all possible variables.

Exercise duration and Recovery in Small Sided Games

The development of the player's physical condition is one of the essential factors for performance (De Villarreal et al., 2015) and also depends on the interaction between exercise duration and subsequent recovery periods, as well as exercise intensity and recovery (Bangsbo, 1994). The chosen training method (continuous or fractionated) of the SSG and the manipulation of key variables such as intensity, duration, frequency, and recovery takes on a fundamental role in player performance during these exercises (Dupont et al., 2003; Seiler & Tønnessen, 2009).

According to Kellmann & Kallus (2007), recovery involves active processes to restore psychological and physiological resources, in addition to states that allow the individual to use these resources again. Therefore, the intensity, duration, and frequency of training based on SSGs causes significant stress on biological systems, which may compromise the ability to work in the following sessions (Kelly et al., 2020; Strudwick & Reilly, 1999). The return of the muscle to its normal state after exercising is part of a process known as recovery. This process comprises two phases, with a fast-initial phase that lasting between ten seconds to a few minutes (mins) and a second phase lasting between a few minutes to a few hours (Gaesser & Brooks, 1984).

The ability to perform high intensity efforts in a repeated series as occurs during SSGs is influenced by the nature of the exercise itself and the periods of recovery, and the more exercise interferes with the body's homeostasis, the greater its effect on recovery metabolism (Tomlin & Wenger, 2001). Similarly, the more complex these regenerative processes are, the greater the ability to generate strength or maintain power in subsequent effort intervals (Tomlin & Wenger, 2001).

In particular, the recovery period between sets may result in an increased HR response in the following series and thus better removal of substrates during the stipulated rest period (Hill-Haas et al., 2008), allowing physiological recovery and higher intensities of work in the following repetitions (Hill-Haas et al., 2009). The duration of each interval, alternating with the rest periods, are used to determine the working period in a variable called the rest ratio. Although most studies on SSGs are prescribed with short rest intervals, some recent studies have used variations in recovery time (e.g., 10 min to 30 min) (Hill-Haas et al., 2011).

Köklü et al. (2015) reported that when the coach selected the fractionated training method, the number and duration of repetitions considerably affected the physical demands of the tasks. These results were corroborated by a study that investigated the effects of different recovery periods of 1, 2, 3, and 4 min, respectively (Köklü et al., 2015). The same conclusions were drawn from a study that had recovery periods of 30 s and 120 s that aimed to analyze the variation of HR, the effects of oxygenation on muscles, and the movement demands resulting from the task (McLean et al., 2016). Thus, exercise duration and recovery time may be a determining factor to control the training load and consequent physical and physiological responses.

Fatigue during Small Sided Games

The effects of fatigue, particularly on soccer, have received substantial attention over the last decade (Waldron & Highton, 2014). Soccer fatigue has been attributed to a number of individual physiological and psychological factors, such as lactate and hydrogen ions (H+) accumulation, glycogen depletion, phosphocreatine depletion, dehydration, neural transmission insufficiency, motivational and mental mechanisms, and tactical or contextual factors (Mohr et al., 2005). The mechanisms responsible for the accumulation of fatigue during training are varied, complex, and not fully understood (Bangsbo et al., 2006; Ferraz et al., 2019; Rampinini et al., 2008); however, depletion of energetic substrates (e.g., muscle glycogen, increased metabolic byproducts, lactate, and potassium), increased pH, and dehydration were identified as factors that may contribute to the accumulation of fatigue during training (Bangsbo et al., 2006) and consequently to the reduction of the training load imposed by the exercise. The progressive decrease in heart rate, rating of perceived exertion, running intensity, and distance was also associated with decreases in training load due to fatigue (Hill-Haas et al., 2009; Köklü et al., 2011; Köklü, Alemdaroğlu, Cihan, Wong, et al., 2017).

Fatigue has been described as a reduction in maximum voluntary muscle strength resulting from exercise (Gandevia, 2001). From this perspective, there are two possible explanations that give rise to fatigue: i) muscle fatigue, when peak force deficiencies are related to processes in muscle cells that affect contractile muscle functions (Bishop, 2012; Knicker et al., 2011) and ii) central fatigue, when the decrease in muscle strength production was related to the reduced neural impulse from the motor cortex to the motor units (Knicker et al., 2011).

During the last decade, several studies have shown that changes in physical performance may be part of the team strategy (Castellano et al., 2011) or a consequence of muscle fatigue (Bishop, 2012) resulting from actions and accelerations performed by players at high intensities (Silva et al., 2016). Indeed, decreases in performance following intermittent high-intensity periods as well as decreases in total distance traveled have been reported in previous studies (Bradley et al., 2009; Casamichana et al., 2012). In addition, muscle fatigue may play a role in changing tactical behavior and decision making as previously demonstrated (Ferraz, Gonçalves, Van Den Tillaar, et al., 2018; Sampaio et al., 2014; Smits et al., 2014).

Mental fatigue can also be a conditioning factor in player performance and behavior. Mental fatigue has been described as a psychobiological impulse characterized by sharp increases in subjective classifications of mental fatigue and mental effort, cognitive difficulties in the ability to maintain attentional focus (Shou & Ding, 2013), identifying and using visual cues, (Boksem et al., 2006) and evaluating and adjusting actions (Lorist et al., 2005), which results from prolonged periods of demanding cognitive activity (Van Cutsem et al., 2017). In this respect, previous studies report that mental fatigue can reduce physical and technical performance during training and soccer game situations (Badin et al., 2016; Ferraz et al., 2019); however, based on the manipulation of variables while performing SSGs, it is possible to change game demands with implications on muscle and mental fatigue (Aguiar et al., 2015; Hill-Haas et al., 2011; Travassos et al., 2014). In fact, players like to perform SSGs because the ball contact time is longer than any other exercise performed and may result in increased motivation and enjoyment of the exercise (Los Arcos et al., 2015). Therefore, having stops of longer durations solely for recovering purposes may imply a strain of mental fatigue derived from the stress related to the anxiety of wanting to play for as long as possible. Previous studies (Boksem et al., 2006) reveal that decreased motivation has been associated with mental fatigue and can affect the level of effort one is willing to exert on a task (Brehm & Self, 1989); thus, manipulation of length of recovery periods may induce changes in physiological and psychological stress by allowing players to achieve optimal levels of arousal and subsequent attentional levels required to maintain high internal and external load indicators during exercise. Ultimately, this research topic is still lacking research and needs further investigation into the impact of muscle and mental fatigue on SSG performance.

Global positioning system technology

Technological advances have recently contributed to improved physiological data collection during the training and competition process in most sports, especially soccer (Boyd et al., 2011). The emergence of these new measurement technologies has allowed data to be increasingly collected with high reliability in the most diverse (Grossman et al., 2010; Sánchez et al., 2018).

Wireless Inertial Motion Analysis Devices (WIMUs) are among the most recent and important inertial devices (Molina-Carmona et al., 2018). They incorporate different sensors (e.g., accelerometer, gyroscope, magnetometer, GPS chip, and UWB chip) that simultaneously measure different variables, such as heart rate, acceleration, speed, time, and distance. The recorded variables can be displayed in real time or downloaded later to a computer.

Given the extreme usefulness of these kinds of devices for training planning and competitions, it is imperative that they are valid, reliable, and tested in contexts similar to those of the real games. Like the WIMO device, which has been previously evaluated (Molina-Carmona et al., 2018), all new technologies that record real data should be rigorously evaluated through controlled methodologies to identify measurement accuracy (Thomas et al., 2015).

The correlation is high ($r > 0.93$) when comparing the distances of a soccer game using traditional video analysis, but with differences of up to 24% in the high intensity distance covered (Aughey & Falloon, 2010; Boyd et al., 2011). However, global position system (GPS) systems have some limitations since they only record the linear aspects of displacement, although other complementary information enriches the description of physical demands, such as approaches, contacts, impacts, and directionality of displacement (MacLeod et al., 2009).

This technology has been used in studies that analyzed the sports performance and physical demands of players during different activities. These studies attempt to analyze the importance of variables that affect physical demands, such as the number of players participating per team (Hill-Haas et al., 2009), training regime (Hill-Haas et al., 2010), rules of manipulation (Hill-Haas et al., 2009), changes in the number of teammates and opponents (Torres-Ronda et al., 2015), repetitions performed during training (Dellal et al., 2011; Dellal et al., 2012), and dimension of the field and skill level (Silva et al., 2014). In addition, other studies have used GPS technology to analyze SSGs in comparison to formal games (Dellal et al., 2012) while factoring in the following variables: positional status, temporal movement variables, heart rate, and tactical behavior (Sampaio et al., 2014). The possibilities of this type of technology are immeasurable and have been a fundamental contribution to the understanding of training and control.

In addition to the literature review, a review study was conducted.

Review Study

Study 1 - The continuous and fractionated game format on the training load in Small Sided Games in soccer

Abstract

Background:
The training load has become relevant for coaches in recent years. Several studies were carried out to verify the impact on the training load during the performance of Small Sided Games in soccer. However, recent research is now focused on the effects of using different methods and the study of different recovery times on training load in SSG deserve more attention.
Objective:
In this brief review, we critically analyze the impact of using different training methods and different recovery time, inferring in relation to their impact on the external and internal training load during the performance of Small Sided Games in Soccer.
Conclusion:
The correct choice of training method can help coaches to increase the performance of their teams and achieve the proposed training objectives.

Key-words

Soccer; different training methods; different recovery times; external load; internal load

Problem Definition

Soccer is typically regarded as an intermittent sport (Bangsbo, 1994) with multiple unpredictable actions. Therefore, it is important for soccer training to recreate the dynamic nature of the game to be representative of all competition requirements. According to the literature, these demanding standards can be achieved by recreating the game through Small-sided Games (SSG) (Hill-Haas et al., 2011; Köklü, 2012). In addition to SSG highlighting similar combinations of technical, tactical, and physical players' abilities as those observed in full-sized matches (Bujalance-Moreno et al., 2019; Hill-Haas et al., 2011), several studies also showed that the manipulation of some variables during these games, like the total duration, and the duration periods between repetitions (i.e., the use of continuous or fractionated methods) (Hill-Haas et al., 2009; Köklü, Alemdaroğlu, Cihan, & Wong, 2017). Regarding the duration of the exercise, the literature described that, using the continuous or fractionated method, during the performance of SSG, for different periods of time causes different changes in the training load (TL) (Köklü, Alemdaroğlu, Cihan, & Wong, 2017), particularly due to the changes that occur in the intensity distribution during the different performance periods (Fanchini et al., 2011).The use of SSG also allows the development of players' decision-making skills under pressure and fatigue (Gabbett & Mulvey, 2008). Indeed, fatigue can significantly affect motor and perceptual processing (Akenhead & Nassis, 2016; Kellis et al., 2006; Mohr et al., 2003; Thorpe et al., 2017), which has a direct relationship with physiological and metabolic failures during SSG. Therefore, correct control and monitoring of the training load is essential to prevent levels of fatigue from limiting the objectives to be achieved and to ensure that the technical and tactical objectives of the exercise are marked out according to the physical objectives. The training load has been described as the training variable that can be manipulated to elicit the desired training response (Coutts et al., 2017), and can be classified as internal or external and reflects the requirements imposed on athletes (Bourdon et al., 2017; Lambert & Borresen, 2010); however, some questions remain unanswered, such as those relating to the use of the continuous and fractional methods as well as the manipulation of three critical variables related to SSG prescription: time duration, interval of rest, and number of repetitions.

The present review highlights the impact on internal and external loads resulting from the application of the continuous and fractionated methods in SSG. It also aims to give importance to the effects of different recovery durations between repetitions on training load during SSG. Ultimately, a review is necessary to summarize the findings and new evidence on changes in training load resulting from performing SSG using the continuous or fractional methods and with different recovery time. To search for relevant publications and ensure the quality of the articles, the following databases were used: Web of Science (the modules “Core” and “Medline”), Scopus and PubMed. Articles that were published in 2020 or before and in English were considered. The search strategy comprised search terms that combined one of two primary keywords (“soccer” or “football”) with a second keyword (small-side games” or “small and conditioned games”) and a third keyword (“recovery time”, "training load”, “continuous method”, “fractionated method”), using the boolean operator. The inclusion criteria for these articles were: (1) relevant data on: training load, training method (continuous/fractional) and / or recovery time, during SSG; (2) the participants included amateur and / or professional male and female soccer players; and (3), the articles were published in English. Studies were excluded if: (1) it did not include data relevant to this study; and (2), were conference abstracts. The articles were screened based on an assessment of both the title and the abstract. All articles without a focus on the investigation were excluded. In total, 133 articles were considered relevant for this review. These articles were read in detail by two senior researchers with substantial experience in the field (including relevant publications) and assessed for relevance and quality. Articles which did not meet the criteria were excluded. After this step, 25 articles remained.

Summary of previous research

Prior investigations on the influence of the continuous and fractionated training methods on training load are inconclusive and present contradictory outcomes (Bujalance-Moreno et al., 2019; Fanchini et al., 2011; Hill-Haas et al., 2009;Köklü, 2012; Köklü, Alemdaroğlu, Cihan, & Wong, 2017; Yücesoy et al., 2019); however, changes in training load may occur during SSG (Köklü, Alemdaroğlu, Cihan, Wong, et al., 2017) as well as improvements in aerobic capacity (Köklü, 2012). Still, the type of changes induced in the internal and external loads and their causes remain controversial among the scientific community. In this regard, some authors (Fanchini et al., 2011; Impellizzeri et al., 2019; Köklü, Alemdaroğlu, Cihan, & Wong, 2017; Yücesoy et al., 2019) have suggested that increasing repetition duration causes an increase in physiological responses, specifically heart rate (HR) (Bujalance-Moreno et al., 2019) and % max.HR (Hill-Haas et al., 2009; Köklü, 2012); therefore, the continuous method induces a greater internal load compared to the fractionated method. In the same line of investigation, other authors (Christopher et al., 2016; Köklü, 2012) state that the physiological responses are similar regardless of the training method chosen by the coach, while divergent opinions are presented in other investigations (Owen et al., 2004; Sampaio et al., 2007). Regarding external load indicators, previous studies that compared SSG performed using both methods with real game situations inferred that, although the intensity is higher in real game situations, the workload is higher during the performance of SSG regardless of the format, particularly in relation to the distance travelled per minute, (Castellano et al., 2012), in addition to other variables that have been analyzed (e.g., intensity of displacements made (Aguiar et al., 2012), total distances travelled, and total distances travelled at high intensities (Aasgaard & Kilding, 2018; Cihan, 2015), but more research is required about this topic. In general, the investigations conducted suggest that both training methods can be used for physiological adaptations and match-specific conditioning, but further research is needed to identify which training method is most efficient for SSG. In addition to selecting the training method, coaches must consider the recovery time chosen between each repetition performed since the ability to maintain high intensities is directly related to the ability to recover quickly from previous repetitions performed (Balsom et al., 1992). In this regard, it has been suggested (Köklü et al., 2015) that short recovery periods can cause increases in training load ; however, other approaches suggest that there are no differences between different recovery time (McLean et al., 2016), while another study suggests that longer recovery periods showed less homogeneity of the heart rate (HR) (Dellal et al., 2011).

Explanation of subject matter

The literature describes that the performance of an exercise using the continuous or fractionated methods can cause changes in the training load (Köklü, Alemdaroğlu, Cihan, & Wong, 2017), especially due to the changes that are verified in the intensity distribution during the different periods of performance (Fanchini et al., 2011). Usually the SSG is prescribed using the fractionated method (Harrison et al., 2014), although the continuous training method is more similar to the demands of the real game (Aguiar et al., 2012). One of the aforementioned studies (Fanchini et al., 2011) concluded that during the total duration of SSG, the value of HR is smaller with shorter repetitions (e.g., 2 min) compared to longer repetitions (e.g., 6 min). Collectively, these results may suggest that when considering the total duration of the SSG, the continuous method induces higher HR responses compared to the fractionated method with shorter repetitions. Some possible justifications for these results have been identified, such as the additional rest between repetitions that causes decreases in HR (Aguiar et al., 2012) and a pacing effect that can induce players to set the pace of the game (Carling et al., 2008). Finally, some studies also show that SSG performed under the continuous or fractionated formats displayed identical physiological responses for both training regimes (Köklü, 2012; Yücesoy et al., 2019). In this regard a previous study, (Christopher et al., 2016) also observed no differences in physiological indicators when comparing both training methods. Collectively, these results suggest that both regimes can be used for physiological adaptations and match-specific conditioning. The development of the player's physical condition is one of the essential factors for performance (Haghighi et al., 2012) and also depends on the interaction between exercise duration and subsequent recovery periods, as well as exercise intensity and recovery (Bangsbo, 1994). Indeed, the recovery period between sets may result in an increased HR response in the following series, thus better removal of substrates during the stipulated rest period (Hill-Haas et al., 2008), which allows physiological recovery and higher intensities of work in the following repetitions (Hill-Haas et al., 2009). Although most studies on SSG are prescribed with short rest intervals, some recent studies have used variations in recovery time (e.g., 10 min to 30 min) (Hill-Haas et al., 2011). The training load is relevant in the player's physical state since performance optimization is only achieved from post-training and competition recovery periods, thus it is necessary to consider an optimum balance between the stress resulting from the stimulus and adequate recovery intervals (Kellmann, 2002). Exercise variables such as duration, recovery, and intensity are therefore considered the predominant vectors of the training load (Brink et al., 2010).

Contradictions and problems

Usually the SSG is prescribed by the fractionated method (Harrison et al., 2014), although the continuous training method is more similar to the demands of real games (Aguiar et al., 2012). One of the aforementioned studies (Fanchini et al., 2011) concluded that during the total duration of SSG, the value of HR is smaller with shorter repetitions (e.g., 2 min) compared to longer repetitions (e.g., 6 min). These results seem to suggest that the continuous method induces higher HR responses compared to the fractionated method with shorter repetitions, considering the total duration of SSG. Some possible justifications for these results have been identified, such as the additional rest between repetitions that causes decreases in HR (Aguiar et al., 2012) and a pacing effect that can induce players to set the pace of the game (Carling et al., 2008). In addition, the duration of repetitions may be a determining factor to be considered, as shorter and successively shorter repetitions appear to cause lower % max HR compared to longer repetitions (Bujalance-Moreno et al., 2019; Hill-Haas et al., 2009; Köklü, 2012). Contrary to this evidence, a study comparing the use of longer and shorter repetitions found that the physiological responses were similar (Köklü, 2012).
On the other hand, SSG could induce various responses in the external load. A previous study, which compared the SSG and a regular game performance, concluded that the

level of intensity during the regular soccer game was higher compared to the performance of the SSG, although the distance covered per minute was greater during the SSG (Castellano et al., 2012). Another study (Aguiar et al., 2012) observed that a reduction in the number of players participating in the SSG caused a decrease in the distance covered and the amount of sprints performed. Other investigations (Aasgaard & Kilding, 2018; Cihan, 2015) reported that the inclusion of defensive strategies (e.g., man-to-man marking) by the coach promoted an increase in the total distance covered, namely at high intensities, while the inclusion of goalkeepers caused an increase in the number of accelerations (Casamichana et al., 2013).

Although the choice of training method is a fundamental factor in defining the training load, the recovery time between repetitions also plays an important role in the training load imposed by the exercise, and should be carefully analyzed by the coaches. Given that the ability to maintain high intensities during exercise, depends on the recovery from repetitions of previous exercises (Balsom et al., 1992). Köklü et al. (2015) reported that, when a coach selects the fractionated training method, the number of repetitions and duration of repetitions is considerably affected by the physical demands of the tasks. These results were corroborated by a study that investigated the effects of different recovery periods of 1, 2, 3, and 4 min, respectively (Köklü et al., 2015). The same conclusions were drawn from a study that had recovery periods of 30 s and 120 s and aimed to analyze variation in HR, the effects of oxygenation on muscles, and the movement demands resulting from the task (McLean et al., 2016). In this respect, exercise duration and recovery time may be determining factors for controlling the training load and consequent physical and physiological responses.

Overall previous studies have allowed coaches better control of training load during SSGs; however, some questions remain unanswered, such as those relating to the use of the continuous and fractional methods as well as, for example, the manipulation of three critical variables related to the SSG prescription: time duration, interval of rest, and number of repetitions. The current data highlight some lack of consensus in the use of both methods and remain inconclusive regarding the effects of manipulation on the variables identified and further studies are needed to clarify the topic due to its importance for training manipulation and control.

Following a new line of investigation, one recent study (Branquinho et al., 2020), which sought to respond to existing gaps in the literature, propose new evidence that can be extremely useful for coaches in the prescription and control of training load during the performance of SSG. In this study (Branquinho et al., 2020), the effects of the continuous and fractionated formats on the training load were investigated during the performance of a five-a-side SSG involving professional soccer players. The players performed the same exercise using the continuous (1 x 24m) and fractionated (2 x 12m; 4 x 6m and 6 x 4m) method, and the results indicated that the use of the continuous method has a tendency to cause less impact on internal and external loads. Furthermore, the authors state that the increase in exercise fractionation through the fractionated method induced increases in the external load. In general, the study revealed that the application of SSG by the fractionated method tends to cause greater training load while performing SSG. The results (Branquinho et al., 2020) emphasizes the importance of the coach in choosing the training method to be used, since the correct manipulation of this variable helps in the management of exercise fatigue and in the increase or decrease of the resulting training load . In addition, it introduced a new paradigm that uses both training methods. According to the author (Branquinho et al., 2020), the fractional method with short repetitions is appropriate if the coach intends to achieve high physical performance and high training load responses for the training unit. Conversely, if the objective is to perform careful management of the players' effort, to reduce the imposed training load, or to focus players on learning content (e.g., tactical components), then the continuous method should be used. This study suggests new approaches for the use of the continuous and fractionated training method, as well as the importance of optimal recovery time when utilizing a five-a-side SSG format.

Suggestions for further research

Following a new trend of investigation, and in order to respond the gaps in the literature, future research can focus on the relationship between exercise and recovery durations during SSG in soccer, since the manipulation of time duration, interval of rest, and number of repetitions are variables with lack of study and little consensus. Particularly and according to the literature gap, it may also be relevant to study the effects of the fractionated method in SSGs when considering the same total duration of exercise (total and in each repetition) and manipulating different recovery times. Other objectives can be tested: i) understanding and comparing the impact of a team's playing style on training load indicators, tactical behavior, and technical performance resulting from SSG applied by different methods; ii) comparing possible differences in the perception of the players' effort in performing different fractionated SSG formats with the same total duration and different recovery time; and iii) investigating changes in technical and tactical components based on the use of different training methods. Some of findings could provide new insights for researchers, coaches, and athletes to improve training efficiency and optimize performances.

Acknowledgments

This work is supported by national funding through the Portuguese Foundation for Science and Technology, I.P., under project UID04045/2020.

Conflict of interest

The authors declare that there is no conflict of interests.

Chapter 3

Experimental Studies

Study 2 - Comparison Between Continuous and Fractionated Game Format on internal and External Load in Small-Sided Games in Soccer

Abstract

This study aimed to identify the effects of continuous and fractionated game formats on internal and external load in small-sided games in soccer. Twenty male professional soccer players participated in the study performing the same exercise (5 vs. 5 players) continuously (1 × 24 min) and in a repeated/fractioned manner (2 × 12 min, 4 × 6 min, and 6 × 4 min). A comparison between playing conditions was assessed by means of standardized mean differences calculated with combined variance and respective confidence intervals of 90%. The limits for the statistics were 0.2, trivial; 0.6, small; 1.2, moderate; 2.0, large; and >2.0, very large. The results indicate that the use of the continuous method seems to present the tendency of less physical impact on the internal and external loads compared to the fractionated method. In addition, the higher number of exercise repetitions in the fractionated method was found to increase the external load compared to the continuous method. This study showed that application of small-sided games by the fractionated method tends to result in higher training loads.

Key-Words: soccer; training load; external load; internal load; continuous method; fractionated method.

Introduction

Football is characterized as an intermittent sport modality involving frequent actions of high intensity, interspersed with longer or shorter recovery periods (Bangsbo et al., 2006). In fact, players perform average sprints of 2–4 s every 90 s during a game, highlighting the importance of anaerobic efforts for success in the game and suggesting these efforts' characterization as long-term intermittent modality (Silva, Magalhaes, Ascensao, Seabra, & Rebelo, 2013). Training methods in football have evolved over the years (Selmi et al., 2018), from privileged exercises without a ball which develop physical capacities to new methods and exercises which simultaneously improve physical capacities along with technical and tactical skills in accordance with the modern demands of the game (Aguiar, Botelho, Lago, Maças, & Sampaio, 2012). Small-sided games (SSGs) have been increasingly used by coaches because of their benefits and advantages, as when properly designed they can represent an effective strategy for multi-component training (Hammami et al., 2018). Indeed, SSGs enables the development of both physical/physiological and technical/tactical skills at the same time (Clemente et al., 2014), thus presenting itself as a more effective training method compared to traditional sprint training (Moran et al., 2019). These findings have recently been corroborated by a study summarizing the effects of SSGs across 16 studies drawn from multiple sports and population types. The authors concluded that SSGs were more effective for the development of skill and endurance than traditional conditioning training and traditional sprinting training (Hammami et al., 2018).

Thus, the adequate design of SSGs that stresses anaerobic efforts is paramount for promoting appropriate training stimuli according to training goals and match demands (Buchheit & Laursen, 2013). For that, coaches should be aware of the relationship between SSGs variables and the required training stimuli and training load (Aguiar et al., 2015; Köklü, Alemdaroğlu, Cihan, & Wong, 2017; Yücesoy et al., 2019). Training load control has been described as a reliable method for monitoring training stimulus response in football (Impellizzeri et al., 2005, 2019) through the use of internal and external load variables that can be conditioned by the manipulation of SSGs through the number of repetitions, duration of each repetition, and duration of rest (Buchheit & Laursen, 2013; Clemente et al., 2014; Köklü, Alemdaroğlu, Cihan, & Wong, 2017; Moran et al., 2019). In addition, the impact of such manipulations on the training load in football and consequently on the aerobic or anaerobic demand of SSGs has yet to be elucidated completely and needs to be investigated (Buchheit & Laursen, 2013; Köklü, Alemdaroğlu, Cihan, & Wong, 2017; Moran et al., 2019). The alteration of these variables can be generally understood as continuous (i.e., without repetitions or rest intervals during the exercise) or fractionated (i.e., exercise performed repeatedly and with rest intervals between repetitions) methods. In fact, the literature has described that the performance of the exercise by either continuous or fractionated methods can cause changes in the training load (Köklü, Alemdaroğlu, Cihan, & Wong, 2017), particularly by the changes that occur in the intensity distribution during the different periods of performance (Fanchini et al., 2011). However, the differences in their application are not yet clear (Impellizzeri et al., 2004; Köklü, Alemdaroğlu, Cihan, & Wong, 2017; Owen et al., 2016; Yücesoy et al., 2019). In fact, few studies have investigated the effects of applying the continuous or fractionated method on SSGs, and previous results are not conclusive and differ according to the experimental design adopted. For example, Fanchini et al. (2011) investigated the internal and external load associated with both fractionated methods. Based on a comparison of 2-, 4-, and 6-min fractionated exercises, the authors found higher responses to the internal training load for 4- compared to 6–min repetitions in SSGs. In rugby, Sampson, Fullagar, & Gabbett (2015) revealed that the number and duration of the repetitions affect the internal (heart rate (HR)) and external (number of displacements at high speed) load in a positive manner. Results from another study (Hill-Haas et al., 2011b) suggest that the use of SSGs through the continuous method induce lower HR responses compared to the fractionated method. However, Hill-Haas, Rowsell, Dawson, & Coutts (2009), concluded that there was a higher internal load but with a lower external load when using continuous vs. fractionated methods. In a recent study that analyzed internal and external load variations between two fractional regimes (6 × 3 min and 3 × 6 min) during SSGs, the results show that longer variations increase the perception of effort and contribute to a large decrease in total running distances and total accelerations and decelerations (Clemente, Nikolaidis, Rosemann, & Knechtle, 2019). These data highlight that the differences in the use of both methods remain inconclusive and further studies are required to clarify the theme (Aguiar et al., 2015; Fanchini et al., 2011; Köklü, 2012; Owen et al., 2016; Sampaio et al., 2014). Moreover, it is interesting to select a fractionated method to compare the same total duration, the same intervals of rest but with different number of repetitions. Thus, the present research aimed to study the effects on internal and external loads resulting from the application of continuous and fractionated methods in SSGs in soccer training.

Materials and Methods

Experimental Approach to the Problem

A cross-sectional field study was used to verify the differences between the continuous and fractionated methods with respect to internal and external load. Players were previously familiar with the different SSG formats and the material used. The study was conducted for four weeks with two days' rest after the team's official game and after a recovery session, to avoid the onset of fatigue. The study always took place on the same field and the 20 players participated in all data collection sessions. The players were distributed into two teams based on skill level and playing position to homogenize the competitive level. The teams did not change during the study. During each session and after a standard 15-min warm-up (Silva, Neiva, Marques, Izquierdo, & Marinho, 2018), one of the four SSG formats was applied, with several balls distributed throughout the field, ensuring that play continued quickly whenever the ball left the field (Casamichana & Castellano, 2010). To best control for circadian variations on the measured variables, all games were performed at the same time during the day (17:00–19:00) and, during these sessions, the average temperature recorded was 20 ◦C.

Subjects

Twenty male professional Portuguese soccer players (age: 25.2 ± 6.1 years; experience: 11.1 ± 4.2 years; height: 176.2 ± 7.3 cm; weight: 75.1 ± 6.7 kg) participated in the study during the 2018/2019 season. Their standard training involves four sessions per week (each lasting around 90 min), in addition to a competitive match. Participants were informed of the study design and its requirements, as well as the possible benefits and risks, and gave their consent prior to the start of the study in accordance with the principles of the Declaration of Helsinki for the study in humans. The study was approved by the local ethical committee (University of Beira Interior).

Small-sided conditioned games

All SSGs were composed of a 5 × 5 player format with a constant area of 40 m × 40 m. Four SSG formats were used in randomized order: one continuous T1 (1 × 24 min) and three fractionated methods, namely T2 (2 × 12 min), T3 (4 × 6 min) and T4 (6 × 4 min), with 2-min recovery between repetitions. No specific verbal instructions were provided before, during, or after the SSGs. Ten balls were placed around the pitch to ensure a quick repositioning if the ball in play went out of bounds. The SSGs followed official football rules with exception of offside. The aim of each game was to outscore the opponents.

Internal Load

Internal load was measured by recording HR (heart rate) with a GARMIN TM HR band (Garmin Ltd., Olathe, KS, USA) with a chest strap sensor (Molina-Carmona et al., 2018). The mean (Av.HR) and maximum (Max.HR) values recorded in each SSG format were considered for analysis.

External Load

External load was recorded using inertial WIMU TM devices (Real Track Systems, Almeria, Spain). The WIMU TM is composed of different sensors for motion analysis and tracking location under external conditions (Muñoz-Lopez et al., 2017), demonstrating a high degree of accuracy (Bastida-Castillo, Gómez Carmona, De la cruz sánchez, & Pino Ortega, 2018). Data were analyzed using the SPRO TM analysis program (RealTrack Systems, Almeria, Spain) and the displacement velocity was defined in four intervals of intensity: Very Low (0–1 m/s), Low (1–4 m/s), Moderate (4–5.5 m/s), and High/Very High (≥5.5 m/s).

Statistical Analysis

A descriptive analysis of the data was performed using standard deviations. Comparison between playing conditions was assessed by means of standardized mean differences calculated with combined variance and respective confidence intervals of 90% (Cumming, 2012; Hopkins et al., 2009). All assumptions were confirmed before data analysis. The limits for the statistics were 0.2, trivial; 0.6, small; 1.2, moderate; 2.0, large; and >2.0, very large (Hopkins et al., 2009). Differences in means (i.e., T1 vs. T2, T1 vs. T3, T1 vs. T4, T2 vs. T3, T2 vs. T4, and T3 vs. T4) for each repetition and comparison of the entire total duration of 24 min were expressed in perception units with 90% confidence limits (CL). The smallest differences found were estimated from standardized units multiplied by 0.2. The probabilities were used to make a qualitative probabilistic mechanistic inference about the real effect; that is, if the effect probabilities were substantially higher and lower were both > 5%, the effect was reported as uncertain. Otherwise, the effect was clear and reported as the magnitude of the observed value. The scale was as follows: 25–75%, possible; 75–95%, likely; 95–99%, very likely; and >99%, most likely (Hopkins et al., 2009).

Results

Table 2 and Figure 1 show the variations in internal and external load between SSG formats T1 vs. T2, T1 vs. T3, T1 vs. T4, T2 vs. T3, T2 vs. T4, and T3 vs. T4. Overall, the fractionated method revealed a higher impact on the external load and subtle changes in the internal load of the players. It is apparent that, for the same time of exercise, the higher was the number of repetitions, the more internal load was imposed on the players.

Figure 1. Standardized Cohen's differences for comparative results of the [T1] vs. [T2], [T1] vs. [T3], [T1] vs. [T4], [T2] vs. [T3], [T2] vs. [T4] and [T3] vs. [T4] SSGs. Error bars indicate uncertainty in true mean changes with 90% confidence intervals.

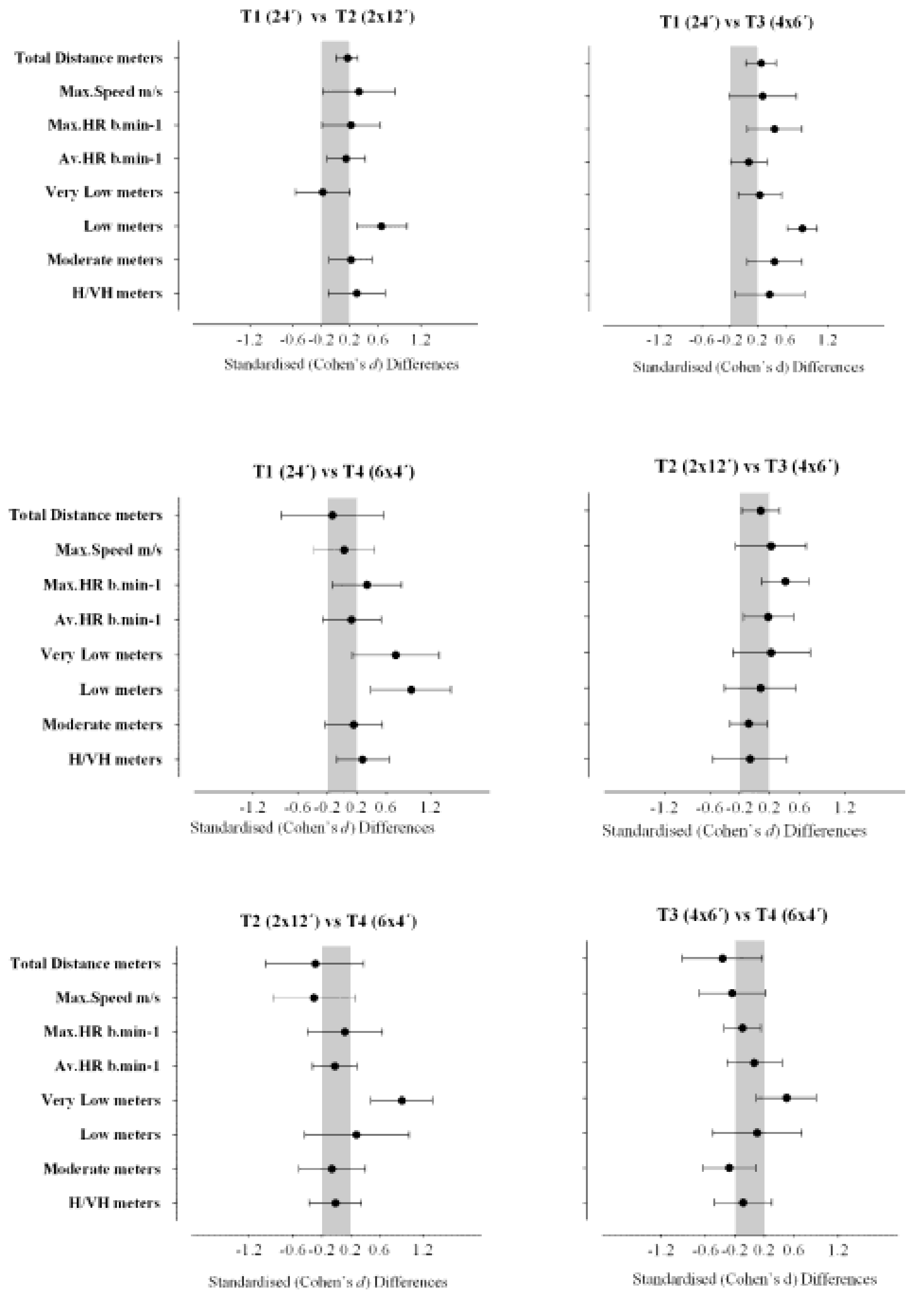


Table 2. Descriptive statistics on the different condition variables

Variables	T1 24' game	T2 2x12´ game	T3 4x6' game	T4 6x4´ game	Change in mean (%; 90% CL)
Total distance meters	2254.5±167.1	2333.60±116.7	2371.28±283.4	2194.9±839.12	a) 79,1; ±74.7*
					b) 116.8; ±100.3*
					c) -59.6 ± 327.6
					d) 37.7±118.3
					e) -138.7±319.3
					f) -176.3±257.0*
Max. Speed kh.h-1	6.05±0.52	6.24±0.59	6.20±0.49	6.06±0.54	a) 0.7; ±1.0*
					b) 0.5; ±1.0
					c) 0.1; ± 0.8
					d) -0.1 ±1.0
					e) -0.6 ±1.1
					f) -0.5 ±0.9
Max. HR b.min-1	181.95±9.07	184.3±10.03	186.60±10.55	185.55±11.16	a) 2.4; ±4.4
					b) 4.7; ±4.1**
					c) 3.6; ± 5.0*
					d) 2.3 ±5.0
					e) 1.3 ±5.5
					f) -1.1 ±2.6*
Av. HR b.min-1	152.7±18.20	155.45±16.90	154.00±19.23	155.15±15.16	a) 2.8; ±5.0*
					b) 1.3; ±4.7
					c) 2.5; ± 7.3
					d) -1.5± 4.5
					e) -0.3±5.6
					f) 1.2±6.9
Very Low meters	262.06±32.03	250.33±50.95	277.06±55.26	309.06±93.41	a) -11.7±24.4
					b) 15.0±20.0*
					c) 47.0±38.2**
					d)26.7±20.1**
					e) 58.7±27.5***
					f) 32.0±26.0**
Low meters	1822.10±176.05	1990.80±171.27	2037±180.68	2063.83±389.43	a) 168.7±92.5***
					b) 215.4±55.7
					c) 241.7±140.0***
					d) 46.7 ± 86.2*
					e) 73.0± 187.3
					f) 26.3± 153.9
Moderate meters	143.95±45.66	157.52±58.25	171.43±65.74	153.88±68.25	a) 13.6 ± 19*
					b) 27.5± 24.6**
					c) 9.9 ± 24.6
					d) 13.9±32.1
					e) -3.6±28.9
					f) -17.5±22.3*
H/VH meters	12.19±12.27	17.03±15.94	18.26±18.85	16.80±14.42	a) 4.8± 6.5*
					b) 6.1± 8.1*
					c) 4.6± 5.7*
					d) 1.2± 7.6
					e) -0.2± 5.9
					f) -1.5± 6.4

Note: Differences in means ((%); ±90% CL) are identified as: (a) T1 vs. T2; (b) T1 vs. T3; (c) T1 vs. T4; (d) T2 vs. T3; (e) T2 vs. T4; and (f) T3 vs. T4. Asterisks indicate the uncertainty in the true differences as follows: * possible, ** likely, and *** very likely

Internal Load

The result of the internal load analyses revealed that the Max.HR of the players showed a possible increase of 4.7 ± 4.1 and 0.6 ± 5.0 (small effect) when comparing T1 vs. T3 and T1 vs. T4, respectively. However, a possible decrease of −1.1 ± 2.6 (trivial effect) was demonstrated by comparing T3 vs. T4. The Av. HR of the players revealed a possible 2.8 ± 5.0 increase (trivial effect) for T1 vs. T4.

External load

The results of total distance revealed possible increases of 79.1±74.7 (trivial effect) and 116.8 ± 100.3 (small effect) for T1 vs. T2 and T1 vs. T3, respectively, and a possible decrease of −176.3 ± 257 (small effect) for T3 vs. T4. Regarding the maximum speed, a possible increase of 0.7 ± 1.0 (small effect) for T1 vs. T2 methods was observed. Analysis of the very low-intensity travel speed revealed possible 15.0 ± 20.0 (small effect), 47.0 ± 38.2 (moderate effect), 26.7 ± 20.1 (small effect), and 32.0 ± 26.0 (small effect) increases and a most likely 58.7 ± 27.5 (moderate effect) increase for T1 vs. T3, T1 vs. T4, T2 vs. T3, T3 vs. T4 and T2 vs. T4, respectively. Similarly, the low-intensity displacement velocity analysis revealed most likely increases of 168.7 ± 92.5 (moderate effect) and 241.7 ± 140.0 (moderate effect) and a possible increase of 46.7 ± 86, 2 (trivial effect) for T1 vs. T2, T1 vs. T4, and T2 vs. T3, respectively. Analysis of moderate-intensity displacement velocity revealed a possible increase of 13.6 ± 19 (small effect) and a likely increase of 27.5 ± 24.6 (small effect) for T1 vs. T2 and T1 vs. T3, respectively. In addition, a possible reduction of 17.5 ± 22.3 (small effect) was revealed for T3 vs. T4. Analysis of high-intensity displacement velocity revealed possible increases of 4.8 ± 6.5 (small effect), 6.1 ± 8.1 (small effect), and 4.6 ± 5.7 (small effect) for T1 vs. T2, T1 vs. T3, and T1 vs. T4, respectively.

Discussion

Overall, the use of the continuous method seems to present the tendency of less physical impact on the internal and external loads compared to the fractionated method. In addition, the increase in the number of exercise repetitions in the fractionated method was found to increase the external load compared to when using the continuous method. This latter method presented the tendency of the decreased in the distances travelled with different intensities. Regarding the HR responses, the data were trivially different, suggesting punctual variations between methods.

Internal Load

HR analysis revealed differences in Max.HR when comparing T1 vs. T3 and T1 vs. T4 formats, suggesting that it may be conditioned using the fractionated method, rather than the continuous method. Thus, evidence was provided in our study that the fractionated method performed by short repetitions (e.g., 4 min) induces further changes in Max.HR. Emphasizing the differences between continuous or fractionated methods, differences were found in a 3 × 3 format SSG study where longer repetitions (3 × 6 min/2 min rest) decreased Max.HR compared to shorter repetitions (3 × 2 min/2 min rest) (Fanchini et al., 2011). Our results appear to reinforce the suggestion that the increase in total recovery time between exercises allow players to reach a higher intensity during exercises. This proposal was supported by previous studies when the results of Max.HR were crossed with intensity displacement velocity during the exercises, because the Max.HR were related to the increase in the pace of the game and the high-intensity actions of players (Clemente et al., 2019). Despite the considered variations in Max.HR responses, it is difficult to quantify the internal load variation based only on the use of continuous or fractionated methods, and other variables may be useful in future studies. However, the results appear to indicate that variations in Max.HR seems to be related to the use of specific 4 × 6 min and 6 × 4 min fractionated methods, thus increasing HR compared to the other longer fractionated (2 × 12 min) and continuous (1 × 24 min) methods used. These data suggest that fractionated methods can to induce a higher internal training load and rest periods between repetitions can be useful in recovery, allowing for increased physical responses in subsequent repetitions. However, the analysis of Av.HR of the present study and some results of previous studies seem to present some divergent data. In a study conducted with national junior soccer players, no differences in physiological responses (internal and external training load) between continuous and fractioned methods were observed (Christopher et al., 2016). Similarly, Hill-Hass et al. (2009) found no differences in physiological responses between the use of continuous and fractionated methods during SSG. These results are supported by a recent study, where three different sets of players performed exercises by both continuous and fractionated methods, and the physiological responses remained constant regardless of the training method used (Köklü, Alemdaroğlu, Cihan, & Wong, 2017). In addition, higher internal training load during continuous SSG performance are described, compared to the fractionated method (Köklü, Alemdaroğlu, Cihan, & Wong, 2017). Furthermore, the Av.HR results found in the present study are also somewhat contradictory. These differences are even more evident if we compare our findings with what was previously reported by Montgomery, Pyne, & Minahan (2010), where high correlations between training load and HR responses were described. Our study does not follow this pattern because players' physical responses appear to be higher in the fractionated method (higher Max.HR) but Av.HR responses tends to remain constant between the two training methods. Differences in protocol design and the fact that the HR may be sensitive to these differences may explain these results.

External load

The results of external load related to the intensity of the displacements performed revealed that there is a tendency (from "possible" to "likely") for higher values in the different displacement variables speeds by the use of the fractionated method compared to the continuous training method. The differences found may be due to the additional passive rest period between each repetition, which has a beneficial impact on delaying the impact of fatigue on players. This ability may have contributed to an improved physiological recovery of the body, including phosphocreatine resynthesis, the removal of metabolic by-products, and immobilized potassium in the muscle (Bangsbo, 1993; Bangsbo et al., 2006; Mohr, Krustrup, & Bangsbo, 2005). The results suggest that the rest period between 2 and 4 min was adequate for maintaining high intensity levels and maximizing energy phosphates as the primary energy source during exercise (Billaut et al., 2011). In addition, it has been previously shown that testosterone and cortisol respond to metabolic stress associated with SSGs, and some authors suggest that these hormonal changes may affect performance (Thorpe & Sunderland, 2012; Walker et al., 2010). Thus, it is important to ensure an optimal total duration of exercise, with the number of repetitions and time of each one being correctly adjusted to avoid acute responses of the above hormones. Regarding the total distance travelled, a higher total distance was identified in two formats performed in the fractionated method (T2 and T3, with a "possible effect") compared to the continuous method. These data are in agreement with what was previously described by Hill-Haas et al. (2009), who showed evidence of an increased total distance travelled during fractionated compared to continuous methods. These findings suggest that the continuous method tends to reduce the physical loads imposed on players, a result that can be explained based on the rest periods used in the fractionated method. However, when comparing the three fractionated methods, it can be inferred that, for this variable, the 4 × 6 min fractionated model presents a higher level of variation, specifically in the distance travelled. These data suggest that the exercise fractionation should not be too long or too short in relation to the total time, suggesting that 1/4 of the total exercise time per repetition is sufficient to guarantee high levels of physical demands consistently. This approach appears to contribute to the optimization of energy systems that support high-intensity explosive actions (Clemente et al., 2017). The maximum speeds between the methods do not seem to change significantly. The data indicate that the ability of players to reach high speeds is independent of the use of continuous or fractionated methods, possibly because the field size is reduced (40 m × 40 m), making it impossible for players to reach higher speeds. In the future, variations in the internal and external loads during SSGs performed by both continuous and fractionated methods in other game formats, with different manipulations of rules and constraints, may be analyzed to develop and clarify the theme. This study highlights the importance of the coach's choice when performing exercise by continuous or fractional methods. Coaches can manipulate this variable in order to manage the effect of exercise fatigue and increase or decrease exercise training load. For example, if the coach wants to maintain high physical performance and high training load responses in order to prepare players for a game's demands, they should choose the fractional method of exercise with short repetitions. However, if the coach wishes to carefully manage the players' efforts (e.g., post-competition muscle regeneration training) and decrease the response to the training load, they should use continuous exercise. If the coach wants to create an exercise with a lower training load, allowing players to focus more on learning other components over the duration, it would be more appropriate to select a continuous exercise (for example, 24 min). However, if the goal is to constantly provide adaptations to the game environment, highlighting what occurs during the game, the exercise should be performed in shorter repetitions (e.g., 4 × 6 min). Future studies should use the potential of this research to provide coaches with additional information, such as the impact on tactical behavior resulting from the application of both methods.

Conclusions

Application of SSGs by the fractionated method results in higher internal (small increments) and external (except very low intensities) loads. If trainers are seeking higher internal and external loads in a 5 × 5 SSG situation, the fractionated method would be the most appropriate one because continuous and longer exercise durations appear to be directly linked to a decrease in internal and external loads. However, it is important to note that the choice of one method always depends on the coach's specific goals for the training session because there are numerous possibilities where both methods can be beneficial for performance enhancement. In addition, the increase in the number of exercise repetitions in the fractionated method seems to increase the external load compared to when using the continuous method during the same time of exercise duration. HR monitoring does not appear to be a suitable variable for assessing SSG load or intensity.

Funding: This research was funded by Portuguese Foundation for Science and Technology, I.P., grant number UID/DTP/04045/2019.

Acknowledgments: The authors thanks to all the players and the technical staff that allow the development of this study.

Conflicts of interest: The authors declare no conflict of interest.

Study 3 – Effects of different recovery times on internal and external load during small-sided games in soccer

Abstract

Background: The ability to maintain a high intensity of exercise over several repetitions depends on recovery from previous exercises. This study aimed to identify the effects of different recovery times on internal and external load during small-sided soccer games.

Hypothesis: An increase in recovery time will increase the external training load and decrease the internal exercise load, which will result in a greater physical impact of the exercise.

Study design: Cross-sectional study

Level of evidence: Level 2.

Methods: Twenty male semiprofessional soccer players participated in the present study. They performed the same exercise (5-a-side game format) continuously (1 ´ 18 minutes) and repeatedly/fractionated (3 ´ 6 minutes) with different recovery times (30 seconds, 1 minute, 1.5 minutes, and 2 minutes). Their internal load (i.e., average heart rate (HR) and maximum HR) and external load (i.e., total distance, maximum speed, and ratio meters) were measured using an HR band and an inertial device equipped with a global positioning system, respectively.

Results: The manipulation of recovery times induced differences in the internal and external load. For the same total duration, the external and internal load indicators exhibited higher values during the fractionated method, particularly with short recovery periods.

Conclusions: The application of small-sided soccer games with different recovery times induced varying responses in training load. To maintain high physical performance and high training load, the fractional method with short recovery periods (i.e., 30 seconds) should be used. In contrast, to carefully manage players' efforts and decrease response to training load, continuous or fractional methods with longer recovery periods (i.e., 1-2 minutes) should be used.

Clinical relevance: The proper prescription of recovery time between exercises facilitates enhanced training efficiency and optimized performance.

Key-words: Soccer; training load; recovery time; fatigue; small-sided games manipulation.

Introduction

In soccer, the capacity of players to continuously promote tactical and strategic adaptations to game dynamics requires high levels of physical conditioning. Small-side games (SSGs) (Hill-Haas et al., 2009; Katis & Kellis, 2009) have been proposed as a tool for developing such capabilities in the context of performance while highlighting similar combinations of the technical, tactical and physical abilities required in full-sized matches (Aguiar et al., 2008; Clemente et al., 2014; Katis & Kellis, 2009). SSGs enhance technical and tactical development as well as specific fitness capacities such as endurance (aerobic and anaerobic) and agility (Hill-Haas et al., 2009). Based on previous research, SSGs are favoured by soccer coaches to improve players' performance (Clemente et al., 2014; Dellal et al., 2011; Katis & Kellis, 2009; Köklü et al., 2015; Los Arcos et al., 2015)

Indeed, SSGs have shown characteristics that allow the optimization of tactical and physical components (Aguiar et al., 2008). In addition, previous research has shown that manipulation of SSG duration and recovery periods between repetitions (Köklü et al., 2017) (i.e., continuous or fractionated methods), previous information about exercise duration (Ferraz, Gonçalves, Coutinho, et al., 2018; Ferraz, Gonçalves, Van Den Tillaar, et al., 2018), and other variables (i.e., pitch size, number of players, coach encouragement, rules or using goalkeepers) allow different SSG intensities and technical/tactical adaptations (Clemente et al., 2014; Köklü et al., 2017).

Due to the variety of behaviours required in SSGs, exercises without any control could promote soccer players' fatigue (Pellegrino et al., 2018). Progressive decreases in
showed less homogeneity in heart rate (HR) for a recovery time of 2 min. In another investigation, (McLean et al., 2016) analysed the effect of increasing the recovery time from 30 s to 120 s during SSG repetitions and concluded that there were no changes to the HR parameters between the analysed conditions. heart rate, running intensity and distance covered have been associated with decreased training load and increased fatigue (Bangsbo et al., 2006). From a physiological perspective, blood lactate and H+ accumulation, glycogen depletion, phosphocreatine (PCr) depletion, dehydration, intramuscular acidosis and insufficient Ca2+ within muscles, were indicated as factors that may contribute to the accumulation of fatigue during each exercise repetition (Alghannam, 2012; Pellegrino et al., 2018; McLean et al., 2016). Moreover, neural

transmission failures, motivational mechanisms, and practice contexts [11,30], have also been associated with fatigue and increased need for load control during exercise.

Thus, the correct manipulation of SSG duration and recovery periods between repetitions according to the physical effort defined for the exercises should be ensured by coaches since the ability to manipulate or maintain a high exercise intensity across multiple exercise repetitions is dependent on the recovery from previous exercise (Balsom et al., 1992). A previous study (Köklü et al., 2015) found that shorter recovery periods induced greater internal loads and increased displacement at low intensity in young soccer players when comparing three-a-side SSG formats performed on an 18 x 30 m field over four repetitions (4 min per repetition) with passive recovery times of 1, 2, 3 or 4 min between repetitions, respectively. Another investigation carried out with senior players (who played in the 2nd Australian division) did not show differences in physiological and technical indicators for different recovery times (30 seconds and 120 seconds) under repetitions of 6 x 2 min performed in three-a-side SSGs on a 15 x 20 m field (McLean et al., 2016). Dellal et al. (2011) used rest periods of 1, 1.5 and 2 min between similar repetitions in two-, three- and four-sided games, respectively, and their results
The results obtained from the aforementioned studies were distinct and inconclusive since different physical responses and varying impacts on training load were noted. Some of the discrepancies between related studies could be attributed to the different conditions used (e.g., goals, game format, number of players, or coach encouragement) (Dellal et al., 2011; Köklü et al., 2015; Köklü et al., 2015; Rampinini et al., 2007).

The existing literature suggests that variations in training load (i.e., internal and external load) can occur during SSGs when using the continuous or fractional training method due to variations in intensity distribution during the different periods of execution (Dellal et al., 2012). Also, different recovery times can induce variations in training load (Dellal et al., 2011; Köklü et al., 2015; McLean et al., 2016) since the performance of the next repetition directly depends on the effect of the recovery period that precedes it (Bangsbo, 1994). Additionally, since different game formats (i.e., 2-a-side to 10-a-side) induce different training load responses (i.e., internal and external load) (Branquinho et al., 2020; Casamichana et al., 2013; Köklü et al., 2015; Köklü et al., 2017), we consider that it may be important to verify the effects of different recovery periods in specific game formats (e.g., five-a-side). To the best of the authors' knowledge, no previous study has investigated the effects of recovery time in the five-a-side format, which has been described to induce physiological responses similar to a

real game situation (80 to 90% maximum HR) (Clemente et al., 2014),(Owen et al., 2004) and cause higher perceived exertion values when compared to four-a-side and six-a-side formats (Sampaio et al., 2014).
Therefore, the present study aimed to investigate the effects of different recovery durations between repetitions of five-sided SSGs in training load on semi-professional soccer players. This study hypothesised that increasing recovery time will increase the external training load and decrease the internal load of the exercise, thereby leading to a higher physical impact of exercise (i.e., higher indicators of training load) due to a higher capacity for the removal of metabolic waste and the resynthesis of phosphocreatine resulting in the higher physical and physiological responses of players throughout the exercise process.

Methods

Experimental Approach to the Problem

A cross-sectional field study was used to examine the differences between a continuous format (1 x 18 min) and a fractionated (3 x 6 min) time distribution in terms of the internal and external loads of players playing SSGs (five-a-side). The fractionated method was performed four times with different recovery times (30 s, 1, 1.5 and 2 min). Players were divided based on their positions, tactical/technical levels and physical capacities (Ferraz, Gonçalves, Coutinho, et al., 2018). Teams' constitutions and respective opponents were maintained throughout the study. The aim of the game was to outscore the opposing team. The external load of the players was measured using a global positioning system (GPS).
The present study was conducted using an adapted version of the protocol used by (Branquinho et al., 2020) over a 5-week period (in April and May) during the in-season (2018/2019). During the weeks before the experiment, players were familiarised with the different SSG formats and materials used in this study. Five training sessions were held on an outdoor artificial grass pitch during the same day and time (from 17:00 until 19:00; average recorded temperature: 14˚C) over five different weeks to control for the fatigue, cardiac variation and work performed in preceding days. After a standard 15-min warm-up, one of the five SSG formats was played in randomised order during each session. During the SSGs, coaches did not provide any encouragement. Additionally, several balls were distributed around the edge of the pitch to maximise the effective playing time by ensuring that play could quickly resume whenever a ball went out of play (Casamichana & Castellano, 2010). During rest periods of the intermittent SSG format, water was allowed and provided to players.

Subjects

Twenty male semi-professional soccer players (age 23.9 years ± 2.1; height 1.78 m ± 0.06; body mass 75.7 kg ± 5.8) with 10.1 years ± 3.8 of experience participated in the present study during the in-season (2019/2020). The regular training of the team involved four sessions during the week (lasting approximately 90 min) as well as a competitive match. All players were informed of the study design and its requirements as well as the possible benefits and risks. In order to gain approval from the local ethics committee and follow the principles of the Declaration of Helsinki for human studies, all players had to provide written informed consent before the commencement of the study.

Data collection

All SSGs involved five-a-side soccer (with goalkeepers) with the aim of scoring as many goals as possible, as per the method described by (Branquinho et al., 2020; Casamichana et al., 2013). The field area was kept constant during the study (40 x 40 m), as per the method described by (Branquinho et al., 2020). Two SSG formats were used: one continuous (SSGCONT - 1 X 18 min) and four fractionated (SSG30 - 3 X 6 min + 30 s of recovery time between sessions; SSG60 - 3 X 6 min + 1 min of recovery time between sessions; SSG90 - 3 X 6 min + 1.30 min of recovery time between sessions; SSG120 - 3 X 6 min + 2 min of recovery time between sessions). All SSGs were monitored to evaluate the internal and external load of each format.

Internal Load

The internal load was measured by recording HR using a GARMIN™ HR band (Garmin Ltd., Olathe, KS, USA), which sent data to the inertial device via Ant+ technology (Molina-Carmona et al., 2018). The average HR (HR Avr) and maximum HR (HR Max) values registered in each SSG format were considered for analysis.

External Load

The external load was recorded using WIMU™ inertial devices (Real Track Systems, Almeria, Spain). WIMU™ incorporates a GPS chipset that tracks players locations in outdoor conditions (Muñoz-Lopez et al., 2017) with high accuracy (50 cm) (Bastida Castillo et al., 2018). Variations in external load (e.g., total distance, max speed and ratio meters) were recorded by tracking data via GPS with a sample frequency of 10 Hz. Data were analysed using the SPRO™ analysis program (Real Track Systems, Almeria, Spain) and the velocity was adjusted in four intensity ranges: moderate [12–18 km/h], high [19–21 km/h], very high [22–24 km/h] and maximum speed [≥24 km/h].

The collected data were imported into a computer and analysed using SPRO™ (Real Track Systems, Almeria, Spain).

Statistical Analyses

A descriptive analysis was performed and standard deviations were determined. Comparisons between the different game formats were inferred through standardised mean differences computed with pooled variance and respective 90% confidence intervals (Cumming, 2012; Hopkins et al., 2009). The limits for statistics were set at: trivial [0.2]; small [0.6]; moderate [1.2],; large [2.0], and very large [>2.0] according to the method described by Hopkins et al.(Hopkins et al., 2009). The differences in means (i.e., SSGCONT vs SSG30SSGCONT vs SSG60, SSGCONT vs SSG90, SSGCONT vs SSG120, SSG30 vs SSG60, SSG30 vs SSG90, SSG30S vs SSG120, SSG60 vs SSG90, SSG60 vs SSG120 and SSG90 vs SSG120 sessions for each condition) and comparisons across all conditions were expressed in percent units with 90% confidence limits (CLs). According to the methodology of (Batterham & Hopkins, 2006), the smallest observable differences were estimated from the standardised units multiplied by 0.2. Probabilities were used to make a qualitative probabilistic mechanistic inference about the true effect (i.e., if the probabilities of the effect being substantially higher and lower were both > 5%, the effect was reported as unclear; if not, the effect was clear and reported as the magnitude of the observed value) (Ferraz, Gonçalves, Coutinho, et al., 2018). The scale was: possible [25–75%]; likely [75–95%]very likely [95–99%]; most likely >99%.(Hopkins et al., 2009).

Results

The results (Table 3 and Figure 2) show the variation in training load between SSGs (i.e., SSGCONT vs SSG30, SSGCONT vs SSG60, SSGCONT vs SSG90, SSGCONT vs SSG120, SSG30 vs SSG60, SSG30 vs SSG90, SSG30 vs SSG120, SSG60 vs SSG90, SSG60 vs SSG120 and SSG90 vs SSG120). In general, the fractionated method revealed a higher impact on the external load and subtle changes in the internal load of the players. However, for the same duration of exercise during SSGs, short recovery periods (i.e., 30 s) induced significantly higher internal and external loads on players.

Table 3. Descriptive statistics on the different condition variables

Variables	SSGCONT 18´ game Continuous	SSG30 3 x 6´ game 30´´ recovery	SSG60 3 x 6´ game 1´ recovery	SSG90 3 x 6´ game 1´30´´recovery	SSG120 3 x 6´ game 2´ recovery	Change in mean (%; 90% CL)
Max. HR b.min-1	183.50 ± 11.67	189.30 ± 11.67	185.35 ± 9.23	187.50 ± 6.45	185.40 ± 9.93	**a)** 5.8 ± 4.8** ↑; **b)** 1.9 ± 4.6; **c)** 4.0 ± 4.5** ↑; **d)** 1.9 ± 4.5; **e)** -4.0 ± 4.4** ↓ **f)** -1.8 ± 3.5* ↓; **g)** -3.9 ± 4.2**↓; **h)** 2.2 ± 3.3* ↑; **i)** 0.1 ± 4.1; **j)** -2.1 ± 2.7* ↓
Av. HR b.min-1	165.70 ± 14.79	172.65 ± 8.59	166.40 ± 12.12	168.75 ± 7.59	167.75 ± 10.07	**a)** 7.0 ± 6.2** ↑; **b)** 0.7 ± 6.4; **c)** 3.1 ± 6.3; **d)** 2.1 ± 5.7; **e)** -6.3 ± 4.9** **f)** -3.9 ± 3.8**↑; **g)** -4.9 ± 4.4** ↑; **h)** 2.4 ± 4.7; **i)** 1.4 ± 5.4; **j)** -1.0 ± 3.1* ↓
Total Distance meters/min	2033.25 ± 174.58	2125.35 ± 161.60	1996.05 ± 173.22	1968 ± 221.83	1996.90 ± 245.11	**a)** 92.1 ± 76.2** ↑; **b)** -37.2 ± 83.1; **c)** -65.3 ± 112.2; **d)** -36.4 ± 123.9; **e)** -129.3 ± 49.1**** ↓; **f)** -157.4 ± 77.8***↓; **g)** -128.5 ± 84.6*** ↓; **h)** -28.1 ± 78.9; **i)** 0.9 ± 85.8; **j)** 28.9 ± 35.5* ↑
Max. Speed km/h	24.43± 1.33	24.60 ± 2.04	24.43 ± 1.84	24.07 ± 1.95	25.16 ± 1.91	**a)** 0.2 ± 0.8; **b)** 0.0 ± 0.9; **c)** -0.4 ± 0.8; **d)** 0.7 ± 0.9** ↑; **e)** -0.2 ± 1.0; **f)** -0.5 ± 1.0; **g)** 0.6 ± 0.9* ↑; **h)** -0.4 ±0.8; **i)** 0.7 ± 0.6** ↑; **j)** 1.1 ± 0.6***↑
Moderate meters	464.41 ± 101.07	511.96 ± 113.33	466.83 ± 110.92	453.22 ± 118.71	494.43 ± 127.64	**a)** 47.5 ± 39.0** ↑; **b)** 2.4 ± 41.9; **c)** -11.2 ± 47.5; **d)** 30.0 ± 50.0* ↑; **e)** -45.1 ± 37.7** ↓; **f)** -58.7 ± 48.9**↓; **g)** -17.5 ± 52.2; **h)** -13.6 ± 43.1; **i)** 27.6 ± 42.0* ↑; **j)** 41.2 ± 31.7** ↑
High Meters	68.74 ± 29.97	84.39 ± 40.47	82.34 ± 37.64	76.15 ± 36.81	85.76 ± 41.58	**a)** 15.7 ± 16** ↑; **b)** 13.6 ± 14.9** ↑; **c)** 7.4 ± 11.4* ↑; **d)** 17.0 ± 17.2** ↑ **e)** -2.1 ± 14.9; **f)** -8.2 ± 12.0* ↓; **g)** 1.4 ± 11.3; **h)** -6.2 ± 9.9* ↓; **i)** 3.4 ± 12.6; **j)** 9.6 ± 12.6* ↑
Very High meters	17.85 ± 12.00	28.11 ± 25.47	29.33 ± 21.78	26.25 ± 20.67	26.90 ± 15.09	**a)** 10.3 ± 9.4** ↑; **b)** 11.5 ± 8.4** ↑; **c)** 8.4 ± 7.4** ↑; **d)** 9.1 ± 6.8** ↑; **e)** 1.2 ± 9.8; **f)** -1.9 ± 7.9; **g)** -1.2 ± 6.8; **h)** -3.1 ± 5.6* ↓; **i)** -2.4 ± 7.3; **j)** 0.7 ± 5.8
Max. Intensity meters	2.98 ± 4.18	6.61 ± 8.81	6.26 ± 8.52	3.33 ± 4.92	6.72 ± 7.25	**a)** 3.6 ± 2.6** ↑; **b)** 3.3 ± 3.4** ↑; **c)** 0.3 ± 1.8; **d)** 3.7 ± 2.6** ↑; **e)** -0.3 ± 3.8; **f)** -3.3 ± 3.1** ↓; **g)** 0.1 ± 3.6; **h)** -2.9 ± 3.0** ↑; **i)** 0.5 ± 4.0; **j)** 3.4 ± 2.4** ↑

Note: Abbreviations and symbols: CL=confidence limits; ↓ =decrease; ↑ =increase. Differences in means ((%); ± 90% CL) are identified as: a) SSGCONT vs SSG30; b) SSGCONT vs SSG60; c) SSGCONT vs SSG90; d) SSGCONT vs SSG120; e) SSG30 vs SSG60, f) SSG30 vs SSG90; g) SSG30 vs SSG120; h) SSG60 vs SSG90; i) SSG60 vs SSG120; j) SSG90 vs SSG120 (*) Indicate the uncertainty in the true differences are as follows: *=possible , **=likely , ***= very likely, ****=most likely

External load

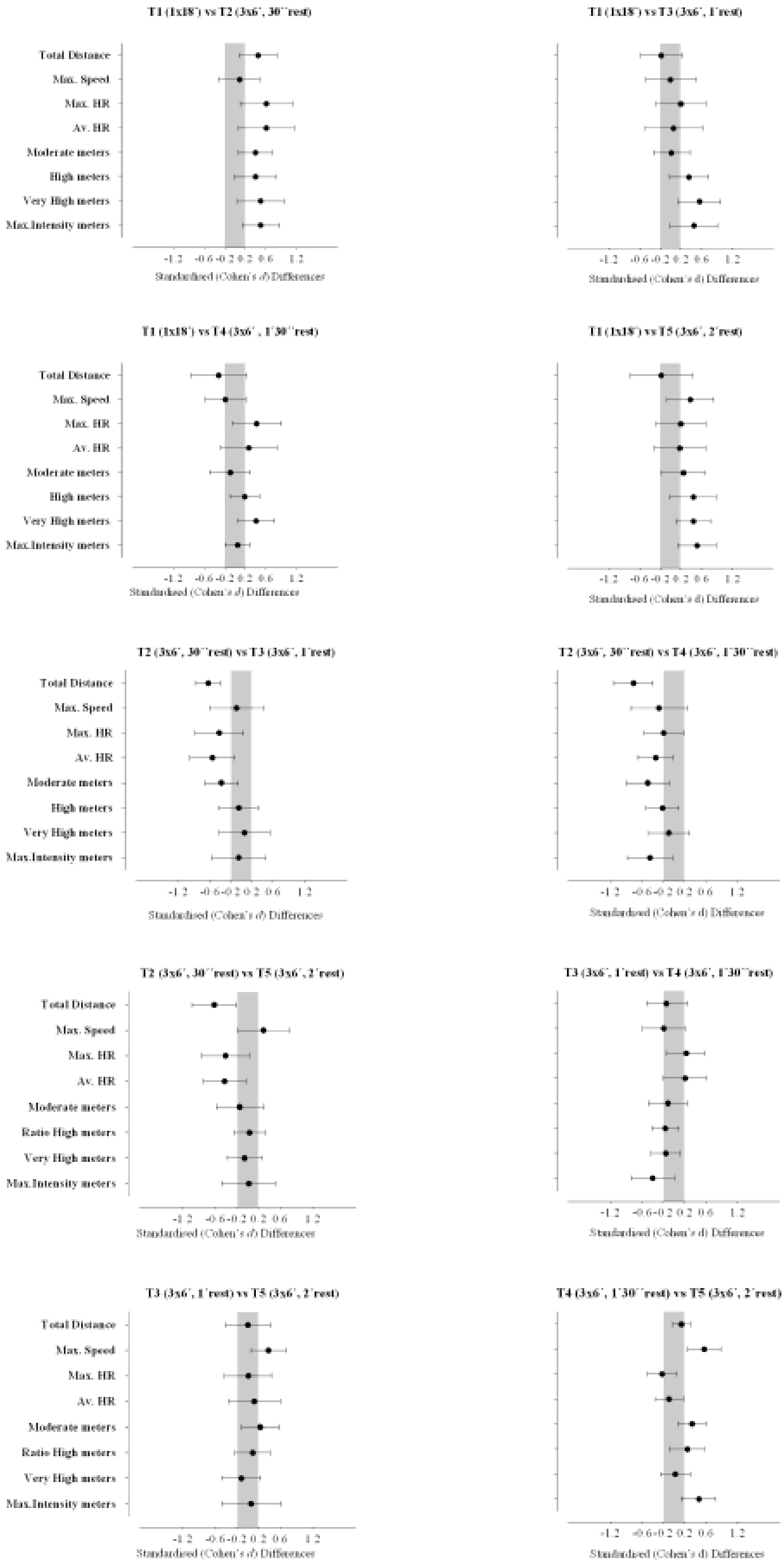
Regarding the total distance covered, the results revealed a likely increase of 92.1 ± 76.2 m (small effect) between SSGCONT vs SSG30 and a most likely decrease of -129.3 ± 49.1 m (small effect) between SSG30 vs SSG60. In the same line, there were very likely decreases of -157.4 ± 77.8 m (moderate effect) and -128.5 ± 84 m (moderate effect) between SSG30 vs SSG90 and SSG30 vs SSG120, respectively. Regarding the maximum speed, likely increases of 0.7 ± 0.9 km/h (trivial effect) and 0.7 ± 0.6 km/h (trivial effect) were observed between SSGCONT vs SSG120 and SSG60 vs SSG120, respectively. In the same line, a very likely increase of 1.1 ± 0.6 km/h (trivial effect) was noted between SSG90 vs SSG120.

Analysis of the moderate-intensity travel speed demonstrated likely decreases of -45.1 ± 37.7 m (trivial effect) and -58.7 ± 48.9 m (small effect) between SSG30 vs SSG60 and SSG30 vs SSG90, respectively. However, likely increases of 47.5 ± 39.0 m (trivial effect) and 41.2 ± 31.7 m (small effect) were observed between SSGCONT vs SSG30 and SSG90 vs SSG120. Similarly, the high-intensity displacement velocity analysis demonstrated likely increases of 15.7 ± 16 m (trivial effect), 13.6 ± 14.9 m (trivial effect) and 17.0 ± 17.2 m (small effect) between SSGCONT vs SSG30, SSGCONT vs SSG60 and SSGCONT vs SSG90, respectively. Analysis of the very high-intensity displacement velocity revealed likely increases of 10.3 ± 9.4 m (small effect), 11.5 ± 8.4 m (small effect), 8.4 ± 7.4 m (trivial effect) and 9.1 ± 6.8 m (small effect) between SSGCONT vs SSG30, SSGCONT vs SSG60, SSGCONT vs SSG90 and SSGCONT vs SSG120, respectively. The analysis of maximum intensity displacement velocity revealed likely increases of 3.6 ± 2.6 m (small effect), 3.3 ± 3.4 m (small effect), 3.7 ± 2.6 m (small effect) and 3.4 ± 2.4 m (small effect) between SSGCONT vs SSG30, SSGCONT vs SSG60, SSGCONT vs SSG120 and SSG90 vs SSG120, respectively.

Internal load

The result of HR Max showed likely increases of 5.8 ± 4.8 $b.min^{-1}$ (moderate effect) and 4.0 ± 4.5 $b.min^{-1}$ (small effect) when comparing SSGCONT vs SSG30 and SSGCONT vs SSG90, respectively. However, a likely decrease of -3.9 ± 4.2 $b.min^{-1}$ (small effect) was demonstrated by comparing SSG90 vs SSG120. The HR Avr of the players revealed a likely 7.0 ± 6.2 $b.min^{-1}$ increase (moderate effect) between SSGCONT vs SSG30. However, likely decreases of -6.3 ± 4.9 $b.min^{-1}$ (small effect), -3.9 ± 3.8 $b.min^{-1}$ (trivial effect) and -4.9 ± 4.4 $b.min^{-1}$ (small effect) were demonstrated by comparing SSG30 vs SSG60, SSG30 vs SSG90 and SSG30 vs SSG120, respectively.

Figure 2 - Standardized Cohen's differences for comparative results of the SSGCONT vs SSG 30, SSGCONT vs SSG60, SSGCONT vs SSG90, SSGCONT vs SSG120, SSG30 vs SSG60, SSG30 vs SSG90, SSG30 vs SSG120, SSG60 vs SSG90, SSG60 vs SSG120, SSG90 vs SSG120, SSGs. Error bars indicate uncertainty in true mean changes with 90% confidence intervals



Discussion

This study investigated the effects of different recovery durations between repetitions in SSGs. Overall, the results reveal that the manipulation of recovery times induced differences in the internal and external load. Moreover, for the same total duration, the external and internal load indicators tended to reveal higher values during the fractionated method, particularly with short recovery periods. While longer recovery periods (e.g., 2 min) tended to cause an increase in the maximum speed of players, short recovery periods of 30 s tended to promote higher internal and external physical requirements during the exercise. Finally, a recovery period of 1.5 min allowed more distance to be travelled at different intensities when compared to the other recovery periods, except for the 30-s recovery period.

In particular, the results revealed that the fractionated method (e.g., 6 min) with short recovery periods (e.g., 30 s) induced further changes to the internal and external load. These results are in agreement with recent research (Fanchini et al., 2011), where the use of a fractionated method also increased the physical and physiological demands of exercises (Fanchini et al., 2011; Hill-Haas et al., 2009).

Through analysing fractional exercises, previous research has also shown that short recovery periods allow players to improve their physiological performance, which emphasises our findings (Köklü et al., 2015). A study revealed that increasing the recovery period duration from 30s to 120s and separating serial SSG sessions significantly improved physiological recovery either systemically (HR) or locally (oxygenation of the vastus lateralis muscle, based on using near-infrared spectroscopy) in experienced semi-professional players (McLean et al., 2016). However, in our study, only the use of a 30s recovery period promoted a generalised increase in both internal and external load indicators.

Previous match analysis studies have also shown that soccer requires players to repeatedly produce maximal actions of short duration with brief recovery periods (Bangsbo et al., 2006; Spencer et al., 2005), which may be a key factor that can explain our results. Soccer requires a combination of movement at different velocities and players must repeatedly produce maximal or near-maximal actions of short duration with brief recovery periods (Pellegrino et al., 2018). It is also apparent that the 30s of recovery in 6-min SSGs could represent a typical game effort where players are exposed to short periods of recovery after moments of high intensity.

The obtained results may also have a psychophysiological justification. Players like to perform SSGs because the ball contact time is longer than any other exercise performed, which may result in increased motivation and enjoyment of exercise (Los Arcos et al., 2015). Thus, having stoppages longer than 30s for recovering purposes may imply a strain of mental fatigue derived from stress related to the anxiety of wanting to play for as long as possible. Previous studies (Boksem et al., 2006) revealed that decreased motivation has been associated with mental fatigue and can affect the level of effort one is willing to exert on tasks (Brehm & Self, 1989). Thus, in the present study, the increasing length of recovery periods may have increased physiological and psychological stress by preventing players from attaining optimal levels of arousal (and subsequent attentional levels) required to maintain high internal and external load indicators during exercise.

It was also apparent that a 2-min recovery period has a positive effect on the 'max speed' variable, while the recovery time of 1.5 min allowed more distance to be travelled at different intensities when compared to the other recovery times (except for the 30-s period). The positive effect of 2 min of recovery on the 'max speed' variable could be due to the increased recovery duration since SSGs are exercises that induce more acceleration and changes of direction with high intensity when compared to real game situations (Dellal et al., 2011). Thus, an increase in the recovery period allows players to maintain the ability to perform explosive actions of high intensity over time (Osgnach et al., 2010) (i.e., sprints).

Furthermore, our study shows that greater distances were covered at various intensities with recovery periods of 1.5 min, which contradicts a previous study by (Köklü et al., 2015). In this previous study, the authors reported that 1 min of recovery between repetitions was sufficient to cause significant increases in distances covered at low intensity, while recovery periods of 3 or 4 min were necessary to increase the distances covered at medium and high intensities.

Overall, this study emphasises the differences caused by different recovery times in the training load during the performance of five-a-side SSG based on the fractional training method. For coaches, these variables can be manipulated to manage physical effort and exercise fatigue by increasing or decrease the training load. For example, to maintain high physical performance and high training load to prepare players for real game demands during SSGs, the fractionated method with short time repetitions and short recovery periods (i.e., 30 s) should be used. In contrast, to carefully manage players' efforts (e.g., post-competition muscle regeneration training) and decrease response to training load, continuous or fractionated methods with longer recovery periods (i.e., 1–2 min) should be used. To ensure a lower training load, it would be advisable to select an exercise performed using the continuous method (e.g., 18 min). To increase and develop maximum player speeds, SSGs should extend the recovery period between repetitions to 2 min. Once different recovery times induce different physical responses

in the players, the coach can manipulate recovery times throughout the season in different phases (e.g., pre-season, competitive period and after the detraining period) depending on the desired level of motor skill development.
These findings provide new evidence on the relationship between exercise and recovery duration for small-sided soccer games that can help researchers, coaches and athletes improve training efficiency and optimise performance. Future studies can use this methodology to include comparisons with other SSG formats and conditions to verify changes.

Acknowledgments

This work is supported by national funding through the Portuguese Foundation for Science and Technology, I.P., under project UID04045/2020.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Chapter 4

Practical recommendations considering a specific game format

Study 4 – The Role of 5-a-side Game Format in Soccer Training: Theorical Concerns and Practical Applications

Abstract

Physical outputs in soccer training can be influenced through the interaction of several variables during the performance of different small side games (SSGs) formats. For this reason, it is relevant to understand how the manipulation of variables such as, training method, exercise duration, number of repetitions or recovery time affect the training loads and the performance. The main aim of this work was to provide coaches with a relevant theoretical aspects and examples of practical applications to use from the specific format of 5-a-sided SSG. To search for relevant publications and ensure the quality of articles, the search strategy used comprised specific search terms based on the research theme. The results showed that, during the 5-a-side game, format the choice of the training method (that is, continuous or fractionated) and the manipulation of the related variables (for example, number of players and game format) are fundamental for the management of the training load. Therefore, the manipulation of the variables using 5-a side format translates into significant variations in the training load, and in the likely improvement of the different domains of soccer training (physiological, technical and tactical), thus evidencing several benefits in the use of this game format. In addition, practical examples of 5-a-side exercises are used based on the theoretical considerations described.

Key-words: Soccer; small-sided games;5-a-sided format; continuous method; fractionated method; training load; recovery time

Introduction

Small Side Games (SSGs) are defined as modified games adjusted by coaches for sports training (Clemente et al., 2012). They are typically played in smaller areas, with adapted rules, and generally involve a smaller number of players than a normal game (i.e., 11-a-side) (Hill-Haas et al., 2011). Nowadays, these types of activities are globally accepted and have become popular in the sports training such as soccer, not only because of the multiple benefits they bring to teams (Aguiar et al., 2012; Hammami et al., 2018; Sampaio et al., 2007), but also due to the ease of cross-application at all ages and competitive levels (Reilly, 2005). In fact, SSGs allow for the simultaneous enhancement of technical and tactical development with specific fitness capacities, such as endurance (aerobic and anaerobic), strength, and agility (Hill-Haas, Rowsell, et al., 2009). They have been considered one of the most effective tool for building team play and one of the essential ways to improve all components of the game (Bujalance-Moreno et al., 2019; Hammami et al., 2018; Hill-Haas et al., 2011). In addition, coaches used SSGs specifically due to their structural similarity to the real game (i.e., 11-a-side), which is also very useful in the development of game models (Dellal et al., 2012; Impellizzeri et al., 2006). Therefore, the inclusion of these types of games in the periodization of soccer teams is emphasized due to the multivariate nature of the exercises and their apparent benefits (Hammami et al., 2018; Hill-Haas, Rowsell, et al., 2009), which can be manipulated based on the number of players used (M. Aguiar et al., 2015; Castillo et al., 2019; Hill-Haas et al., 2011). In addition, benefits have previously been reported in the literature resulting from the use of 5-side formats (Branquinho et al., 2020; Köklü et al., 2015), which will therefore be the focus of analysis in this work. .

Several studies have shown that the manipulation of some variables during SSGs, like duration between repetitions (Hill-Haas, Rowsell, et al., 2009; Köklü et al., 2017), previous information about duration (Ferraz, Gonçalves, Coutinho, et al., 2018; Ferraz, Gonçalves, Van Den Tillaar, et al., 2018), pitch size, number of players, coach encouragement, rules, the use of goalkeepers, or the knowledge of the duration of the exercise, enable different intensities and different technical/tactical adaptations (Clemente et al., 2014; Ferraz, Gonçalves, Van Den Tillaar, et al., 2018; Köklü et al., 2017) and consequently different training load responses (Branquinho et al., 2020; Clemente et al., 2019).

Training load is understood as a quantitative measure of the physical and physiological work performed during the exercise period, where the coach tries to modulate the external load while monitoring the internal load (Coutts et al., 2017; Halson, 2014;

Impellizzeri et al., 2005; Malone et al., 2015). Monitoring and management of the training load during soccer exercises proved to be an essential factor in determining the players' individual adaptations, responses, fatigue, and needs for recovery in addition to minimizing the risk of overreaching and consequent injury or illness (Bourdon et al., 2017). As such, training load can be classified as internal or external and reflects the requirements imposed on athletes (Bourdon et al., 2017; Ian Lambert & Borresen, 2010). The external training load was characterized as an objective measure of the work that the athlete performs during training or competitions and is important for understanding the athlete's capabilities relative to his performance (Halson, 2014). Typically, the demands of the athlete's own movement (distance covered, accelerations, changes in direction, and power output) are described (Burgess, 2017). Whereas, the internal training load was previously defined as the biological requirement (physiological or psychological) that the work performed imposes on the athlete's structures (Bourdon et al., 2017; Burgess, 2017; Halson, 2014).

Several studies (Bujalance-Moreno et al., 2019; Casamichana et al., 2013; Hill-Haas, Rowsell, et al., 2009; Köklü et al., 2017) have been conducted to monitor internal and external training loads during SSGs. The results highlighted the extended potential of SSGs, as they not only increase the motivation of the players but also promote specific physical conditions and technical/tactical capacities in soccer (Hammami et al., 2018; Little, 2009; Los Arcos et al., 2015). Generally, SSGs are performed in a continuous (i.e., without repetitions or rest intervals during the exercise) or fractionated format which is characterized as a form of interval training (i.e., exercise performed repeatedly and with rest intervals between repetitions) (Casamichana et al., 2013; Köklü, 2012; Yücesoy et al., 2019), and both methods must consider (i) intensity and duration of the work; (ii) type of recovery (rest/active recovery) and duration of the recovery; and (iii) total duration of work (number of interval of work × duration of work) (Halouani et al., 2014). The continuous method was recently characterized and compared with the fractionated method (Branquinho et al., 2020). It was concluded that for the same exercise time, the use of the continuous method can decrease the training load responses compared to the use of the fractional method with short recovery periods. That is, there are changes in the intensity of the exercises based on the duration of the task. (Fanchini et al., 2011) In fact, previous studies emphasized the existing differences in the training methods, and concluded that the use of the fractional method, caused a decrease in the perceived effort, an increase in the total running distances and accelerations (Clemente et al., 2019), as well as increases in the HR responses (Branquinho et al., 2020). In a practical environment, if the coach intends to increase training load responses (i.e., total distance covered, total distance covered at various intensities, maximum speed) and internal load (i.e., HR max and HR average), the fractional method is generally the most appropriate whereas the continuous method is useful if a reduction in the training load is desired (i.e., recovery objectives; tactical objectives; initial learning of game principles; or introduction of new exercise...). However, the responses resulting from the choice of the training method will always be directly dependent on the choice and manipulation of other variables (i.e., exercise duration, recovery time, and field size) in order to increase or decrease the training load responses.

During this work, our focus was on the 5-a-side format, which was chosen due to its proven influence in changing the training load and usefulness in improving different training domains (i.e., technical and tactical) during SSGs (Aguiar et al., 2012; Amatria et al., 2016; Aslan, 2013; Ball et al., 2011; Castellano et al., 2013; Castillo et al., 2019; F. Clemente et al., 2012; Clemente et al., 2019; Goncalves et al., 2017; Italo, 2017; Jastrzębski & Radzimiński, 2015). In fact, the regular 5-a-side format has been associated with greater total distance covered and running distance than smaller formats such as the 3-a-side (Castellano et al., 2013). Furthermore, higher maximum speeds and greater displacements at different intensities have also been previously reported (Castellano et al., 2013) when comparing the 5-a-side format with smaller and larger formats (3-a-side and 7-a-side). The 5-a-side format has also been described (Castellano et al., 2013) as allowing more accelerations compared to 7-a-side. In addition, 5-a-side can also be used by coaches to promote organizational training by sectors (e.g., tactical training), since it has previously been associated with greater correlation between teammates, promotion of self-organized behavior, and greater predictability in positional coordination (Gonçalves et al., 2016). This knowledge is important for the prescription of appropriate training loads, according to the objectives of the coach, and is fundamental to the process of adaptation, players' effort management, and injury prevention (Castillo et al., 2019).

This work therefore aims to infer about the potential benefit of implementing the 5-a-side format as a useful tool for the coach, given the impact it assumes on all training domains (i.e., physiological, physical, technical, and tactical). Some standard exercises based on our research on 5-a-side SSGs are presented as practical applications, to help coaches manipulate the game format according to the possible objectives required for the training session.

Methods

Search Strategy

To search for relevant publications and ensure the quality of articles, the following databases were used: Web of Science (the modules “Core” and “Medline”), Scopus and PubMed. Articles that were published in 2020 or earlier and in English were considered. The search strategy comprised specific search terms based on the research theme. The search strategy comprised search terms that combined one of the two primary keywords (“soccer” or “football”) with a second keyword (small-side games” or “small and conditioned games”), with a third keyword (“recovery time”, “training load”, “continuous method”, “fractionated method”) and a fourth keyword (“5-a-side”), using the boolean operator.

Continuous vs Fractionated Training Methods During Small Sided Games

The literature describes that the performance during SSGs using the continuous or interval (fractionated) methods can cause changes in the training load (Koklu et al., 2012), particularly due to the variations in the intensity distribution during the different periods of performance (Dellal et al., 2012).

Most studies on SSGs use the fractionated method; however, differences have been derived from the use of the continuous and fractionated methods and the possible types of manipulations to ensure the desired training loads. Yet, few studies have investigated how to change the physical and physiological indicators responses (i.e. external and internal load) resulting from SSG, based on the choice of the continuous or fractional training method.(Branquinho et al., 2020; Casamichana et al., 2013; Fanchini et al., 2011; Köklü, 2012; Yücesoy et al., 2019). Curiously, to the best of our knowledge, no study has analyzed the impact of choosing the training method (continuous or fractional), specifically in the 5-a-side format. In addition, no specific information has been reported in the literature regarding the total exercise time and recovery time manipulation to characterize the training load responses according to the chosen training method.

The continuous method is more similar to the demands of real games (Aguiar et al., 2012) and is characterized by a large volume of work without interruptions; the main objective is to improve the aerobic capacity of players (Bompa, 2009). Its use during SSGs caters to the development of aerobic capacity during the preparatory periods of the season (Hill-Haas et al., 2011). The continuous method can be categorized as uniform or varied. The former is characterized by the maintenance of effort over a period of time, while the latter consists of the performance of prolonged efforts with significant variations in intensity but without having to effectively cease the activity (Alves et al., 2006).

Conversely, the fractionated method is performed in the form of intervals, with recovery times between each repetition (M. Aguiar et al., 2012). A previous study (Laursen, 2010) highlighted the potential of the fractionated method in trained athletes using repeated short or long periods of high-intensity exercise interspersed with recovery periods (Billat, 2001). Greater cardiovascular and peripheral adaptations have been reported in athletes performing several fractionated exercises at high intensities interspersed with resting periods (Billat, 2001; Faude et al., 2013; Laursen & Jenkins, 2002). Table 1 summarizes four studies examining the differences between continuous and fractionated method during SSGs and their impact on training load.

Table 4. Continuous *vs* Fractionated SSG studies (2010-2020)

Studies	Sample	SSG Format	Training Prescription		Recovery	Differences observed between methods in training load
			CM	FM		
Köklü et al. (58)	Men (n=20); ages 16.6 ± 0.5 years.	2-a-side 3-a-side 4-a-side	6 min 9 min 12 min	3 x 2 min 3 x 3 min 3 x 4 min	- - -	CM and FM could be used to improve internal load. 3-a-side, 4-a-side of FM and 3-a-side of CM could be used to improve maximum oxygen uptake. Whereas CM 4-a-side might be used to develop the anaerobic threshold. CM and FM 2-a-side could be used to improve lactate tolerance.
Yücesoy et al. (75)	Men (n=16); ages 22.3 ± 1.6 years.	4-a-side	18 min	3 x 6 min	3 min	CM and FM induces similar responses on internal loads
Casamichana et al. (18)	Men (n=10); ages 21.3 ± 3.4 years.	5-a-side	16 min	2 x 8 min 4 x 4 min	1 min 2 min	CM induces greater physical loads. HR responses did not show significant differences
Branquinho et al. (14)	Men (n=20); ages 25.2 ± 6.1 years.	5-a-side	24 min	2 x 12 min 4 x 6 min 6 x 4 min	2 min	FM induces greater training loads compared to CM

Note: CM = Continuous method; FM = Fractionated method; HR = Heart rate

Regarding peripheral and central adaptations, some results have found no differences between the methods (Edge et al., 2006; Seiler & Tønnessen, 2009), whereas other reports suggest that the continuous method performed at submaximal intensities promotes better peripheral adaptations, while the fractionated method promotes better central adaptations (Helgerud et al., 2007).

The Impact of the Relationship Between Number of Players and Training Method in Training Load Responses During SSGs

Management of the number of players involved during the performance of SSGs allows for regulation of the exercise intensity and technical actions (Jones & Drust, 2007; Katis & Kellis, 2009; Köklü, 2012; Köklü et al., 2017; Little, 2009; Owen et al., 2004; Sampaio et al., 2007), when the coach also controls other variables (i.e., pitch size). Overall, the research conducted suggests that formats with fewer players induce changes in internal load indicators (e.g., greater heart rate (HR) responses) when compared to larger formats (Hill-Haas, Dawson, et al., 2009; Hill-Haas et al., 2010; Katis & Kellis, 2009; Owen et al., 2004). In contrast, other studies did not find significant differences between formats (Aroso et al., 2004; Hill-Haas et al., 2008; Jones & Drust, 2007; Sampaio et al., 2007); It is worth noting, however, that regular maximum heart rate (HR_{max}) values during SSGs vary between 80 and 90% of HR_{max} (Hill-Haas et al., 2011). That is, the differences found between the studies analyzed, indicate that the same type of formats can effectively induce different internal loads responses, which may be due to different training methods or different recovery times.

External load indicators were also analyzed (i.e., total distance covered at various intensities and high-intensity efforts) based on the number of participants in the SSG. With regard to the total distance covered at different intensities, there is some consensus in the literature since most authors say there are no significant differences between the formats analyzed (Hill-Haas et al., 2008; Hill-Haas, Dawson, et al., 2009; Hill-Haas et al., 2010; Jones & Drust, 2007). Conversely, in relation to the amount of high-intensity efforts, the same is not true. Previous research (Jones & Drust, 2007; Platt et al., 2001) has suggested that decreasing the number of players causes an increase in high-intensity efforts (e.g., sprints). Later, the opposite was suggested by Hill-Haas et al. (Hill-Haas et al., 2008), while another study found no significant differences (Hill-Haas et al., 2010). In addition, studies have reported the impact of the number of players on the technical requirements imposed by the exercise (Jones & Drust, 2007; Katis & Kellis, 2009), with the smaller formats inducing the increase in the number of individual ball contacts per game compared to longer formats (i.e., 4-a-side *vs* 8-a-side), while more long passes and headers were more frequent during 6-a.side game formats. Thus, these data suggest the number of players should be meticulously defined by the coach, as SSGs with fewer players (i.e., 5-a-side) also increase technical stimuli.

The 5-a-side Game Format as a Toll During Soccer Training

It is essential that coaches maintain a broad perspective to better understand the stimuli imposed on players during the performance of SSGs and to enhance the adaptations resulting from training. The 5-a-side format has often been used (Aguiar et al., 2013; Branquinho et al., 2020; Casamichana & Castellano, 2010; Da Silva et al., 2011; Hill-Haas et al., 2010; Kelly & Drust, 2009; Little & Williams, 2006; Owen et al., 2004; Rampinini et al., 2007) to improve physical and physiological performance of soccer players in the different domains of training. In fact, this specific format can be of great use to coaches, given the practical benefits that were evidenced previously, namely greater physiological responses (Allen et al., 1998; Hill-Haas, Coutts, et al., 2009) and greater physical responses (Castellano et al., 2013; Clemente et al., 2019) compared to other SSG formats. In addition, improvements in tactical skill and adaptation to the game model have been reported through modulated conditions based on numerical superiority (i.e., 4 *vs* 5-a-side) and coordination conditions (Gonçalves et al., 2016). A summary of some studies that used this type of format during SSGs is shown in Table 5 and Table 6, where changes in exercise intensity can be verified based on the manipulations performed (i.e., pitch size, total duration, training regimen, and recovery time). The 5-a-side format was previously characterized (Allen et al., 1998;Hill-Haas, Coutts, et al., 2009) by inducing physiological responses (i.e., HR) higher than those seen during a formal 11-a-side game. In this sense, field area is one of the variables that directly influences the physiological stress imposed during the performance of SSGs (Silva et al., 2014) and therefore assumes a fundamental role during the manipulation of the 5-a-side format. Most studies conducted in this regard identified an increase in internal load responses (i.e., HR_{max}) with an increase in the field size, as described in Table 2 (Casamichana & Castellano, 2010; Da Silva et al., 2011; Owen et al., 2004; Rampinini et al., 2007), when comparing 5-a-side games with different pitch sizes. Moreover, other studies conducted with only one field size have corroborated these results (Branquinho et al., 2020; Hill-Haas et al., 2010; Little & Williams, 2006).

Other studies (Kelly & Drust, 2009; Owen et al., 2004) have also verified the influence of the field dimensions on technical actions and found no significant differences in the frequency of most actions, such as passes, receptions, dribbling, and interceptions, during 5-a-side games; however, there was an exponential increase in the number of shots and tackles in 5-a-side games with smaller dimensions (Kelly & Drust, 2009; Owen et al., 2004). In fact, the increase in tackles performed during this format in fields with smaller dimensions is likely related to the smaller area per player, which causes a greater proximity between players and consequently an increase in physical contact. In addition, greater interaction between players, as a result of the dimensions of the field and the number of players, creates a window of opportunity to improve decision-making and peripheral vision, promoting the coupling of perception-action and coordination (Aguiar et al., 2015; Davids et al., 2013). The increase in the number of shots is likely related to the proximity to the goals, which makes the players attempt more shots. That is, field size is directly related to performance during the 5-a-side format; therefore, it must be carefully considered by the coach, who may prefer to combine the physical component with the tactical component, or, on the other hand, restrict physical contact to a minimum during the training session (Kelly & Drust, 2009).

The intensity of the SSGs depends on several factors such as the format (i.e., 5-a-side) and training method (continuous or fractionated) chosen, which play a fundamental role in the training load. For that reason, the use of large fields does not necessarily give intensity to the exercise. An example of this is presented in a study conducted by Hill-Hass et al. (Hill-Haas et al., 2010), who used a 47 x 35 m field in a 5-a-side game for 24 min performed using the continuous method. The results showed responses of only 82.5% HR_{max} that were lower than others found in studies with smaller fields and the same total exercise duration (Little & Williams, 2006). These results corroborate the conclusions of a recent study (Branquinho et al., 2020) which investigated the effects of continuous and fractionated training on internal and external load in soccer SSGs and concluded that the exercise performed by the continuous method induced lower responses in the training load. Therefore, the fractionated method presented itself as a more beneficial alternative if the objective was high-intensity training and high training loads through the performance of a 5-a-side SSG format.

Additionally, it is important to note that the addiction of specific rules by the coach during the 5-a-side SSG, such as, as the “pressure and/or individual marking” (Little & Williams, 2006), the “ball possession”, to have or not “goalkeeper”, the “goal size” (Castellano et al., 2013), or the “coach encouragement” (Kelly & Drust, 2009; Rampinini et al., 2007) tends to increase the responses of HR max as shown in Table 3. As such, the aforementioned rules are also variable to consider in the prescription of SSGs.

Table 5. Summary of studies examining the effects in a 5-a-sided small-sided game intensity in soccer

Reference	n	Age	Pitch Size	Duration	Training regimen		Recovery	Training Load Responses						
											Distance Covered			
					CM	FM		Heart rate Max	Max Speed	Total Distance (meters)	VLI	LI	HI	VHI
Little and Williams (62)	23	22.8±4.5	45 x 30 m	24 min	-	4 x 6 min	1.30 min	89.3% HR$_{max}$	-	-	-	-	-	-
Rampinini et al. (67)	20	24.5±4.1	20 x 28 m	12 min	-	3 x 4 min	3 min	86% HR$_{max}$	-	-	-	-	-	-
			25 x 35 m					86.1% HR$_{max}$	-	-	-	-	-	-
			30 x 42 m					86.9% HR$_{max}$	-	-	-	-	-	-
Owen et al. (65)	13	17.46±1.05	30 x 25 m	9 min	-	3 x 3 min	12 min	75.7% HR$_{max}$	-	-	-	-	-	-
			35 x 30 m					79.5% HR$_{max}$	-	-	-	-	-	-
			40 x 35 m					80.2% HR$_{max}$	-	-	-	-	-	-
Casamichana and Castellano (17)	10	15.5±0.5	32 x 23m	15 min	-	3 x 5 min	5 min	93% HR$_{max}$	-	695±37	401±27	238±41	50±21	4.9±5
			50 x 35 m		-			94.6% HR$_{max}$	-	908±30	390±30	329±54	155±41	28±33
			62 x 44 m		-			94.6% HR$_{max}$	-	999±50	378±37	366±74	180±42	74±58
Hill-Hass et al. (44)	20	15.6 ±0.8	47 x 35 m	24 min	24 min	-		82.5% HR$_{max}$	-	2526±302	-	-	-	-
Da Silva et al. (71)	16	13.5±0.7	30 x 30 m	12 min	-	3 x 4 min	3 min	86.9% HR$_{max}$	-	-	-	-	-	-
Castellano et al. (19)	14	21.3±2.3	43 x 30 m	9 min	-	3 x 3 min	5 min	93.8% HR$_{max}$	-	-	-	-	-	-
Aguiar et al. (1)	10	18.0±0.6	150 m² Per player	18 min	-	3 x 6 min	1 min	84.56% HR$_{max}$	-	-	-	-	-	-
Branquinho et al. (14)	20	25.2±6.1	40 x 40 m	24 min	24 min	-	2 min	181.95 ± 95 b.min^{-1}	6.05 ± 0.52 m/s	2254± 167	262±32	1822±176	143±45	12± 12
					-	2 x 12 min	2 min	184.3 ± 10.03 b.min^{-1}	6.24 ± 0.59 m/s	2333 ± 116	250±50	1990±171	2037±180	2063±389
					-	4 x 6 min		186.60 ± 10.55 b.min^{-1}	6.20 ± 0.49 m/s	2371 ± 283	277±55	157±58	171±65	153±68
					-	6 x 4 min		185.55 ± 11.16 b.min^{-1}	6.06 ± 0.54 m/s	2194 ± 839	309±93	17± 15	18±18	16± 14

Note: CM = Continuous method; FM = Fractionated method; TL= Training Load; min = minute; m= meters; HR$_{max}$= Maximum heart rate; m/s= meters per second; VLI= Very low intensity; LI= Low intensity; HI= High intensity, VHI= Very high intensity

Table 6. Summary of studies examining the effects of rules modifications/coach encouragement in a 5-a-sided small-sided game intensity in team sports.

Reference	n	Age	Pitch Size	Duration	Training regimen		Recovery	Rules / CE	Training Load Responses
					CM	FM			Heart rate (% of maximum)
Little and Williams (62)	23	22.8±4.5	55 x 32 m	10 m	-	2 x 5 min	2 min	Pressure half switch	89.9% HR_{max}
Kelly and Drust, (53)	8	18±1	30 x 20 m	16 m	-	4 x 4 min	2 min	CE	91% HR_{max}
			40 x 30 m		-				90% HR_{max}
			50 x 40m		-				89%
Rampinini et al. (67)	20	24.5±4.1	42 x 30 m	12 m	-	3 x 4 min	3 min	CE	88.8%
Castellano et al. (19)	14	21.3±2.3	55 x 38 m	15 m	-	3 x 5 min	5 min	With possession	94.6%
								With GK	92.1%
								With small goals	91.5%

Note: CM = Continuous method; FM = Fractionated method; TL = Training load; min = minute; m= meters; CE= Coach encouragement

Finally, there appears to be a relationship between recovery periods with reduced time duration (i.e., 1:30 min and 2 min) (Branquinho et al., 2020; Little & Williams, 2006) and higher intensities. In fact, the recovery between high-intensity exercises results in a reduction of physiological fatigue, preventing the increase in hydrogen production (due to increased activity of the glycolytic pathway), with a consequent reduction of muscle pH (i.e., increase of acidosis), elevation of interstitial K+ content, and reduced levels of energy substrates (i.e., creatine phosphate (PCr) and glycogen) (Alghannam, 2012). Possible explanations are related to the availability of PCr. Considering this possibility, the accumulation of lactic acid increases and the muscle pH decreases (Alghannam, 2012). Although pH is the most prevalent factor for maintaining strength production during high-intensity exercises, the availability of PCr is actually more prevalent for the initial part of high-intensity exercises (Köklü et al., 2015). Moreover, the results of a recent study (Spencer et al., 2005) emphasized that HR adaptive responses occur more quickly with fast recoveries (i.e., 1-2 min) during 5-a-side SSGs.

With regard to physical demands, the studies shown in Table 5 may indicate an increase in the external load with an increase in the fractionation of the exercise (Branquinho et al., 2020) and field size (Casamichana & Castellano, 2010). In fact, an increase in the total distance covered and the displacements at different intensities is common, which means that these variables must be should be considered as coaches develop training plans. Moreover, the external load can be positively or negatively affected depending on the game format (Branquinho et al., 2020).

All of these changes related to the 5-a-side format appear to also be dependent on different numbers of repetitions (Branquinho et al., 2020; Köklü, 2012), different durations of repetitions (Branquinho et al., 2020; Köklü, 2012), and different recovery times during the SSG. Thus, players' performance during 5-a-side games depends on the interaction between exercise duration and subsequent recovery periods, as well as exercise intensity and recovery (Bangsbo, 1994). Moreover, recovery involves active processes to restore psychological and physiological resources that allow the player to use these resources again (Kellmann & Kallus, 2007); therefore, the intensity, duration, and frequency of training based on SSGs causes significant stress on biological systems, which may compromise the ability to work in the following sessions (Kelly et al., 2020; Strudwick & Reilly, 1999). As such, the training stimulus must consider the balance between volume, intensity, and recovery, and SSG training programs should be prepared based on this information.

Despite this, the use of 5-a-side SSGs is a key training method, especially for amateur and semi-professional players because at their playing levels, players have shorter training durations per week and need to optimize or mix the physical, technical, and tactical components to gain time (Castellano et al., 2013). In this sense, a methodological design of 5-a-side soccer games will be proposed, which can be a useful tool for coaches for training prescription. It is important to note, however, that the use of these formats will always be related to and dependent upon the objectives in the physical, technical, and tactical domains of each coach for his team.

Practical Applications: 5-a-side Games Exercises Example

To maximize the benefit resulting from application of 5-a-side SSGs requires properly structured exercises based on the objectives desired by the coach, considering of the different training domains (i.e., physical condition, technical, and tactical), and in the type of stimulus desired for the training unit or cycle.. The 5-a-side format is an effective tool that can be utilized by coaches but always requires a framework and is designed based on the team's objectives. It is crucial to focus the training not only on improving performance (Fig 3-4) according to the coach's game model and ideas for the team, but also on maintenance and recovery physical condition (Fig 5-6), which means that training load management plays a key role in soccer performance. To mitigate for the effects of cumulative fatigue, training loads can be adjusted during a training cycle. Depending on the training period (e.g., pre-season, in-season, or detraining phase), the objectives and variables can be manipulated to control the intensity of the 5-a-side SSG. Among these variables are the size of playing field, number of players, recovery, and training method (Branquinho et al., 2020; Christopher et al., 2016; Filipe Manuel Clemente et al., 2017; Halouani et al., 2014; Köklü et al., 2015; Yücesoy et al., 2019).

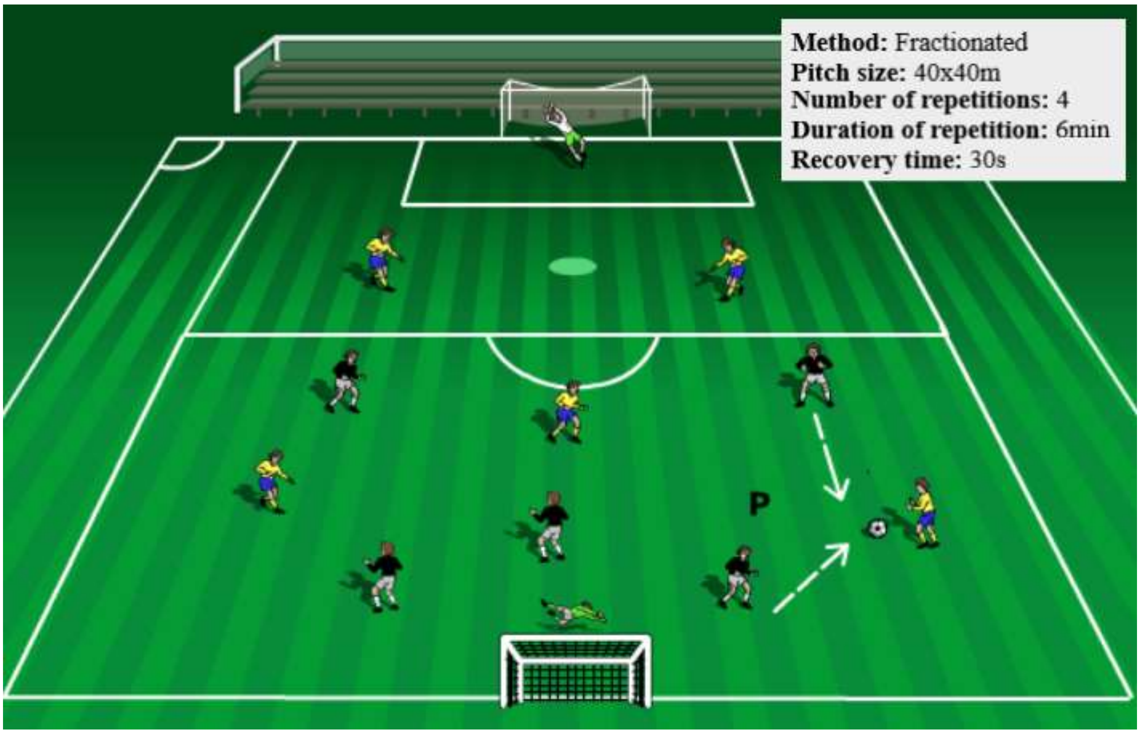
Some suggestions may be given for creating training exercises based on the 5-a-side format according to the training objectives. In the practical context, if the coach wants to increase the physical and physiological responses and obtain high training loads from his players during the pre-season (for example) in order to develop the fitness condition for the start competition season, they can use exercise type as described in Fig 3, which is performed by the fractionated training method, with a short recovery period, including regular goals and goalkeepers, in a 40mx40m field. However, taking into account that the training loads prescribed during the competitive season should be subject to regular management and monitoring in order to avoid overtraining and injuries, if the coach wants to reduce the stimulus resulting from the previous exercise, he could use the exercise type as of Fig 4. Although the exercise of Fig 4 is also performed by the fractionated training method (which induces greater physical and physiological responses), it was adjusted with manipulations that allow a slight reduction of the imposed load, compared to the exercise of Fig 3 (i.e., inclusion of small goals, a longer recovery time, a reduction in the playing field, a reduction in the total duration of the exercise and consequently a smaller fractionation of the same).

On the other hand, if the goal of the coach is to decrease training load responses, he should preferably use exercises performed by the continuous method. But here too, the exercises can be manipulated according to the specific objectives desired by the coach for the session or competitive period in question. If the coach's goal is recovery / regeneration after the game or careful management of the fatigue resulting from training, coaches can use the exercises type as described in Fig 5-6 during the competitive season.

In addition, if the goal of the coach is to practice new content (exercise), new tactical ideas (i.e., pre-season) or to carry out tactical approaches in preparation for the game (competitive season), he could use exercises types as described in Fig 5-6 in the same way considering that the use of the exercise in Fig 5 induces slight increases in the training load compared to the exercise in Fig 6, due to the manipulations to which it was subjected.

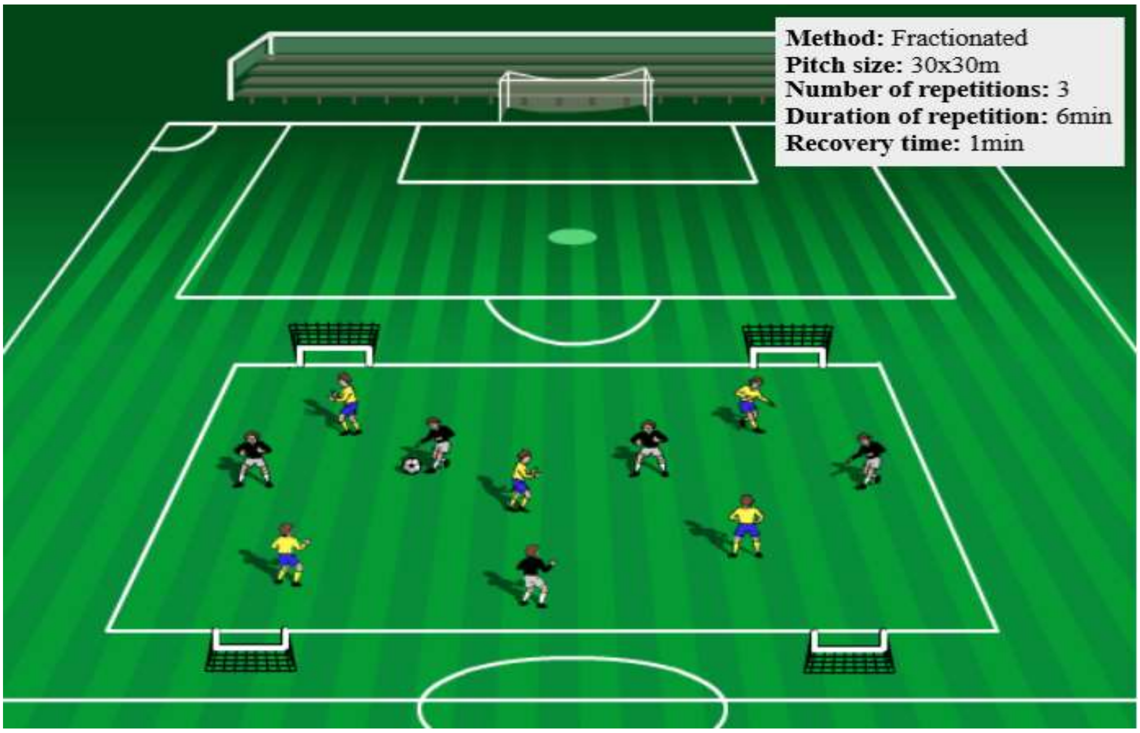
It is important to note that the choice of each exercise and the phase of the season in which it should be inserted always depends on the goals of the coach and the physical condition of the players in the period in question (pre-season or competitive season). In table 4, a way of using these exercises over a training cycle is suggested. In addition, care must be taken when implementing the training programs and exercise regimes, as different age groups and competitive levels are expected to receive different external and internal loads for the same training stimuli.

Figure 3. 5-a-side game fractionated format 1



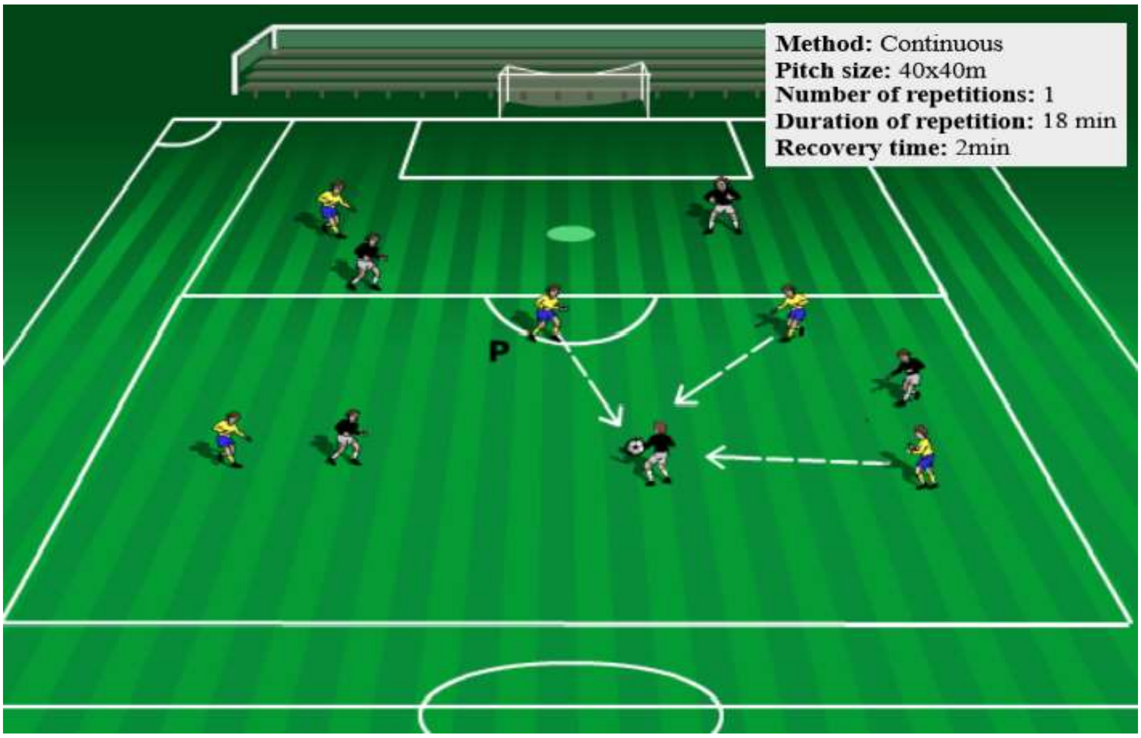
Note - **Method:** fractionated; **Pitch size:** 40x40m ; **Number of repetitions:** 4 ; **Duration of the repetition:** 6m ; **Recovery time:** 30s ; **Rules:** With Goalkeepers, pressure, with coach encouragement ; **Physiological Target:** 90 – 95 % HR_{max} ; **Technical target:** score as many goals as possible ; **Tactical target:** offensive / defensive organization, ball carrier pressure, defense / attack transition ; **training cycle:** weekly microcycle, acquisitive operationalization of the game organization (assimilation of content and coach ideas) ; **P** = Pressure

Figure 4. 5-a-side game fractionated format 2



Note: –**Method:** fractionated; **Pitch size:** 30x30m ; **Number of repetitions:** 3 ; **Duration of the repetition:** 6m ; **Recovery time:** 1min ; **Rules:** with small goals; **Physiological Target:** 85 – 90 % HR_{max} ; **Technical target:** shooting accuracy, pass and reception in reduced space, decision making **Tactical target:** offensive / defensive organization, ball carrier pressure, defense / attack transition ; **Training cycle:** weekly microcycle, acquisitive operationalization of the game organization (assimilation of content and coach ideas)

Figure 5. 5-a-side game continuous format 1



Note – **Method:** continuous ; **Pitch size:** 40x40m ; **Number of repetitions:** 1 ; **Duration of the repetition:** 18m ; **Recovery time:** 2 ; **Rules:** without goal keeper or small goals pressure; **Physiological Target:** 75 – 85 % HR_{max} ; **Technical target:** pass and reception in reduced space, decision making **Tactical target:** ball possession, ball carrier pression, decision making; **Training cycle:** weekly microcycle – recovery ; **P** = Pressure

Figure 6. 5-a-sided game continuous format 2

Note - **Method:** continuous ; **Pitch size:** 30x30m ; **Number of repetitions:** 1 ; **Duration of the repetition:** 24min; **Recovery time:** 2 min ; **Rules:** without goal keeper or small goals pressure, ball possession, with floaters; **Physiological Target:** 70 – 80 % HR_{max} ; **Technical target:** pass and reception in reduced space, decision making, **Tactical target:** offensive / defensive organization, ball possession, with numerical superiority ; T**raining cycle:** weekly microcycle - recovery, regeneration.

Figure 7. Applicability of Continuous and Fractionated Exercises during a competitive week training cycle

Week Microcycle	Monday	Tuesday	Wednesday	Thursdays	Friday	Saturday	Sunday
Objective	Recovery	Recovery/Tactical	Acquisitive operationalization of the game organization	Acquisitive operationalization of the game organization	Tactical/Recovery		
Physiological target	70-80% HRmax	75-80% HRmax	90-95% HRmax	85-90% HRmax	70-80% HRmax	Day off	GAME
Exercise	Continuous Exercise 4 (Fig 6)	Continuous Exercise 5 (Fig 3)	Fractionated Exercise 1 (Fig 3)	Fractionated Exercise 2 (Fig 4)	Continuous exercise 3-4 (Figures 5 and 6)		

Conclusion

Considering their variability in application and manipulations with a direct impact on training load and player performance, SSGs can be considered a versatile tool available to coaches. The choice of training method (i.e., continuous or fractionated) and manipulation of related variables (e.g., number of players and game format) are fundamental to management of the training load and control of fatigue during exercise. This work specifically highlighted the benefits of using the 5-a-side format based on the dimensions of the field, number of repetitions, duration of repetitions, and rest interval chosen by the coach. It also examined the changes that occur in the training load as a result of these choices. Furthermore, it highlighted the ways in which manipulation of the aforementioned variables makes it possible to enhance the different domains of soccer training (physical, technical, and tactical), emphasizing the benefits resulting specifically from the use of the 5-a-side format, although other game formats (i.e., 2-a-side, 3-a-side, 6-a-side, 7-a-side…) are also important in the development of soccer players. Whatever the choice of SSG format, this must always consider the aims of the coach depending on the period of the season, training session, and the aims proposed to the team in the different training domains.

Acknowledgements

This work is supported by national funding through the Portuguese Foundation for Science and Technology, I.P., under project UID04045/2020.

Chapter 5

General Discussion

The aim of this investigation was to analyze the effects of continuous and fractionated game formats on internal and external load in small-sided games in soccer and to identify the effects of different recovery times on internal and external load during these exercises. The lack of research on the impact of performing SSGs using the continuous or fractionated methods on training load, as well as the influence of recovery duration during SSG performance, was the starting point of our experimental research. Our findings confirmed the hypothesis that using the fractionated method during SSGs, which were characterized by the same total duration and same rest interval but used different recovery times, induces a change in internal and external load (study 2,3). Our data also confirmed that increasing the number of repetitions in the fractionated method raises the internal and external load compared to the continuous method (study 3). Moreover, the increase in recovery time tends to decrease the internal load and increase the external load, leading to a higher physical impact of the exercise (higher indicators of training load) (study 3).

Our results report that use of the fractionated method induces a greater training load compared to the continuous training method (Study 2). Furthermore, when using the fractionated method, the recovery time influences training load. Longer recovery times (e.g., 2 min) seem to induce increases in the maximum speed of the players, recoveries of 1.30 min may increase the total distance covered, and 30 s of recovery between repetitions may be sufficient for players to recover the exercises they performed since they induce significant changes in the training load (study 3). Moreover, increasing the number of exercise repetitions in the fractionated method led to an increased external load compared to the continuous method (study 2).

In particular, the continuous method displayed the tendency to decrease the distances travelled with different intensities (study 2,3), and regarding the HR responses, the data were trivially different, which suggests few variations between methods (study 2). In addition to the results revealing that manipulation of recovery times induced differences in internal and external load, it was also possible conclude that for the same total duration time, the external and internal load indicators tended to show higher values during the fractionated method, particularly with short moments of recovery time (e.g., 30 s) (study 3). While longer recovery time periods (e.g., 2 min) tend to cause an increase in the “max speed” of players, short recovery periods of 30 s tend to promote higher internal and external physical requirements of the exercise (study 3). Finally, a recovery time of 1 min 30 s allowed more distance travelled at different intensities compared to the other recovery times, with the exception of 30 s recovery times (study 3).

These findings were consistent with previous reports that showed distinct effects on internal and external training load depending on the method used in SSGs (continuous or fractionated). The results reinforce the idea that application of the continuous method in SGGs may induce lower training loads than the fractionated method. Furthermore, short recovery periods may allow players to maintain high intensities during repetitions when using the fractionated method in SSGs (study 2,3). (Hill-Haas et al., 2009; Köklü et al., 2015; Köklü et al., 2017).

Emphasizing the differences between the continuous and fractionated methods, a previous study found differences in a three-a-side SSG format when longer repetitions (3×6 min/2 min rest) decreased Max.HR compared to shorter repetitions (3×2 min/2 min rest) (Fanchini et al., 2011). This was supported by previous studies when the results of Max.HR were crossed with intensity displacement velocity during the exercises, because the Max.HR was related to the increase in the pace of the game and the high-intensity actions of players (Clemente et al., 2019). Our results in both studies indicate that variations in max.HR may be related to the use of specific 4×6 min, 6×4 min (study 2), and 3x6 min (study 3) short, fractionated methods, thus increasing Max.HR compared to the other longer fractionated 2x12 min and continuous 1x24 min (study 2) and 1x18 min (study 3) methods used in study 2 and 3, respectively. In addition, a short recovery time of 30 s presents the tendency to induces further changes in Max.HR.

Collectively, these data suggest that fractionated methods can induce a higher internal training load and highlight the importance of rest periods between repetitions to increase physical responses in subsequent repetitions.

Regarding Av.HR, the results found in studies 2 and 3 are similar and also somewhat contradictory. The physiological responses of the players appear higher in the fractional method (higher Max.HR), but the Av.HR responses tend to remain constant between the two training methods. The fact that HR may not be sensitive to the differences between methods may explain these results in comparison with others previously reported, where no differences were found in physiological responses relative to the continuous method or fractional method (Christopher et al., 2016; Hill-Haas et al., 2009).

Regarding the intensity of the displacements performed, there is a tendency towards higher values when applying the fractionated method compared to the continuous method in both studies. In fact, there is an increase in the number of displacements performed for the different variables analyzed (e.g., very low intensity, low intensity, moderate intensity, and high/very high intensity) when comparing the SSG performed using the fractionated and continuous methods in study 2. The results of study 3 show greater distances covered at various intensities (e.g., moderate, high, very high, and max intensity) with recovery periods between 30 s and 2 min, which contradicts a previous study (Köklü et al., 2015). In this study, the authors report that 3 or 4 min were necessary to increase the distances covered at medium and high intensities.
Regarding the total distance travelled, a higher total distance was identified in two formats performed in the fractionated method (T2 and T3) compared to the continuous method in study 1. These data are in agreement with what was previously described by Hill-Haas et al. (2009), which showed evidence of an increased total distance travelled using the fractionated method compared to the continuous method. In study 3, we observed that a recovery of 30 s is enough to reach greater total distances travelled compared to all other recovery times.

The maximum speeds between the methods do not appear to change significantly (study 2,3). The data indicate that the ability of players to reach high speeds is independent of the use of the continuous or fractionated methods; however, long recovery periods (e.g., 2 min) with the fractional method may be able to achieve high speeds in the following repetitions (study 3).

Study 2 also shows that increasing the number of exercise repetitions is likely more beneficial in delaying the onset of fatigue in external load variables, allowing players to maintain high levels of intensity for longer periods. Similar evidence was previously reported through a study (Sampson et al., 2015) in which a long exercise duration (continuous method) caused moderate effects on external load indicators, whereas in short and repetitive exercise (fractionated method), only small variations were observed. These outcomes suggest that the main effects of fatigue arise with continued effort over longer periods (Sampson et al., 2015).

Collectively, these results highlight the importance of an accurate definition of the series duration and recovery time period between each series for the correct preparation (Müller, 1953). The ideal combination of these variables induces increases in working capacity, and consequently, in maintaining high training loads during the following repetitions (Laursen, 2010). While keeping high training load, blood flow increases, which accelerates muscle metabolic recovery accommodated by phosphocreatine (PCr) resynthesis, regulation of organic phosphate concentration, and muscle lactate oxidation (Seiler & Tønnessen, 2009). In addition, with appropriate management of the above variables, it is possible to maintain a minimum level of VO_2, which reduces the time required to reach VO_{2max} during the following repetitions (Billat, 2001; Midgley & Mc Naughton, 2006) and allows players to maintain high performances with each repetition performed.

Study 3 also concluded that short recovery periods (30 s) are sufficient for maintaining the training load and slowing the onset of fatigue during exercise. The consequences of physiological fatigue reported in the literature are therefore minimized, preventing the increase in hydrogen production (due to increased activity of the glycolytic pathway), with a consequent reduction of muscle pH (i.e., increase of acidosis), elevation of interstitial K+ content, and reduced levels of energy substrates (i.e., creatine phosphate and glycogen) (Alghannam, 2012). Possible explanations are related to the availability of PCr. Considering this possibility, the accumulation of lactic acid increases and the muscle pH decreases (Alghannam, 2012). Although pH is the most prevalent factor for maintaining strength production during high intensity exercises, the availability of PCr is actually more prevalent for the initial part of high intensity exercises (Köklü et al., 2015). Moreover, the results of a recent study (Spencer et al., 2005) emphasize that HR adaptive responses occur more quickly with up to 1-minute recoveries.

Previous studies have also shown that soccer requires players to repeatedly produce maximum short-term actions interspersed with brief periods of recovery (Spencer et al., 2005), and this may be a key factor in explaining our results. A soccer match requires a combination of movements at different speeds, and participants must repeatedly produce maximum or near maximum short-term actions with a short recovery period. Thus, SSGs performed with short repetitions and short recovery periods recreate the real game situation, causing adaptations that enhance the performance of the players during the competition.

Furthermore, the ability to perform high intensity efforts repeatedly is influenced by the nature of exercise and recovery periods. In general, the greater exercise interferes with homeostasis, the greater its effect on recovery metabolism (Brehm & Gutin, 1986).

Tomlin & Wenger, (2001) adds that the more complex these regenerative processes are, the greater the ability to generate strength or maintain power in subsequent effort intervals (Brehm & Gutin, 1986; Gaitanos et al., 1993; Tomlin & Wenger, 2001).

Therefore, one short recovery period between series can promote physiological recovery, allowing higher intensities of work in the following series (Hill-Haas et al., 2009). Also, during high-intensity activities performed during SSGs, it has been reported that PCr is responsible for approximately half of the energy supply for ATP resynthesis, and the contribution of PCr is determined by the amount of PCr restored in the body during the rest period (Glaister et al., 2008).

During SSGs using the fractionated method, in each repetition, there are marked drops in the PCr concentrations in the body. These changes cause elevations in lactate concentration and H^+, which has been suggested as one of the causes of reduced performance during subsequent repetitions (Aziz et al., 2007; Bravo et al., 2008), that can also be justified by progressive depletion of glycogen reserves (Spencer et al., 2005).

However, during the recovery period, the rate of glycolytic activity for ATP resynthesis is regulated by synergies between various metabolic processes that require little time to make the non-total but sufficient energy available for the next activity. Moreover, during recovery from short, high-intensity efforts (<5 mins), VO_2 remains elevated to reestablish metabolism to resting conditions based on processes that promote resynthesis of PCr (Bangsbo et al., 2006; Spencer et al., 2005). Therefore, and according to the soccer game demands, if it is imperative that players are able to perform maximum sprints and other movements repeatedly with high intensity, the use of fractionated SSGs with 30 s of recovery is suggested. For this mechanism to be effective, however, it is necessary that there are high levels of PCr in the fast and slow fibers to quickly resynthesize degraded ATP during exertion (Mohr et al., 2003). The resynthesis mechanism of phosphocreatine is fast and shows biphasic behavior through fast (21–22 s) and slow (~ 170–180 s) phases (Harris et al., 2000), which makes it clear that different recovery times may have implications on player performance. Thus, our results show that 30 s may be sufficient to allow considerable resynthesis of phosphocreatine and that 1.30 min and 2 min allow complete resynthesis.

In addition, the results of study 3 may also have a psychophysiological explanation. In fact, players like to perform SSGs because the time of contact with the ball is longer than any other exercise performed and can result in greater motivation and pleasure

derived from the exercise. Thus, having recovery periods longer than 30 s can translate into unnecessary mental fatigue and strain derived from stress related to the anxiety of wanting to play as long as possible. In this sense, previous studies (Boksem et al., 2005, 2006) revealed that the decrease in motivation was associated with mental fatigue and can affect the level of effort that one wishes to exert on a task (Brehm & Self, 1989).
Our results also revealed that very significant changes were not found between the continuous and fractionated methods for the internal load indicators analyzed. Although small variations in the internal load indicators are reported between the training methods, more significant increases were found in some external load indicators, which may be considered better indicators of the physical impact of exercise.

From a practical point of view, this thesis presents important and novel data that can be useful for coaches and highlights the importance of their decision making when organizing exercises using the continuous or fractionated methods. In addition, this thesis explored the impact of varying recovery time on training load during the performance of a SSG based on fractionated training (Study 3). Also, the conclusion and implications were straightforward regarding a specific game format (5-a-side) (study 2 – 4).

For example, if the coach wants to maintain high physical performance and high training load responses to prepare players for a game's demands, they should choose the fractional method with short repetitions and short recovery time periods (i.e., 30 s) (Study 3). Alternatively, if the coach wishes to carefully manage the players' efforts (e.g., post-competition muscle regeneration training) and decrease the response to the training load, they should use continuous method. If the coach wants to create an exercise with a lower training load, allowing players to focus more on learning other components over the duration, it would be more appropriate to select a continuous method (e.g., 24 min) (Study 2). Finally, if the goal is to constantly provide adaptations to the game environment, highlighting what occurs during the game, the exercise should be performed in shorter repetitions (e.g., 4×6 min) (Study 2).

In order to achieve the maximum benefit resulting from the application of SSGs, it is essential that the coach prescribes properly structured exercises, based on the desired goals for the different training domains (i.e., physiological, physical, technical and tactical) and the type of stimulus desired for the unit or training cycle in question. Additionally, it is important that the focus is not only on improving performance but also on maintenance and recovery of the players, which means that controlling the imposed training load, plays a key role in soccer performance.

To increase or decrease fatigue, training loads can be adjusted during a training cycle, depending on the training period (for example, pre-season, season or detraining period), goals and variables can be manipulated to control the intensity of the SSG. Among these variables are the size of the playing field, number of players, recovery time and training method. These variables can be manipulated to manage physical efforts and exercise fatigue and increase or decrease the training load. For example, during an SSG, to carefully manage players' efforts (e.g., post-competition muscle regeneration training) and decrease responses to training load, continuous or fractionated methods with longer recovery times (i.e., 1–2 min) should be used. To ensure a lower training load, it would be more advisable to select an exercise performed by the continuous method (e.g., 18 min). Finally, to request and develop maximum player speeds, SSGs should extend the recovery period between repetitions to 2 min. Once different recovery times induce different physical responses in the players, the coach can then manipulate SSGs throughout the season in different phases (e.g., pre-season, competitive period, and after the detraining period) depending on the level of development of the motor skills desired.

These findings provide new evidence for the relationship between exercise and recovery durations during SSGs in soccer and offer new insights for researchers, coaches, and athletes to improve training efficiency and optimize performances.

The main limitations of this thesis include the following:

i. Only one SSG format was used.
ii. The investigation was conducted in only one age group.
iii. Only HR indicators were used to measure the internal load.
iv. Changes in tactical behavior and technical proficiency for training methods were not considered.

Chapter 6

Overall Conclusions

This thesis emphasizes that during the SSG, the fractionated training method induces higher training load compared to the continuous method. Also, different fractionated methods induce different training loads. About the effect of different recovery times, for the same total exercise time, differences in training load were found.

The main conclusions of this thesis are:

I. The application of a SSG by using fractionated method allow to induce a greater training load (greater physical impact) compared to the use of the continuous training method

II. In SSGs the increase in the number of exercise repetitions (fractionated method) led to increase the external load compared to when using the continuous method.

III. The continuous method presented the tendency of the decreased in the distances travelled with different intensities.

IV. Regarding the HR responses, the data were trivially different, suggesting punctual variations between methods.

V. During SSGs, although the possible increases in the internal and external load, the external load seems to be more susceptible to greater variations when comparing the use of the continuous and fractionated method.

VI. The manipulation of the recovery times induced differences in internal and external load.

VII. For the same total exercise duration, the use of different recovery times is enough to induce different responses in the internal and external loads, during SSGs.

VIII. When performing a SSG with the same total duration time, the external and internal load indicators tend to reveal higher values during the fractionated method particularly with short moments of recovery time.

IX. Small variations in exercise duration and recovery time can have important implications for players' physical performance.

X. The physical impact of the SSG appears to be very sensitive to small variations in time (in the total duration, in the duration of each repetition, in the duration of the interval between repetitions)

XI. Longer recovery time periods (e.g., 2 min) tend to cause an increase in the 'max speed' of players,

XII. Short recovery time periods of 30 s tend to promote generally higher internal and external physical requirement of the exercise and appear to be sufficient to maintain a high level of exercise intensity during SSG

XIII. The recovery time of 1 min 30 s allowed more distance travelled at different intensities compared to the other recovery times, with exception of the recovery times of 30-s duration.

XIV. Longer recovery times (i.e., 1-2 min) do not necessarily imply an increase in the internal and external exercise load in a SSG.

XV. If the coach's goal is to induce high training loads in 5-a-side SSG situations, the fractionated method is the most appropriate, since longer exercise durations appear to have a direct relationship with the decrease in internal and external training loads.

XVI. During 5-a-side SSG the continuous method seems to provide the ideal training load for recovery / regeneration training

XVII. Both methods are suitable to enhance performance during 5-a-side SSG, and the choice of training method to be used should be dependent to the type of objectives defined for the training session.

Chapter 7

Suggestions for future investigations

This study provides useful knowledge about the training method to be used in SSG and the consequences of training variables manipulation such as the total duration of the exercise, the duration of each repetition and the duration of each rest interval between exercise repetitions. However more detailed information on the topic is need. Some possible future investigations are listed below:

I. Replicate these studies with different age groups and game formats.
II. Replicate the study using more internal load variables.
III. To continue the experimental investigation in a broader context, in other soccer training exercises.
IV. Understanding and comparing the impact of a team's playing style on training load indicators, tactical behavior and technical performance resulting from SSGs applied by different methods.
V. Compare possible differences in the perception of the players' effort in performing different fractionated SSG formats with the same total duration and different recovery times.
VI. Future studies should investigate whether there are changes in the technical and tactical component based on the use of different training methods.

Chapter 8

References

Chapter 1 – General Introduction

Aguiar, M., Gonçalves, B., Botelho, G., Lemmink, K., & Sampaio, J. (2015). Footballers' movement behaviour during 2-, 3-, 4- and 5-a-side small-sided games. *Journal of Sports Sciences*, *33*(12), 1259–1266. https://doi.org/10.1080/02640414.2015.1022571

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. https://doi.org/10.1123/ijspp.2015-0331

Alghannam, A. F. (2012). Metabolic limitations of performance and fatigue in football. *Asian Journal of Sports Medicine*, *3*(2), 65–73. https://doi.org/10.5812/asjsm.34699

Balsom, P. D., Seger, J. Y., Sjodin, B., & Ekblom, B. (1992). Maximal-intensity intermittent exercise: Effect of recovery duration. *International Journal of Sports Medicine*, *13*(7), 528–533. https://doi.org/10.1055/s-2007-1021311

Bangsbo, J. (1994). The physiology of soccer - With special reference to intense intermittent exercise. *Acta Physiologica Scandinavica, Supplement*, *151*(619), 1–155.

Billat, L. V. (2001). Interval training for performance: A scientific and empirical practice. Special recommendations for middle- and long-distance running. Part I: Aerobic interval training. *Sports Medicine*, *31*(1), 13–31. https://doi.org/10.2165/00007256-200131010-00002

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2006). Mental fatigue, motivation and action monitoring. *Biological Psychology*, *72*(2), 123–132. https://doi.org/10.1016/j.biopsycho.2005.08.007

Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., Gabbett, T. J., Coutts, A. J., Burgess, D. J., Gregson, W., & Cable, N. T. (2017). Monitoring athlete training loads: Consensus statement. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), 161–170. https://doi.org/10.1123/IJSPP.2017-0208

Brehm, J. W., & Self, E. A. (1989). The Intensity of Motivation. *Annual Review of Psychology*, *40*(1), 109–131. https://doi.org/10.1146/annurev.ps.40.020189.000545

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. https://doi.org/10.1080/02640414.2018.1535821

Burgess, D. J. (2017). The research doesn't always apply: Practical solutions to evidence-based training-load monitoring in elite team sports. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), 136–141. https://doi.org/10.1123/ijspp.2016-0608.

Casamichana, D., Castellano, J., & Dellal, A. (2013). Influence of different training regimes on physical and physiological demands during small-sided soccer games: Continuous vs. intermittent format. *Journal of Strength and Conditioning Research*, *27*(3), 690–697. https://doi.org/10.1519/JSC.0b013e31825d99dc

Clemente, F. M., Martins, F. M. L., & Mendes, R. S. (2014). Periodization based on small-sided soccer games: Theoretical considerations. *Strength and Conditioning Journal*, *36*(5), 34–43. https://doi.org/10.1519/SSC.0000000000000067

Coutts, A. J., Crowcroft, S., & Kempton, T. (2017). Developing athlete monitoring systems: Theoretical basis and practical applications1. In *Sport, Recovery, and Performance: Interdisciplinary Insights* (pp. 19–32). Routledge. https://doi.org/10.4324/9781315268149

Davids, K., Araújo, D., Correia, V., & Vilar, L. (2013). How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exercise and Sport Sciences Reviews*, *41*(3), 154–161. https://doi.org/10.1097/JES.0b013e318292f3ec

Dellal, A., Hill-Haas, S., Lago-Penas, C., & Chamari, K. (2011). Small-sided games in soccer: Amateur vs. professional players' physiological responses, physical, and technical activities. *Journal of Strength and Conditioning Research*, *25*(9), 2371–2381. https://doi.org/10.1519/JSC.0b013e3181fb4296

Desgorces, F. D., Sénégas, X., Garcia, J., Decker, L., & Noirez, P. (2007). Methods to quantify intermittent exercises. *Applied Physiology, Nutrition and Metabolism*, *32*(4), 762–769. https://doi.org/10.1139/H07-037

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. *Journal of Strength and Conditioning Research*, *25*(2), 453–458. https://doi.org/10.1519/JSC.0b013e3181c1f8a2

Faude, O., Schnittker, R., Schulte-Zurhausen, R., Müller, F., & Meyer, T. (2013). High intensity interval training vs. high-volume running training during pre-season conditioning in high-level youth football: A cross-over trial. *Journal of Sports Sciences*, *31*(13), 1441–1450. https://doi.org/10.1080/02640414.2013.792953

Ferraz, R., Gonçalves, B., Coutinho, D., Marinho, D. A., Sampaio, J., & Marques, M. C. (2018). Pacing behaviour of players in team sports: Influence of match status manipulation and task duration knowledge. *PLoS ONE*, *13*(2), e0192399. https://doi.org/10.1371/journal.pone.0192399

Ferraz, R., Gonçalves, B., Van Den Tillaar, R., Jiménez Sáiz, S., Sampaio, J., & Marques, M. C. (2018). Effects of knowing the task duration on players' pacing patterns during soccer small-sided games. *Journal of Sports Sciences*, *36*(1), 116–122. https://doi.org/10.1080/24733938.2017.1283433

Gabbett, T. J., & Mulvey, M. J. (2008). Time-motion analysis of small-sided training games and competition in elite women soccer players. *Journal of Strength and Conditioning Research*, *22*(2), 543–552. https://doi.org/10.1519/JSC.0b013e3181635597

Halouani, J., Chtourou, H., Gabbett, T., Chaouachi, A., & Chamari, K. (2014). Small-sided games in team sports training: A brief review. *Journal of Strength and Conditioning Research*, *28*(12), 3594–3618. https://doi.org/10.1519/JSC.0000000000000564

Halson, S. L. (2014). Monitoring Training Load to Understand Fatigue in Athletes. *Sports Medicine*, *44*, 139–147. https://doi.org/10.1007/s40279-014-0253-z

Hammami, A., Gabbett, T. J., Slimani, M., & Bouhlel, E. (2018a). Does small-sided games training improve physical ftness and team-sport-specifc skills? a systematic review and meta-analysis. *Journal of Sports Medicine and Physical Fitness*, *58*(10), 1446–1455. https://doi.org/10.23736/S0022-4707.17.07420-5

Hammami, A., Gabbett, T. J., Slimani, M., & Bouhlel, E. (2018b). Does small-sided games training improve physical ftness and team-sport-specifc skills? a systematic review and meta-analysis. *Journal of Sports Medicine and Physical Fitness*, *58*(10), 1446–1455. https://doi.org/10.23736/S0022-4707.17.07420-5

Hazir, T. (2010). Physical Characteristics and Somatotype of Soccer Players according to Playing Level and Position. In *Journal of Human Kinetics* (Vol. 26, Issue 1, pp. 83–95). https://doi.org/10.2478/v10078-010-0052-z

Hill-Haas, Stephen V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football: A systematic review. In *Sports Medicine* (Vol. 41, Issue 3, pp. 199–220). https://doi.org/10.2165/11539740-000000000-00000

Hill-Haas, Stephen V., Rowsell, G. J., Dawson, B. T., & Coutts, A. J. (2009). Acute physiological responses and timemotion characteristics of two small-sided training regimes in youth soccer players. *Journal of Strength and Conditioning Research*, *23*(1), 111–115. https://doi.org/10.1519/JSC.0b013e31818efc1a

Hill-Haas, S V, Dawson, B. T., Coutts, A. J., & Rowsell, G. J. (2009). Sixth International Conference on Sport, Leisure and Ergonomics: 14–16 November 2007. *Journal of Sports Sciences*, *27*(sup1), S1–S35. https://doi.org/10.1080/02640410902761199

Hoff, J., Wisløff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002). Soccer specific aerobic endurance training. *British Journal of Sports Medicine*, *36*(3), 218–221. https://doi.org/10.1136/bjsm.36.3.218

Iaia, M. F., Rampinini, E., & Bangsbo, J. (2009). High-intensity training in football. *International Journal of Sports Physiology and Performance*, *4*(3), 291–306. https://doi.org/10.1123/ijspp.4.3.291

Ian Lambert, M., & Borresen, J. (2010). Measuring training load in sports. *International Journal of Sports Physiology and Performance*, *5*(3), 406–411. https://doi.org/10.1123/ijspp.5.3.406

Katis, A., & Kellis, E. (2009). Effects of small-sided games on physical conditioning and performance in young soccer players. *Journal of Sports Science and Medicine*, *8*(3), 374–380.

Kellis, E., Katis, A., & Vrabas, I. S. (2006). Effects of an intermittent exercise fatigue protocol on biomechanics of soccer kick performance. *Scandinavian Journal of Medicine and Science in Sports*, *16*(5), 334–344. https://doi.org/10.1111/j.1600-

0838.2005.00496.x

Köklü, Y. (2012). A comparison of physiological responses to various intermittent and continuous small-sided games in young soccer players. *Journal of Human Kinetics*, *31*(1), 89–96. https://doi.org/10.2478/v10078-012-0009-5

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. https://doi.org/10.1123/ijspp.2016-0584

Lago-Peñas, C., Lago-Ballesteros, J., Dellal, A., & Gómez, M. (2010). Game-related statistics that discriminated winning, drawing and losing teams from the Spanish soccer league. *Journal of Sports Science and Medicine*, *9*(2), 288–293.

Laursen, P. B. (2010). Training for intense exercise performance: High-intensity or high-volume training? *Scandinavian Journal of Medicine and Science in Sports*, *20*(SUPPL. 2), 1–10. https://doi.org/10.1111/j.1600-0838.2010.01184.x

Laursen, Paul B., & Jenkins, D. G. (2002). The scientific basis for high-intensity interval training: Optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Medicine*, *32*(1), 53–73. https://doi.org/10.2165/00007256-200232010-00003

Little, T. (2009a). Optimizing the use of soccer drills for physiological development. *Strength and Conditioning Journal*, *31*(3), 67–74. https://doi.org/10.1519/SSC.0b013e3181a5910d

Little, T. (2009b). Optimizing the use of soccer drills for physiological development. *Strength and Conditioning Journal*, *31*(3), 67–74. https://doi.org/10.1519/SSC.0b013e3181a5910d

Los Arcos, A., Vázquez, J. S., Martín, J., Lerga, J., Sánchez, F., Villagra, F., & Zulueta, J. J. (2015). Effects of Small-Sided Games vs. Interval Training in Aerobic Fitness and Physical Enjoyment in Young Elite Soccer Players. *PloS One*, *10*(9), e0137224–e0137224. https://doi.org/10.1371/journal.pone.0137224

McMorris, T., & Graydon, J. (1996). The Effect of Exercise on the Decision-Making Performance of Experienced and Inexperienced Soccer Players. *Research Quarterly for Exercise and Sport*, *67*(1), 109–114. https://doi.org/10.1080/02701367.1996.10607933

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, *21*(7), 519–528. https://doi.org/10.1080/0264041031000071182

Mohr, M., Krustrup, P., & Bangsbo, J. (2005). Fatigue in soccer: A brief review. *Journal of Sports Sciences*, *23*(6), 593–599. https://doi.org/10.1080/02640410400021286

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.

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. https://doi.org/10.1080/02640410600811858

Reilly, T. (1997). Energetics of high-intensity exercise (soccer) with particular reference to fatigue. *Journal of Sports Sciences*, *15*(3), 257–263. https://doi.org/10.1080/026404197367263

Reilly, Thomas. (2005). An ergonomics model of the soccer training process. *Journal of Sports Sciences*, *23*(6), 561–572. https://doi.org/10.1080/02640410400021245

Sampaio, J. E., Lago, C., Gonçalves, B., Maçãs, V. M., & Leite, N. (2014). Effects of pacing, status and unbalance in time motion variables, heart rate and tactical behaviour when playing 5-a-side football small-sided games. *Journal of Science and Medicine in Sport*, *17*(2), 229–233. https://doi.org/10.1016/j.jsams.2013.04.005

Sampaio, J., Garcia, G., Maçãs, V., Ibáñez, S. J., Abrantes, C., & Caixinha, P. (2007). Heart rate and perceptual responses to 2x2 and 3x3 small-sided youth soccer games. *Journal of Sports Science and Medicine*, *6*(10), 121–122.

Silva, J. R., Brito, J., Akenhead, R., & Nassis, G. P. (2016). The Transition Period in Soccer: A Window of Opportunity. *Sports Medicine*, *46*(3), 305–313. https://doi.org/10.1007/s40279-015-0419-3

Smith, D. J. (2003). A Framework for Understanding the Training Process Leading to Elite Performance. *Sports Medicine*, *33*(15), 1103–1126. https://doi.org/10.2165/00007256-200333150-00003

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Medicine*, *35*(6), 501–536. https://doi.org/10.2165/00007256-

200535060-00004

Thorpe, R. T., Atkinson, G., Drust, B., & Gregson, W. (2017). Monitoring fatigue status in elite team-sport athletes: Implications for practice. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), 27–34. https://doi.org/10.1123/ijspp.2016-0434

Waldron, M., & Highton, J. (2014). Fatigue and pacing in high-intensity intermittent team sport: An update. *Sports Medicine*, *44*(12), 1645–1658. https://doi.org/10.1007/s40279-014-0230-6

Yücesoy, M., Erkmen, N., Aktas, S., Güven, F., & Durmaz, M. (2019). Interval Versus Continuous Small-Sided Soccer Games With Same Pitch Size and Number of Players. *Facta Universitatis, Series: Physical Education and Sport*, 631. https://doi.org/10.22190/fupes181009057y

Chapter 2 – Literature Review

Aasgaard, M., & Kilding, A. E. (2018). Does Man Marking Influence Running Outputs and Intensity During Small-Sided Soccer Games? *Journal of Strength and Conditioning Research*, 1. https://doi.org/10.1519/jsc.0000000000002668

Aguiar, M., Abrantes, C., Macas, V., Leite, N., Sampaio, J., & Ibanez, S. (2008). Effects of Intermittent or Continuous Training on Speed, Jump and Repeated-Sprint Ability in Semi-Professional Soccer Players~!2008-03-27~!2008-05-19~!2008-06-12~! *The Open Sports Sciences Journal*, *1*(1), 15–19. https://doi.org/10.2174/1875399x00801010015

Aguiar, Marco, Botelho, G., Lago, C., MaçAs, V., & Sampaio, J. (2012). A review on the effects of soccer small-sided games. *Journal of Human Kinetics*, *33*(1), 103–113. https://doi.org/10.2478/v10078-012-0049-x

Aguiar, Marco, Gonçalves, B., Botelho, G., Lemmink, K., & Sampaio, J. (2015). Footballers' movement behaviour during 2-, 3-, 4- and 5-a-side small-sided games. *Journal of Sports Sciences*, *33*(12), 1259–1266. https://doi.org/10.1080/02640414.2015.1022571

Alves, R. N., Costa, L. O. P., & Samulski, D. M. (2006). Monitoramento e prevenção do supertreinamento em atletas. *Revista Brasileira de Medicina Do Esporte*, *12*(5), 291–296. https://doi.org/10.1590/s1517-86922006000500013

Andrzejewski, M., Chmura, J., Pluta, B., Strzelczyk, R., & Kasprzak, A. (2013). Analysis of sprinting activities of professional soccer players. *Journal of Strength and Conditioning Research*, *27*(8), 2134–2140. https://doi.org/10.1519/JSC.0b013e318279423e

Aroso, J., Rebelo, A. N., & Gomes-Pereira, J. (2004). Physiological impact of selected game-related exercises. *Journal of Sports Sciences*, *22*(6), 522.

Aslan, A. (2013). Cardiovascular responses, perceived exertion and technical actions during small-sided recreational soccer: Effects of pitch size and number of players. *Journal of Human Kinetics*, *38*(1), 95–105. https://doi.org/10.2478/hukin-2013-0049

Aughey, R. J., & Falloon, C. (2010). Real-time versus post-game GPS data in team sports. *Journal of Science and Medicine in Sport*, *13*(3), 348–349. https://doi.org/10.1016/j.jsams.2009.01.006

Badin, O. O., Smith, M. R., Conte, D., & Coutts, A. J. (2016). Mental fatigue: Impairment of technical performance in small-sided soccer games. *International Journal of Sports Physiology and Performance*, *11*(8), 1100–1105. https://doi.org/10.1123/ijspp.2015-0710

Baker, J. S., McCormick, M. C., & Robergs, R. A. (2010). Interaction among Skeletal Muscle Metabolic Energy Systems during Intense Exercise. *Journal of Nutrition and Metabolism*, *2010*, 905612. https://doi.org/10.1155/2010/905612

Balsom, P., Lindholm, T., Nilsson, J., & Ekblom, B. (1999). Precision football. *Kempele, Finland: Polar Electro Oy*. https://scholar.google.es/scholar?q=Balsom+et+al.%2C+1999&btnG=&hl=es&as_sdt=0%2C5#3

Bangsbo, J. (1993). The physiology of soccer - With special reference to intense intermittent exercise. *Acta Physiologica Scandinavica, Supplement*, *151*(619), 1–155.

Bangsbo, J. (1994). The physiology of soccer - With special reference to intense intermittent exercise. *Acta Physiologica Scandinavica, Supplement*, *151*(619), 1–155.

Bangsbo, Jens, Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Nutrition and Football: The FIFA/FMARC Consensus on Sports Nutrition*, *24*(07), 1–18. https://doi.org/10.4324/9780203967430

Billat, V. L., Hamard, L., & Koralsztein, J. P. (2002). The influence of exercise duration at VO2 max on the off-transient pulmonary oxygen uptake phase during high intensity running activity. *Archives of Physiology and Biochemistry*, *110*(5), 383–392. https://doi.org/10.1076/apab.110.5.383.11831

Bishop, C., Turner, A., & Read, P. (2018). Effects of inter-limb asymmetries on physical and sports performance: a systematic review. *Journal of Sports Sciences*, *36*(10), 1135–1144. https://doi.org/10.1080/02640414.2017.1361894

Bishop, D. J. (2012). Fatigue during intermittent-sprint exercise. *Clinical and Experimental Pharmacology and Physiology*, *39*(9), 836–841. https://doi.org/10.1111/j.1440-1681.2012.05735.x

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2006). Mental fatigue, motivation and action monitoring. *Biological Psychology*, *72*(2), 123–132. https://doi.org/10.1016/j.biopsycho.2005.08.007

Bompa, T. O. (2009). *Entrenamiento de equipos deportivos*. Paidotribo.

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. https://doi.org/10.1123/ijspp.6.3.311

Bradley, P. S., Archer, D. T., Hogg, B., Schuth, G., Bush, M., Carling, C., & Barnes, C. (2016). Tier-specific evolution of match performance characteristics in the English Premier League: it's getting tougher at the top. *Journal of Sports Sciences*, *34*(10), 980–987. https://doi.org/10.1080/02640414.2015.1082614

Bradley, P. S., Carling, C., Gomez Diaz, A., Hood, P., Barnes, C., Ade, J., Boddy, M., Krustrup, P., & Mohr, M. (2013). Match performance and physical capacity of players in the top three competitive standards of English professional soccer. *Human Movement Science*, *32*(4), 808–821. https://doi.org/10.1016/j.humov.2013.06.002

Bradley, P. S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krustrup, P. (2009). High-intensity running in English FA Premier League soccer matches. *Journal of Sports Sciences*, *27*(2), 159–168. https://doi.org/10.1080/02640410802512775

Brehm, J. W., & Self, E. A. (1989). The Intensity of Motivation. *Annual Review of Psychology*, *40*(1), 109–131. https://doi.org/10.1146/annurev.ps.40.020189.000545

Brink, M. S., Nederhof, E., Visscher, C., Schmikli, S. L., & Lemmink, K. A. P. M. (2010). Monitoring load, recovery, and performance in young elite soccer players. *Journal of Strength and Conditioning Research*, *24*(3), 597–603. https://doi.org/10.1519/JSC.0b013e3181c4d38b

Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part II: Anaerobic energy, neuromuscular load and practical applications. *Sports Medicine*, *43*(10), 927–954. https://doi.org/10.1007/s40279-013-0066-5

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. https://doi.org/10.1080/02640414.2018.1535821

Bush, M., Barnes, C., Archer, D. T., Hogg, B., & Bradley, P. S. (2015). Evolution of match performance parameters for various playing positions in the English Premier League. *Human Movement Science*, *39*, 1–11. https://doi.org/10.1016/j.humov.2014.10.003

Carling, C., Bloomfield, J., Nelsen, L., & Reilly, T. (2008). The role of motion analysis in elite soccer: Contemporary performance measurement techniques and work rate data. *Sports Medicine*, *38*(10), 839–862. https://doi.org/10.2165/00007256-200838100-00004

Carraro, A., Gobbi, E., Ferri, I., Benvenuti, P., & Zanuso, S. (2014). Enjoyment perception during exercise with aerobic machines. *Perceptual and Motor Skills*, *119*(1), 146–155. https://doi.org/10.2466/29.06.PMS.119c15z3

Casamichana, D., & Castellano, J. (2014). Variables contextuales y distancia recorrida en la copa mundial Sudáfrica'10. *Revista Internacional de Medicina y Ciencias de la Actividad Fisica y del Deporte*, *14*(56), 603–617. http://www.redalyc.org/articulo.oa?id=54232971002

Casamichana, David, & 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. https://doi.org/10.1080/02640414.2010.521168

Casamichana, David, Castellano, J., Calleja-Gonzalez, J., RomaN, J. S., & Castagna, C. (2013). Relationship between indicators of training load in soccer players. *Journal of*

Strength and Conditioning Research, *27*(2), 369–374. https://doi.org/10.1519/JSC.0b013e3182548af1

Casamichana, David, Castellano, J., & Castagna, C. (2012). Comparing the physical demands of friendly matches and small-sided games in semiprofessional soccer players. *Journal of Strength and Conditioning Research*, *26*(3), 837–843. https://doi.org/10.1519/JSC.0b013e31822a61cf

Casamichana, David, Castellano, J., & Dellal, A. (2013). Influence of different training regimes on physical and physiological demands during small-sided soccer games: Continuous vs. intermittent format. *Journal of Strength and Conditioning Research*, *27*(3), 690–697. https://doi.org/10.1519/JSC.0b013e31825d99dc

Castellano, J., Blanco-Villaseñor, A., & Álvarez, D. (2011). Contextual variables and time-motion analysis in soccer. *International Journal of Sports Medicine*, *32*(6), 415–421. https://doi.org/10.1055/s-0031-1271771

Castellano, Julen, 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. *Journal of Strength and Conditioning Research*, *27*(5), 1295–1303. https://doi.org/10.1519/JSC.0b013e318267a5d1

Castellano, Julen, Casamichana, D., & Lago, C. (2012). The use of match statistics that discriminate between successful and unsuccessful soccer teams. *Journal of Human Kinetics*, *31*(1), 139–147. https://doi.org/10.2478/v10078-012-0015-7

Christopher, J., Beato, M., & Hulton, A. T. (2016). Manipulation of exercise to rest ratio within set duration on physical and technical outcomes during small-sided games in elite youth soccer players. *Human Movement Science*, *48*, 1–6. https://doi.org/10.1016/j.humov.2016.03.013

Cihan, H. (2015). The effect of defensive strategies on the physiological responses and time-motion characteristics in small-sided games. *Kinesiology*, *47*(2), 179–187.

Clemente, Filipe M., Martins, F. M. L., & Mendes, R. S. (2014). Periodization based on small-sided soccer games: Theoretical considerations. *Strength and Conditioning Journal*, *36*(5), 34–43. https://doi.org/10.1519/SSC.0000000000000067

Clemente, Filipe Manuel, Mendes, B., Nikolaidis, P. T., Calvete, F., Carriço, S., & Owen, A. L. (2017). Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. *Physiology and Behavior*, *179*, 262–267. https://doi.org/10.1016/j.physbeh.2017.06.021

da Mota, G. R., Thiengo, C. R., Gimenes, S. V., & Bradley, P. S. (2016). The effects of ball possession status on physical and technical indicators during the 2014 FIFA World Cup Finals. *Journal of Sports Sciences*, *34*(6), 493–500. https://doi.org/10.1080/02640414.2015.1114660

Davids, K., Araújo, D., Correia, V., & Vilar, L. (2013). How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exercise and Sport Sciences Reviews*, *41*(3), 154–161. https://doi.org/10.1097/JES.0b013e318292f3ec

Dellal, A., Jannault, R., Lopez-Segovia, M., & Pialoux, V. (2011). Influence of the numbers of players in the heart rate responses of youth soccer players within 2 vs. 2, 3 vs. 3 and 4 vs. 4 small-sided games. *Journal of Human Kinetics*, *28*(1), 107–114. https://doi.org/10.2478/v10078-011-0027-8

Dellal, Alexandre, Chamari, K., Pintus, A., Girard, O., Cotte, T., & Keller, D. (2008). Heart rate responses during small-sided games and short intermittent running training in elite soccer players: A comparative study. *Journal of Strength and Conditioning Research*, *22*(5), 1449–1457. https://doi.org/10.1519/JSC.0b013e31817398c6

Dellal, Alexandre, Keller, D., Carling, C., Chaouachi, A., Wong, D. P., & Chamari, K. (2010). Physiologic effects of directional changes in intermittent exercise in soccer players. *Journal of Strength and Conditioning Research*, *24*(12), 3219–3226. https://doi.org/10.1519/JSC.0b013e3181b94a63

Dellal, Alexandre, Varliette, C., Owen, A., Chirico, E. N., & Pialoux, V. (2012). Small-sided games versus interval training in amateur soccer players: Effects on the aerobic capacity and the ability to perform intermittent exercises with changes of direction. *Journal of Strength and Conditioning Research*, *26*(10), 2712–2720. https://doi.org/10.1519/JSC.0b013e31824294c4

Di Salvo, V., Pigozzi, F., González-Haro, C., Laughlin, M. S., & De Witt, J. K. (2013). Match performance comparison in top English soccer leagues. *International Journal of Sports Medicine*, *34*(6), 526–532. https://doi.org/10.1055/s-0032-1327660

Drew, M. K., & Finch, C. F. (2016). The Relationship Between Training Load and Injury, Illness and Soreness: A Systematic and Literature Review. *Sports Medicine*, *46*(6), 861–883. https://doi.org/10.1007/s40279-015-0459-8

Drust, B., Reilly, T., & Cable, N. T. (2000). Physiological responses to laboratory-based soccer-specific intermittent and continuous exercise. *Journal of Sports Sciences*, *18*(11), 885–892. https://doi.org/10.1080/026404100750017814

Duk, O. S., Min, K. S., Kawczyński, A., Chmura, P., Mroczek, D., & Chmura, J. (2011). Endurance and speed capacity of the korea republic football national team during the world cup of 2010. *Journal of Human Kinetics*, *30*(1), 115–121. https://doi.org/10.2478/v10078-011-0079-9

Dupont, G., Blondel, N., & Berthoin, S. (2003). Performance for short intermittent runs: Active recovery vs. passive recovery. *European Journal of Applied Physiology*, *89*(6), 548–554. https://doi.org/10.1007/s00421-003-0834-2

Edge, J., Bishop, D., & Goodman, C. (2006). The effects of training intensity on muscle buffer capacity in females. *European Journal of Applied Physiology*, *96*(1), 97–105. https://doi.org/10.1007/s00421-005-0068-6

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. *Journal of Strength and Conditioning Research*, *25*(2), 453–458. https://doi.org/10.1519/JSC.0b013e3181c1f8a2

Ferraz, R., Gonçalves, B., Coutinho, D., Marinho, D. A., Sampaio, J., & Marques, M. C. (2018). Pacing behaviour of players in team sports: Influence of match status manipulation and task duration knowledge. *PLoS ONE*, *13*(2), e0192399. https://doi.org/10.1371/journal.pone.0192399

Ferraz, R., Gonçalves, B., Van Den Tillaar, R., Jiménez Sáiz, S., Sampaio, J., & Marques, M. C. (2018). Effects of knowing the task duration on players' pacing patterns during soccer small-sided games. *Journal of Sports Sciences*, *36*(1), 116–122. https://doi.org/10.1080/24733938.2017.1283433

Ferraz, R. M. P., van den Tillaar, R., Pereira, A., & Marques, M. C. (2019). The effect of fatigue and duration knowledge of exercise on kicking performance in soccer players. *Journal of Sport and Health Science*, *8*(6), 567–573. https://doi.org/10.1016/j.jshs.2016.02.001

Ferraz, R., van den Tillar, R., & Marques, M. C. (2017). The influence of different exercise intensities on kicking accuracy and velocity in soccer players. *Journal of Sport and Health Science*, *6*(4), 462–467. https://doi.org/10.1016/j.jshs.2015.10.001

Folgado, H., Duarte, R., Fernandes, O., & Sampaio, J. (2014). Competing with lower level opponents decreases intra-team movement synchronization and time-motion demands during pre-season soccer matches. *PLoS ONE*, *9*(5), e97145–e97145. https://doi.org/10.1371/journal.pone.0097145

Gabbett, T. J. (2006). Skill-Based Conditioning Games as an Alternative to Traditional Conditioning for Rugby League Players. *The Journal of Strength and Conditioning Research*, *20*(2), 309. https://doi.org/10.1519/r-17655.1

Gabbett, T., Jenkins, D., & Abernethy, B. (2009). Game-Based Training for Improving Skill and Physical Fitness in Team Sport Athletes. *International Journal of Sports Science & Coaching*, *4*(2), 273–283. https://doi.org/10.1260/174795409788549553

Gaesser, G. A., & Brooks, G. A. (1984). Metabolic bases of excess post-exercise oxygen consumption: A review. *Medicine and Science in Sports and Exercise*, *16*(1), 29–43. https://doi.org/10.1249/00005768-198401000-00008

Gamble, P. (2004). A skill-based conditioning games approach to metabolic conditioning for elite rugby football players. *Journal of Strength and Conditioning Research*, *18*(3), 491–497. https://doi.org/10.1519/1533-4287(2004)18<491:ASCGAT>2.0.CO;2

Gandevia, S. C. (2001). Spinal and supraspinal factors in human muscle fatigue. *Physiological Reviews*, *81*(4), 1725–1789. https://doi.org/10.1152/physrev.2001.81.4.1725

Gharbi, Z., Dardouri, W., Haj-Sassi, R., Chamari, K., & Souissi, N. (2015). Aerobic and anaerobic determinants of repeated sprint ability in team sports athletes. *Biology of Sport*, *32*(3), 207–212. https://doi.org/10.5604/20831862.1150302

Giménez, J. V., Jiménez-Linares, L., Leicht, A. S., & Gómez, M. A. (2020). Predictive modelling of the physical demands during training and competition in professional soccer players. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2019.12.008

Gonzalo-Skok, O., Tous-Fajardo, J., Suarez-Arrones, L., Arjol-Serrano, J. L., Casajús, J. A., & Mendez-Villanueva, A. (2017). Single-leg power output and between-limbs imbalances in team-sport players: Unilateral versus bilateral combined resistance training. *International Journal of Sports Physiology and Performance*, *12*(1), 106–114. https://doi.org/10.1123/ijspp.2015-0743

Grossman, P., Wilhelm, F. H., & Brutsche, M. (2010). Accuracy of ventilatory measurement employing ambulatory inductive plethysmography during tasks of everyday life. *Biological Psychology*, *84*(1), 121–128. https://doi.org/10.1016/j.biopsycho.2010.02.008

Halouani, J., Chtourou, H., Gabbett, T., Chaouachi, A., & Chamari, K. (2014). Small-sided games in team sports training: A brief review. *Journal of Strength and Conditioning Research*, *28*(12), 3594–3618. https://doi.org/10.1519/JSC.0000000000000564

Halson, S. L. (2014). Monitoring Training Load to Understand Fatigue in Athletes. *Sports Medicine*, *44*, 139–147. https://doi.org/10.1007/s40279-014-0253-z

Hammami, A., Gabbett, T. J., Slimani, M., & Bouhlel, E. (2018). Does small-sided games training improve physical ftness and team-sport-specifc skills? a systematic review and meta-analysis. *Journal of Sports Medicine and Physical Fitness*, *58*(10), 1446–1455. https://doi.org/10.23736/S0022-4707.17.07420-5

Harrison, C. B., Kilding, A. E., Gill, N. D., & Kinugasa, T. (2014). Small-sided games for young athletes: is game specificity influential? *Journal of Sports Sciences*, *32*(4), 336–344. https://doi.org/10.1080/02640414.2013.824600

Helgerud, J., Engen, L. C., Wisløff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. *Medicine and Science in Sports and Exercise*, *33*(11), 1925–1931. https://doi.org/10.1097/00005768-200111000-00019

Helgerud, Jan, Høydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., Simonsen, T., Helgesen, C., Hjorth, N., Bach, R., & Hoff, J. (2007). Aerobic high-intensity intervals improve VO2max more than moderate training. *Medicine and Science in Sports and Exercise*, *39*(4), 665–671. https://doi.org/10.1249/mss.0b013e3180304570

Hevilla-Merino, A., & Castillo-Rodríguez, A. (2018). Fluctuation of the Psychological Characteristics of Sports Performance on Young Soccer Players. Basal State vs. Precompetitive. *Cuadernos de Psicologia del Deporte*, *18*(3), 169–178.

Hill-Haas, Stephen, Coutts, A., Rowsell, G., & Dawson, B. (2008). Variability of acute physiological responses and performance profiles of youth soccer players in small-sided games. *Journal of Science and Medicine in Sport*, *11*(5), 487–490. https://doi.org/10.1016/j.jsams.2007.07.006

Hill-Haas, Stephen 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. *Journal of Strength and Conditioning Research*, *24*(8), 2149–2156. https://doi.org/10.1519/JSC.0b013e3181af5265

Hill-Haas, Stephen V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football: A systematic review. *Sports Medicine*, *41*(3), 199–220. https://doi.org/10.2165/11539740-000000000-00000

Hill-Haas, Stephen V., Rowsell, G. J., Dawson, B. T., & Coutts, A. J. (2009). Acute physiological responses and timemotion characteristics of two small-sided training regimes in youth soccer players. *Journal of Strength and Conditioning Research*, *23*(1), 111–115. https://doi.org/10.1519/JSC.0b013e31818efc1a

Hill-Haas, S V, Dawson, B. T., Coutts, A. J., & Rowsell, G. J. (2009). Sixth International Conference on Sport, Leisure and Ergonomics: 14–16 November 2007. *Journal of Sports Sciences*, *27*(sup1), S1–S35. https://doi.org/10.1080/02640410902761199

Hoff, J., & Helgerud, J. (2004). Endurance and strength training for soccer players: Physiological considerations. *Sports Medicine*, *34*(3), 165–180. https://doi.org/10.2165/00007256-200434030-00003

Impellizzeri, F. M., Marcora, S. M., Castagna, C., Reilly, T., Sassi, A., Iaia, F. M., & Rampinini, E. (2006). Physiological and performance effects of generic versus specific aerobic training in soccer players. *International Journal of Sports Medicine*, *27*(6), 483–492. https://doi.org/10.1055/s-2005-865839

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load: 15 years on. *International Journal of Sports Physiology and Performance*, *14*(2), 270–273. https://doi.org/10.1123/ijspp.2018-0935

Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005). Physiological assessment of aerobic training in soccer. *Journal of Sports Sciences*, *23*(6), 583–592. https://doi.org/10.1080/02640410400021278

Jones, S., & Drust, B. (2007). Physiological and technical demands of 4 v 4 and 8 v 8 games in elite youth soccer players. *Kinesiology*, *39*(2), 150–156.

Katis, A., & Kellis, E. (2009). Effects of small-sided games on physical conditioning and performance in young soccer players. *Journal of Sports Science and Medicine*, *8*(3), 374–380.

Kellmann, M. (2002). *Enhancing Recovery: Preventing Underperformance in Athletes*. Human Kinetics. https://books.google.com/books?id=Qp-WkTxvlvIC&pgis=1

Kellmann, M., & Kallus, K. W. (2007). Mood, Recovery-Stress State, and Regeneration. In M. Lehmann, C. Foster, U. Gastmann, H. Keizer, & J. M. Steinacker (Eds.), *Overload, Performance Incompetence, and Regeneration in Sport* (pp. 101–117). Springer US. https://doi.org/10.1007/978-0-585-34048-7_8

Kelly, D. M., & Drust, B. (2009). The effect of pitch dimensions on heart rate responses and technical demands of small-sided soccer games in elite players. *Journal of Science and Medicine in Sport*, *12*(4), 475–479. https://doi.org/10.1016/j.jsams.2008.01.010

Kelly, D. M., Strudwick, A. J., Atkinson, G., Drust, B., & Gregson, W. (2020). Quantification of training and match-load distribution across a season in elite English Premier League soccer players. *Science and Medicine in Football*, *4*(1), 59–67. https://doi.org/10.1080/24733938.2019.1651934

Knicker, A. J., Renshaw, I., Oldham, A. R. H., & Cairns, S. P. (2011). Interactive processes link the multiple symptoms of fatigue in sport competition. *Sports Medicine*, *41*(4), 307–328. https://doi.org/10.2165/11586070-000000000-00000

Köklü, Y., Alemdaroılu, U., Dellal, A., & Wong, D. P. (2015). Effect of different recovery durations between bouts in 3-a-side games on youth soccer players' physiological responses and technical activities. *Journal of Sports Medicine and Physical Fitness*, *55*(5), 430–438.

Köklü, Yusuf. (2012). A comparison of physiological responses to various intermittent and continuous small-sided games in young soccer players. *Journal of Human Kinetics*, *31*(1), 89–96. https://doi.org/10.2478/v10078-012-0009-5

Köklü, Yusuf, 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. https://doi.org/10.1123/ijspp.2016-0584

Köklü, Yusuf, Alemdaroğlu, U., Cihan, H., Wong, D. P., Köklö, 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. https://doi.org/10.1123/ijspp.2016-0584

Köklü, Yusuf, Aşçi, A., Koçak, F. Ü., Alemdaroğlu, U., & Dündar, U. (2011). Comparison of the physiological responses to different small-sided games in elite young soccer players. *Journal of Strength and Conditioning Research*, *25*(6), 1522–1528. https://doi.org/10.1519/JSC.0b013e3181e06ee1

Köklü, Yusuf, Sert, Ö., Alemdaroılu, 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. *Journal of Strength and Conditioning Research*, *29*(4), 964–971. https://doi.org/10.1519/JSC.0b013e3182a744a1

Little, T. (2009). Optimizing the use of soccer drills for physiological development. *Strength and Conditioning Journal*, *31*(3), 67–74. https://doi.org/10.1519/SSC.0b013e3181a5910d

Little, T., & Williams, A. G. (2006). Suitability of soccer training drills for endurance training. *Journal of Strength and Conditioning Research*, *20*(2), 316–319. https://doi.org/10.1519/R-17094.1

Lorist, M. M., Boksem, M. A. S., & Ridderinkhof, K. R. (2005). Impaired cognitive control and reduced cingulate activity during mental fatigue. *Cognitive Brain Research*, *24*(2), 199–205. https://doi.org/10.1016/j.cogbrainres.2005.01.018

Los Arcos, A., Vázquez, J. S., Martín, J., Lerga, J., Sánchez, F., Villagra, F., & Zulueta, J. J. (2015). Effects of Small-Sided Games vs. Interval Training in Aerobic Fitness and Physical Enjoyment in Young Elite Soccer Players. *PloS One*, *10*(9), e0137224–e0137224. https://doi.org/10.1371/journal.pone.0137224

MacLeod, H., Morris, J., Nevill, A., & Sunderland, C. (2009). The validity of a non-differential global positioning system for assessing player movement patterns in field hockey. *Journal of Sports Sciences*, *27*(2), 121–128. https://doi.org/10.1080/02640410802422181

Malone, J. J., Di Michele, R., Morgans, R., Burgess, D., Morton, J. P., & Drust, B. (2015). Seasonal training-load quantification in elite English Premier League soccer players. *International Journal of Sports Physiology and Performance*, *10*(4), 489–497. https://doi.org/10.1123/ijspp.2014-0352

McLean, S., Kerhervé, H., Lovell, G. P., Gorman, A. D., & Solomon, C. (2016). The effect of recovery duration on vastus lateralis oxygenation, heart rate, perceived exertion and time motion descriptors during small sided football games. *PLoS ONE*, *11*(2), e0150201. https://doi.org/10.1371/journal.pone.0150201

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, *21*(7), 519–528. https://doi.org/10.1080/0264041031000071182

Mohr, M., Krustrup, P., & Bangsbo, J. (2005). Fatigue in soccer: A brief review. *Journal of Sports Sciences*, *23*(6), 593–599. https://doi.org/10.1080/02640410400021286

Molina-Carmona, I., Gómez-Carmona, C., Bastida-Castillo, A., & Pino-Ortega, J. (2018). Validez del dispositivo inercial WIMU PRO para el registro de la frecuencia cardiaca en un test de campo. *SPORT TK-Revista EuroAmericana de Ciencias Del Deporte*, *7*(1), 81. https://doi.org/10.6018/321921

Morgans, R., Adams, D., Mullen, R., McLellan, C., & Williams, M. (2014). Technical and physical performance over an english championship league season. *International Journal of Sports Science and Coaching*, *9*(5), 1033–1042. https://doi.org/10.1260/1747-9541.9.5.1033

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.

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. https://doi.org/10.1080/02640410600811858

Rampinini, E., Impellizzeri, F. M., Castagna, C., Azzalin, A., Bravo, D. F., & Wisløff, U. (2008). Effect of match-related fatigue on short-passing ability in young soccer players. *Medicine and Science in Sports and Exercise*, *40*(5), 934–942. https://doi.org/10.1249/MSS.0b013e3181666eb8

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*, *18*(9), 669–683. https://doi.org/10.1080/02640410050120050

Reilly, Thomas. (2006). The Science of Training - Soccer. In *The Science of Training - Soccer*. Routledge. https://doi.org/10.4324/9780203966662

Reilly, Thomas, & Mark Williams, A. (2003). Science and soccer: Second edition. In *Science and Soccer: Second Edition*. https://doi.org/10.4324/9780203417553

Reilly, Thomas, Morris, T., & Whyte, G. (2009). The specificity of training prescription and physiological assessment: A review. *Journal of Sports Sciences*, *27*(6), 575–589. https://doi.org/10.1080/02640410902729741

Rodríguez-Fernández, A., Sanchez-Sanchez, J., Ramirez-Campillo, R., Nakamura, F. Y., Rodríguez-Marroyo, J. A., & Villa-Vicente, J. G. (2019). Relationship Between Repeated Sprint Ability, Aerobic Capacity, Intermittent Endurance, and Heart Rate Recovery in Youth Soccer Players. *Journal of Strength and Conditioning Research*, *33*(12), 3406–3413. https://doi.org/10.1519/JSC.0000000000002193

Sáez De Villarreal, E., Suarez-Arrones, L., Requena, B., Haff, G. G., & Ferrete, C. (2015). Effects of Plyometric and Sprint Training on Physical and Technical Skill Performance in Adolescent Soccer Players. *Journal of Strength and Conditioning Research*, *29*(7), 1894–1903. https://doi.org/10.1519/JSC.0000000000000838

Sampaio, J. E., Lago, C., Gonçalves, B., Maçãs, V. M., & Leite, N. (2014). Effects of pacing, status and unbalance in time motion variables, heart rate and tactical behaviour when playing 5-a-side football small-sided games. *Journal of Science and Medicine in Sport*, *17*(2), 229–233. https://doi.org/10.1016/j.jsams.2013.04.005

Sánchez, G. F. L., Balsalobre, F. J. B., Díaz-Suárez, A., & Smith, L. (2018). Effects of a 12-week-long program of vigorous-intensity physical activity on the body composition of 6-and 7-year-old children. *Journal of Human Sport and Exercise*, *13*, S445–S453. https://doi.org/10.14198/jhse.2018.13.Proc2.28

Sassi, R., Reilly, T., & Impellizzeri FA. (2005). Comparison of Small-Sided Games and Interval Training in Elite Professional Soccer Players. *Science and Football V.*, 341–343.

Seiler, S., & Tønnessen, E. (2009). Intervals , Thresholds , and Long Slow Distance : the Role of Intensity and Duration in Endurance Training. *Training*, *13*(13), 32–53. http://sportsci.org/2009/ss.htm

Selmi, O., Gonçalves, B., Ouergui, I., Sampaio, J., & Bouassida, A. (2018). Influence of well-being variables and recovery state in physical enjoyment of professional soccer players during small-sided games. *Research in Sports Medicine*, *26*(2), 199–210. https://doi.org/10.1080/15438627.2018.1431540

Shou, G., & Ding, L. (2013). Ongoing EEG oscillatory dynamics suggesting evolution of mental fatigue in a color-word matching stroop task. In *International IEEE/EMBS Conference on Neural Engineering, NER*. https://doi.org/10.1109/NER.2013.6696189

Silva, J. R., Brito, J., Akenhead, R., & Nassis, G. P. (2016). The Transition Period in Soccer: A Window of Opportunity. *Sports Medicine*, *46*(3), 305–313. https://doi.org/10.1007/s40279-015-0419-3

Silva, P., Duarte, R., Sampaio, J., Aguiar, P., Davids, K., Araújo, D., & Garganta, J. (2014). Field dimension and skill level constrain team tactical behaviours in small-sided and conditioned games in football. *Journal of Sports Sciences*, *32*(20), 1888–1896. https://doi.org/10.1080/02640414.2014.961950

Smits, B. L. M., Pepping, G. J., & Hettinga, F. J. (2014). Pacing and decision making in sport and exercise: The roles of perception and action in the regulation of exercise intensity. *Sports Medicine*, *44*(6), 763–775. https://doi.org/10.1007/s40279-014-0163-0

Spencer, M., Bishop, D., Dawson, B., & Goodman, C. (2005). Physiological and metabolic responses of repeated-sprint activities: Specific to field-based team sports. *Sports Medicine*, *35*(12), 1025–1044. https://doi.org/10.2165/00007256-200535120-00003

Strudwick, A., & Reilly, T. (1999). The physiological load imposed on elite young professional soccer players during intense training and competitive match-play. *Journal of Sports Sciences*, *17*, 925.

Thomas, J. R., Nelson, J. K., & Silverman, S. J. (2015). *Research methods in physical activity*. Human kinetics.

Tierney, P. J., Young, A., Clarke, N. D., & Duncan, M. J. (2016). Match play demands of 11 versus 11 professional football using Global Positioning System tracking: Variations across common playing formations. *Human Movement Science*, *49*, 1–8. https://doi.org/10.1016/j.humov.2016.05.007

Tomlin, D. L., & Wenger, H. A. (2001). The relationship between aerobic fitness and recovery from high intensity intermittent exercise. *Sports Medicine*, *31*(1), 1–11. https://doi.org/10.2165/00007256-200131010-00001

Torres-Ronda, L., Gonçalves, B., Marcelino, R., Torrents, C., Vicente, E., & Sampaio, J. (2015). Heart rate, time-motion, and body impacts when changing the number of teammates and opponents in soccer small-sided games. *Journal of Strength and Conditioning Research*, *29*(10), 2723–2730. https://doi.org/10.1519/JSC.0000000000000932

Travassos, B., Gonçalves, B., Marcelino, R., Monteiro, R., & Sampaio, J. (2014). How perceiving additional targets modifies teams' tactical behavior during football small-sided games. *Human Movement Science*, *38*, 241–250. https://doi.org/10.1016/j.humov.2014.10.005

Van Cutsem, J., Marcora, S., De Pauw, K., Bailey, S., Meeusen, R., & Roelands, B. (2017). The Effects of Mental Fatigue on Physical Performance: A Systematic Review. *Sports Medicine*, *47*(8), 1569–1588. https://doi.org/10.1007/s40279-016-0672-0

Waldron, M., & Highton, J. (2014). Fatigue and pacing in high-intensity intermittent team sport: An update. *Sports Medicine*, *44*(12), 1645–1658. https://doi.org/10.1007/s40279-014-0230-6

Yücesoy, M., Erkmen, N., Aktas, S., Güven, F., & Durmaz, M. (2019). Interval Versus Continuous Small-Sided Soccer Games With Same Pitch Size and Number of Players. *Facta Universitatis, Series: Physical Education and Sport*, 631. https://doi.org/10.22190/fupes181009057y

Chapter 2 – Review Study – Study 1

Aasgaard, M., & Kilding, A. E. (2018). Does Man Marking Influence Running Outputs and Intensity During Small-Sided Soccer Games? *Journal of Strength and Conditioning Research*, 1. https://doi.org/10.1519/jsc.0000000000002668

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*(1), 103–113. https://doi.org/10.2478/v10078-012-0049-x

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. https://doi.org/10.1123/ijspp.2015-0331

Balsom, P. D., Seger, J. Y., Sjodin, B., & Ekblom, B. (1992). Maximal-intensity intermittent exercise: Effect of recovery duration. *International Journal of Sports Medicine*, *13*(7), 528–533. https://doi.org/10.1055/s-2007-1021311

Bangsbo, J. (1994). The physiology of soccer - With special reference to intense intermittent exercise. *Acta Physiologica Scandinavica, Supplement*, *151*(619), 1–155.

Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., Gabbett, T. J., Coutts, A. J., Burgess, D. J., Gregson, W., & Cable, N. T. (2017). Monitoring athlete training loads: Consensus statement. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), 161–170. https://doi.org/10.1123/IJSPP.2017-0208

Branquinho, L., Ferraz, R., Travassos, B., & Marques, M. C. (2020). Comparison between continuous and fractionated game format on internal and external load in small-sided games in soccer. *International Journal of Environmental Research and Public Health*, *17*(2). https://doi.org/10.3390/ijerph17020405

Brink, M. S., Nederhof, E., Visscher, C., Schmikli, S. L., & Lemmink, K. A. P. M. (2010). Monitoring load, recovery, and performance in young elite soccer players. *Journal of Strength and Conditioning Research*, *24*(3), 597–603. https://doi.org/10.1519/JSC.0b013e3181c4d38b

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. https://doi.org/10.1080/02640414.2018.1535821

Carling, C., Bloomfield, J., Nelsen, L., & Reilly, T. (2008). The role of motion analysis in elite soccer: Contemporary performance measurement techniques and work rate data. *Sports Medicine*, *38*(10), 839–862. https://doi.org/10.2165/00007256-200838100-00004

Casamichana, D., Castellano, J., & Dellal, A. (2013). Influence of different training regimes on physical and physiological demands during small-sided soccer games: Continuous vs. intermittent format. *Journal of Strength and Conditioning Research*, *27*(3), 690–697. https://doi.org/10.1519/JSC.0b013e31825d99dc

Castellano, J., Casamichana, D., & Lago, C. (2012). The use of match statistics that discriminate between successful and unsuccessful soccer teams. *Journal of Human Kinetics*, *31*(1), 139–147. https://doi.org/10.2478/v10078-012-0015-7

Christopher, J., Beato, M., & Hulton, A. T. (2016). Manipulation of exercise to rest ratio within set duration on physical and technical outcomes during small-sided games in elite youth soccer players. *Human Movement Science*, *48*, 1–6. https://doi.org/10.1016/j.humov.2016.03.013

Cihan, H. (2015). The effect of defensive strategies on the physiological responses and time-motion characteristics in small-sided games. *Kinesiology*, *47*(2), 179–187.

Coutts, A. J., Crowcroft, S., & Kempton, T. (2017). Developing athlete monitoring systems: Theoretical basis and practical applications1. In *Sport, Recovery, and Performance: Interdisciplinary Insights* (pp. 19–32). Routledge. https://doi.org/10.4324/9781315268149

Dellal, A., Jannault, R., Lopez-Segovia, M., & Pialoux, V. (2011). Influence of the numbers of players in the heart rate responses of youth soccer players within 2 vs. 2, 3 vs. 3 and 4 vs. 4 small-sided games. *Journal of Human Kinetics*, *28*(1), 107–114. https://doi.org/10.2478/v10078-011-0027-8

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. *Journal of Strength and Conditioning Research*, *25*(2), 453–458. https://doi.org/10.1519/JSC.0b013e3181c1f8a2

Gabbett, T. J., & Mulvey, M. J. (2008). Time-motion analysis of small-sided training games and competition in elite women soccer players. *Journal of Strength and Conditioning Research*, *22*(2), 543–552. https://doi.org/10.1519/JSC.0b013e3181635597

Haghighi, A., Moghadasi, M., Nikseresht, A., Torkfar, A., & Haghighi, M. (2012). Effects of plyometric versus resistance training on sprint and skill performance in young soccer players. *European Journal of Experimental Biology*, *2*(6), 2348–2351.

Harrison, C. B., Kilding, A. E., Gill, N. D., & Kinugasa, T. (2014). Small-sided games for young athletes: is game specificity influential? *Journal of Sports Sciences*, *32*(4), 336–344. https://doi.org/10.1080/02640414.2013.824600

Hill-Haas, Stephen, Coutts, A., Rowsell, G., & Dawson, B. (2008). Variability of acute physiological responses and performance profiles of youth soccer players in small-sided games. *Journal of Science and Medicine in Sport*, *11*(5), 487–490. https://doi.org/10.1016/j.jsams.2007.07.006

Hill-Haas, Stephen V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football: A systematic review. *Sports Medicine*, *41*(3), 199–220. https://doi.org/10.2165/11539740-000000000-00000

Hill-Haas, Stephen V., Rowsell, G. J., Dawson, B. T., & Coutts, A. J. (2009). Acute physiological responses and timemotion characteristics of two small-sided training regimes in youth soccer players. *Journal of Strength and Conditioning Research*, *23*(1), 111–115. https://doi.org/10.1519/JSC.0b013e31818efc1a

Hill-Haas, S V, Dawson, B. T., Coutts, A. J., & Rowsell, G. J. (2009). Sixth International Conference on Sport, Leisure and Ergonomics: 14–16 November 2007. *Journal of Sports Sciences*, *27*(sup1), S1–S35. https://doi.org/10.1080/02640410902761199

Ian Lambert, M., & Borresen, J. (2010). Measuring training load in sports. *International Journal of Sports Physiology and Performance*, *5*(3), 406–411. https://doi.org/10.1123/ijspp.5.3.406

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load: 15 years on. *International Journal of Sports Physiology and Performance*, *14*(2), 270–273. https://doi.org/10.1123/ijspp.2018-0935

Kellis, E., Katis, A., & Vrabas, I. S. (2006). Effects of an intermittent exercise fatigue protocol on biomechanics of soccer kick performance. *Scandinavian Journal of Medicine and Science in Sports*, *16*(5), 334–344. https://doi.org/10.1111/j.1600-0838.2005.00496.x

Kellmann, M. (2002). *Enhancing Recovery: Preventing Underperformance in Athletes*. Human Kinetics. https://books.google.com/books?id=Qp-WkTxvlvIC&pgis=1

Köklü, Y., Alemdaroılu, U., Dellal, A., & Wong, D. P. (2015). Effect of different recovery durations between bouts in 3-a-side games on youth soccer players' physiological responses and technical activities. *Journal of Sports Medicine and Physical Fitness*, *55*(5), 430–438.

Köklü, Yusuf. (2012). A comparison of physiological responses to various intermittent and continuous small-sided games in young soccer players. *Journal of Human Kinetics*, *31*(1), 89–96. https://doi.org/10.2478/v10078-012-0009-5

Köklü, Yusuf, 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. https://doi.org/10.1123/ijspp.2016-0584

Köklü, Yusuf, Alemdaroğlu, U., Cihan, H., Wong, D. P., Köklö, 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. https://doi.org/10.1123/ijspp.2016-0584

McLean, S., Kerhervé, H., Lovell, G. P., Gorman, A. D., & Solomon, C. (2016). The effect of recovery duration on vastus lateralis oxygenation, heart rate, perceived exertion and time motion descriptors during small sided football games. *PLoS ONE*, *11*(2), e0150201. https://doi.org/10.1371/journal.pone.0150201

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, *21*(7), 519–528. https://doi.org/10.1080/0264041031000071182

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.

Sampaio, J., Garcia, G., Maçãs, V., Ibáñez, S. J., Abrantes, C., & Caixinha, P. (2007). Heart rate and perceptual responses to 2x2 and 3x3 small-sided youth soccer games. *Journal of Sports Science and Medicine*, *6*(10), 121–122.

Thorpe, R. T., Atkinson, G., Drust, B., & Gregson, W. (2017). Monitoring fatigue status in elite team-sport athletes: Implications for practice. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), 27–34. https://doi.org/10.1123/ijspp.2016-0434

Yücesoy, M., Erkmen, N., Aktas, S., Güven, F., & Durmaz, M. (2019). Interval Versus Continuous Small-Sided Soccer Games With Same Pitch Size and Number of Players. *Facta Universitatis, Series: Physical Education and Sport*, 631. https://doi.org/10.22190/fupes181009057y

Chapter 3 – Experimental Studies – Study 2

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*(1), 103–113. https://doi.org/10.2478/v10078-012-0049-x

Aguiar, M., Gonçalves, B., Botelho, G., Lemmink, K., & Sampaio, J. (2015). Footballers' movement behaviour during 2-, 3-, 4- and 5-a-side small-sided games. *Journal of Sports Sciences*, *33*(12), 1259–1266. https://doi.org/10.1080/02640414.2015.1022571

Bangsbo, J. (1993). The physiology of soccer - With special reference to intense intermittent exercise. *Acta Physiologica Scandinavica, Supplement*, *151*(619), 1–155.

Bangsbo, Jens, Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Nutrition and Football: The FIFA/FMARC Consensus on Sports Nutrition*, *24*(07), 1–18. https://doi.org/10.4324/9780203967430

Bastida Castillo, A., Gómez Carmona, C. D., De la cruz sánchez, E., & Pino Ortega, J. (2018). Accuracy, intra- and inter-unit reliability, and comparison between GPS and UWB-based position-tracking systems used for time–motion analyses in soccer. *European Journal of Sport Science*, *18*(4), 450–457. https://doi.org/10.1080/17461391.2018.1427796

Billaut, F., Bishop, D. J., Schaerz, S., & Noakes, T. D. (2011). Influence of knowledge of sprint number on pacing during repeated-sprint exercise. *Medicine and Science in Sports and Exercise*, *43*(4), 665–672. https://doi.org/10.1249/MSS.0b013e3181f6ee3b

Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part II: Anaerobic energy, neuromuscular load and practical applications. *Sports Medicine*, *43*(10), 927–954. https://doi.org/10.1007/s40279-013-0066-5

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. https://doi.org/10.1080/02640414.2010.521168

Christopher, J., Beato, M., & Hulton, A. T. (2016). Manipulation of exercise to rest ratio within set duration on physical and technical outcomes during small-sided games in elite youth soccer players. *Human Movement Science*, *48*, 1–6. https://doi.org/10.1016/j.humov.2016.03.013

Clemente, Filipe M., Martins, F. M. L., & Mendes, R. S. (2014). Periodization based on small-sided soccer games: Theoretical considerations. *Strength and Conditioning Journal*, *36*(5), 34–43. https://doi.org/10.1519/SSC.0000000000000067

Clemente, Filipe Manuel, Mendes, B., Nikolaidis, P. T., Calvete, F., Carriço, S., & Owen, A. L. (2017). Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. *Physiology and Behavior*, *179*, 262–267. https://doi.org/10.1016/j.physbeh.2017.06.021

Cumming, G. (2012). *Understanding the new statistics: Effect sizes, confidence intervals, and meta-analysis*. Routledge.

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. *Journal of Strength and Conditioning Research*, *25*(2), 453–458. https://doi.org/10.1519/JSC.0b013e3181c1f8a2

Hammami, A., Gabbett, T. J., Slimani, M., & Bouhlel, E. (2018). Does small-sided games training improve physical ftness and team-sport-specifc skills? a systematic review and meta-analysis. *Journal of Sports Medicine and Physical Fitness*, *58*(10), 1446–1455. https://doi.org/10.23736/S0022-4707.17.07420-5

Hill-Haas, S. V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football: A systematic review. *Sports Medicine*, *41*(3), 199–220. https://doi.org/10.2165/11539740-000000000-00000

Hill-Haas, S. V., Rowsell, G. J., Dawson, B. T., & Coutts, A. J. (2009). Acute physiological responses and timemotion characteristics of two small-sided training regimes in youth soccer players. *Journal of Strength and Conditioning Research*, *23*(1), 111–115. https://doi.org/10.1519/JSC.0b013e31818efc1a

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load: 15 years on. *International Journal of Sports Physiology and Performance*, *14*(2), 270–273. https://doi.org/10.1123/ijspp.2018-0935

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use of RPE-based training load in soccer. *Medicine and Science in Sports and Exercise*, *36*(6), 1042–1047. https://doi.org/10.1249/01.MSS.0000128199.23901.2F

Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005). Physiological assessment of aerobic training in soccer. *Journal of Sports Sciences*, *23*(6), 583–592. https://doi.org/10.1080/02640410400021278

Köklü, Y. (2012). A comparison of physiological responses to various intermittent and continuous small-sided games in young soccer players. *Journal of Human Kinetics*, *31*(1), 89–96. https://doi.org/10.2478/v10078-012-0009-5

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. https://doi.org/10.1123/ijspp.2016-0584

Manuel Clemente, F., Theodoros Nikolaidis, P., Rosemann, T., & Knechtle, B. (2019). Variations of internal and external load variables between intermittent small-sided soccer game training regimens. *International Journal of Environmental Research and Public Health*, *16*(16), 2923. https://doi.org/10.3390/ijerph16162923

Mohr, M., Krustrup, P., & Bangsbo, J. (2005). Fatigue in soccer: A brief review. *Journal of Sports Sciences*, *23*(6), 593–599. https://doi.org/10.1080/02640410400021286

Molina-Carmona, I., Gómez-Carmona, C., Bastida-Castillo, A., & Pino-Ortega, J. (2018). Validez del dispositivo inercial WIMU PRO para el registro de la frecuencia cardiaca en un test de campo. *SPORT TK-Revista EuroAmericana de Ciencias Del Deporte*, *7*(1), 81. https://doi.org/10.6018/321921

Montgomery, P. G., Pyne, D. B., & Minahan, C. L. (2010). The physical and physiological demands of basketball training and competition. *International Journal of Sports Physiology and Performance*, *5*(1), 75–86. https://doi.org/10.1123/ijspp.5.1.75

Moran, J., Blagrove, R. C., Drury, B., Fernandes, J. F. T., Paxton, K., Chaabene, H., & Ramirez-Campillo, R. (2019). Effects of Small-Sided Games vs. Conventional Endurance Training on Endurance Performance in Male Youth Soccer Players: A Meta-Analytical Comparison. *Sports Medicine*, *49*(5), 731–742. https://doi.org/10.1007/s40279-019-01086-w

Muñoz-Lopez, A., Granero-Gil, P., Pino-Ortega, J., & De Hoyo, M. (2017). The validity and reliability of a 5-hz GPS device for quantifying athletes' sprints and movement demands specific to team sports. *Journal of Human Sport and Exercise*, *12*(1), 156–166. https://doi.org/10.14198/jhse.2017.121.13

Owen, A. L., Dunlop, G., Rouissi, M., Haddad, M., Mendes, B., & Chamari, K. (2016). Analysis of positional training loads (ratings of perceived exertion) during various-sided games in European professional soccer players. *International Journal of Sports Science and Coaching*, *11*(3), 374–381. https://doi.org/10.1177/1747954116644064

Sampaio, J. E., Lago, C., Gonçalves, B., Maçãs, V. M., & Leite, N. (2014). Effects of pacing, status and unbalance in time motion variables, heart rate and tactical behaviour when playing 5-a-side football small-sided games. *Journal of Science and Medicine in Sport*, *17*(2), 229–233. https://doi.org/10.1016/j.jsams.2013.04.005

Sampson, J. A., Fullagar, H. H. K., & Gabbett, T. (2015). Knowledge of bout duration influences pacing strategies during small-sided games. *Journal of Sports Sciences*, *33*(1), 85–98. https://doi.org/10.1080/02640414.2014.925571

Selmi, O., Gonçalves, B., Ouergui, I., Sampaio, J., & Bouassida, A. (2018). Influence of well-being variables and recovery state in physical enjoyment of professional soccer players during small-sided games. *Research in Sports Medicine*, *26*(2), 199–210. https://doi.org/10.1080/15438627.2018.1431540

Silva, J. R., Magalhaes, J., AscensaO, A., Seabra, A. F., & Rebelo, A. N. N. (2013). Training status and match activity of professional soccer players throughout a season. *Journal of Strength and Conditioning Research*, *27*(1), 20–30. https://doi.org/10.1519/JSC.0b013e31824e1946

Silva, L. M., Neiva, H. P., Marques, M. C., Izquierdo, M., & Marinho, D. A. (2018). Effects of Warm-Up, Post-Warm-Up, and Re-Warm-Up Strategies on Explosive Efforts in Team Sports: A Systematic Review. *Sports Medicine*, *48*(10), 2285–2299. https://doi.org/10.1007/s40279-018-0958-5

Thorpe, R., & Sunderland, C. (2012). Muscle damage, endocrine, and immune marker response to a soccer match. *Journal of Strength and Conditioning Research*, *26*(10), 2783–2790. https://doi.org/10.1519/JSC.0b013e318241e174

Walker, S., Ahtiainen, J., & Häkkinen, K. (2010). Acute neuromuscular and hormonal responses during contrast loading: Effect of 11 weeks of contrast training. *Scandinavian Journal of Medicine and Science in Sports*, *20*(2), 226–234. https://doi.org/10.1111/j.1600-0838.2009.00914.x

Yücesoy, M., Erkmen, N., Aktas, S., Güven, F., & Durmaz, M. (2019). Interval Versus Continuous Small-Sided Soccer Games With Same Pitch Size and Number of Players. *Facta Universitatis, Series: Physical Education and Sport*, 631. https://doi.org/10.22190/fupes181009057y

Chapter 3 – Experimental Studies – Study 3

Aguiar, M., Abrantes, C., Macas, V., Leite, N., Sampaio, J., & Ibanez, S. (2008). Effects of Intermittent or Continuous Training on Speed, Jump and Repeated-Sprint Ability in Semi-Professional Soccer Players~!2008-03-27~!2008-05-19~!2008-06-12~! *The Open Sports Sciences Journal*, *1*(1), 15–19. https://doi.org/10.2174/1875399x00801010015

Alghannam, A. F. (2012). Metabolic limitations of performance and fatigue in football. *Asian Journal of Sports Medicine*, *3*(2), 65–73. https://doi.org/10.5812/asjsm.34699

Baker, J. S., McCormick, M. C., & Robergs, R. A. (2010). Interaction among Skeletal Muscle Metabolic Energy Systems during Intense Exercise. *Journal of Nutrition and Metabolism*, *2010*, 905612. https://doi.org/10.1155/2010/905612

Balsom, P. D., Seger, J. Y., Sjodin, B., & Ekblom, B. (1992). Maximal-intensity intermittent exercise: Effect of recovery duration. *International Journal of Sports Medicine*, *13*(7), 528–533. https://doi.org/10.1055/s-2007-1021311

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Nutrition and Football: The FIFA/FMARC Consensus on Sports Nutrition*, *24*(07), 1–18. https://doi.org/10.4324/9780203967430

Bastida Castillo, A., Gómez Carmona, C. D., De la cruz sánchez, E., & Pino Ortega, J.

(2018). Accuracy, intra- and inter-unit reliability, and comparison between GPS and UWB-based position-tracking systems used for time–motion analyses in soccer. *European Journal of Sport Science*, *18*(4), 450–457. https://doi.org/10.1080/17461391.2018.1427796

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2006). Mental fatigue, motivation and action monitoring. *Biological Psychology*, *72*(2), 123–132. https://doi.org/10.1016/j.biopsycho.2005.08.007

Branquinho, L., Ferraz, R., Travassos, B., & Marques, M. C. (2020). Comparison between continuous and fractionated game format on internal and external load in small-sided games in soccer. *International Journal of Environmental Research and Public Health*, *17*(2). https://doi.org/10.3390/ijerph17020405

Brehm, J. W., & Self, E. A. (1989). The Intensity of Motivation. *Annual Review of Psychology*, *40*(1), 109–131. https://doi.org/10.1146/annurev.ps.40.020189.000545

Calderón Pellegrino, G., Paredes-Hernández, V., Sánchez-Sánchez, J., García-Unanue, J., & Gallardo, L. (2018). Effect of the Fatigue on the Physical Performance in Different Small-Sided Games in Elite Football Players. *Journal of Strength and Conditioning Research*, 1. https://doi.org/10.1519/jsc.0000000000002858

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. https://doi.org/10.1080/02640414.2010.521168

Casamichana, D., Castellano, J., & Dellal, A. (2013). Influence of different training regimes on physical and physiological demands during small-sided soccer games: Continuous vs. intermittent format. *Journal of Strength and Conditioning Research*, *27*(3), 690–697. https://doi.org/10.1519/JSC.0b013e31825d99dc

Clemente, F. M., Martins, F. M. L., & Mendes, R. S. (2014). Periodization based on small-sided soccer games: Theoretical considerations. *Strength and Conditioning Journal*, *36*(5), 34–43. https://doi.org/10.1519/SSC.0000000000000067

Cumming, G. (2012). *Understanding the new statistics: Effect sizes, confidence intervals, and meta-analysis*. Routledge.

Dellal, A., Jannault, R., Lopez-Segovia, M., & Pialoux, V. (2011). Influence of the numbers of players in the heart rate responses of youth soccer players within 2 vs. 2, 3 vs. 3 and 4 vs. 4 small-sided games. *Journal of Human Kinetics*, *28*(1), 107–114. https://doi.org/10.2478/v10078-011-0027-8

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. *Journal of Strength and Conditioning Research*, *25*(2), 453–458. https://doi.org/10.1519/JSC.0b013e3181c1f8a2

Ferraz, R., Gonçalves, B., Coutinho, D., Marinho, D. A., Sampaio, J., & Marques, M. C. (2018). Pacing behaviour of players in team sports: Influence of match status manipulation and task duration knowledge. *PLoS ONE*, *13*(2), e0192399. https://doi.org/10.1371/journal.pone.0192399

Ferraz, R., Gonçalves, B., Van Den Tillaar, R., Jiménez Sáiz, S., Sampaio, J., & Marques, M. C. (2017). Effects of knowing the task duration on players' pacing patterns during soccer small-sided games. *Journal of Sports Sciences*, *36*(1), 116–122. https://doi.org/10.1080/24733938.2017.1283433

Harris, G. R., Stone, M. H., O'Bryant, H. S., Proulx, C. M., & Johnson, R. L. (2000). Short-Term Performance Effects of High Power, High Force, or Combined Weight-Training Methods. *Journal of Strength and Conditioning Research*, *14*(1), 14–20. https://doi.org/10.1519/00124278-200002000-00003

Hill-Haas, Stephen V., Rowsell, G. J., Dawson, B. T., & Coutts, A. J. (2009). Acute physiological responses and timemotion characteristics of two small-sided training regimes in youth soccer players. *Journal of Strength and Conditioning Research*, *23*(1), 111–115. https://doi.org/10.1519/JSC.0b013e31818efc1a

Hill-Haas, S V, Dawson, B. T., Coutts, A. J., & Rowsell, G. J. (2009). Sixth International Conference on Sport, Leisure and Ergonomics: 14–16 November 2007. *Journal of Sports Sciences*, *27*(sup1), S1–S35. https://doi.org/10.1080/02640410902761199

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Katis, A., & Kellis, E. (2009). Effects of small-sided games on physical conditioning and performance in young soccer players. *Journal of Sports Science and Medicine*, *8*(3), 374–380.

Köklü, Y., Alemdaroılu, U., Dellal, A., & Wong, D. P. (2015). Effect of different recovery durations between bouts in 3-a-side games on youth soccer players' physiological responses and technical activities. *Journal of Sports Medicine and Physical Fitness*, *55*(5), 430–438.

Köklü, Yusuf, 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. https://doi.org/10.1123/ijspp.2016-0584

Köklü, Yusuf, Sert, Ö., Alemdaroılu, 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. *Journal of Strength and Conditioning Research*, *29*(4), 964–971. https://doi.org/10.1519/JSC.0b013e3182a744a1

Los Arcos, A., Vázquez, J. S., Martín, J., Lerga, J., Sánchez, F., Villagra, F., & Zulueta, J. J. (2015). Effects of Small-Sided Games vs. Interval Training in Aerobic Fitness and Physical Enjoyment in Young Elite Soccer Players. *PloS One*, *10*(9), e0137224–e0137224. https://doi.org/10.1371/journal.pone.0137224

McLean, S., Kerhervé, H., Lovell, G. P., Gorman, A. D., & Solomon, C. (2016). The effect of recovery duration on vastus lateralis oxygenation, heart rate, perceived exertion and time motion descriptors during small sided football games. *PLoS ONE*, *11*(2), e0150201. https://doi.org/10.1371/journal.pone.0150201

Molina-Carmona, I., Gómez-Carmona, C., Bastida-Castillo, A., & Pino-Ortega, J. (2018). Validez del dispositivo inercial WIMU PRO para el registro de la frecuencia cardiaca en un test de campo. *SPORT TK-Revista EuroAmericana de Ciencias Del Deporte*, *7*(1), 81. https://doi.org/10.6018/321921

Muñoz-Lopez, A., Granero-Gil, P., Pino-Ortega, J., & De Hoyo, M. (2017). The validity and reliability of a 5-hz GPS device for quantifying athletes' sprints and movement demands specific to team sports. *Journal of Human Sport and Exercise*, *12*(1), 156–166. https://doi.org/10.14198/jhse.2017.121.13

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. *Medicine and Science in Sports and Exercise*, *42*(1), 170–178. https://doi.org/10.1249/MSS.0b013e3181ae5cfd

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.

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. https://doi.org/10.1080/02640410600811858

Sampaio, J. E., Lago, C., Gonçalves, B., Maçãs, V. M., & Leite, N. (2014). Effects of pacing, status and unbalance in time motion variables, heart rate and tactical behaviour when playing 5-a-side football small-sided games. *Journal of Science and Medicine in Sport*, *17*(2), 229–233. https://doi.org/10.1016/j.jsams.2013.04.005

Spencer, M., Bishop, D., Dawson, B., & Goodman, C. (2005). Physiological and metabolic responses of repeated-sprint activities: Specific to field-based team sports. *Sports Medicine*, *35*(12), 1025–1044. https://doi.org/10.2165/00007256-200535120-00003

Chapter 4 – Practical Recommendations Considering a Specific Game Format – Study 4

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*(1), 103–113. https://doi.org/10.2478/v10078-012-0049-x

Aguiar, M. V.D., Botelho, G. M. A., Gonçalves, B. S. V., & Sampaio, J. E. (2013). Physiological responses and activity profiles of football small-sided games. *Journal of Strength and Conditioning Research*, *27*(5), 1287–1294. https://doi.org/10.1519/JSC.0b013e318267a35c

Alghannam, A. F. (2012). Metabolic limitations of performance and fatigue in football. *Asian Journal of Sports Medicine*, *3*(2), 65–73. https://doi.org/10.5812/asjsm.34699

Allen, J. D., Butterly, R., Welsch, M. A., & Wood, R. (1998). The physical and physiological value of 5-a-side soccer training to 11-a-side match play. *Journal of Human Movement Studies*, *34*(1), 1–11.

Alves, R. N., Costa, L. O. P., & Samulski, D. M. (2006). Monitoramento e prevenção do supertreinamento em atletas. *Revista Brasileira de Medicina Do Esporte*, *12*(5), 291–

296. https://doi.org/10.1590/s1517-86922006000500013

Amatria, M., Lapresa, D., Arana, J., Anguera, M. T., & Garzón, B. (2016). Optimization of game formats in U-10 soccer using logistic regression analysis. *Journal of Human Kinetics*, *54*(1), 163–171. https://doi.org/10.1515/hukin-2016-0047

Aroso, J., Rebelo, A. N., & Gomes-Pereira, J. (2004). Physiological impact of selected game-related exercises. *Journal of Sports Sciences*, *22*(6), 522.

Aslan, A. (2013). Cardiovascular responses, perceived exertion and technical actions during small-sided recreational soccer: Effects of pitch size and number of players. *Journal of Human Kinetics*, *38*(1), 95–105. https://doi.org/10.2478/hukin-2013-0049

Ball, K., Aughey, R. J., Science, E., Living, A., Players, F., Pyne, D., Santisteban, J., Bilbao, A. C., & Country, B. (2011). Note . This article will be published in a forthcoming issue of the International Journal of Sports Physiology and Performance . The article appears here in its peer-reviewed and accepted form ; it has not been copyedited , proofread , or formatted by the. *International Journal*, 1–16.

Bangsbo, J. (1994). Energy demands in competitive soccer. *Journal of Sports Sciences*, *12*(SPEC. ISSUE), S5-12. https://doi.org/10.1080/02640414.1994.12059272

Billat, L. V. (2001). Interval training for performance: A scientific and empirical practice. Special recommendations for middle- and long-distance running. Part I: Aerobic interval training. *Sports Medicine*, *31*(1), 13–31. https://doi.org/10.2165/00007256-200131010-00002

Bompa, T. O. (2009). *Entrenamiento de equipos deportivos*. Paidotribo.

Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., Gabbett, T. J., Coutts, A. J., Burgess, D. J., Gregson, W., & Cable, N. T. (2017). Monitoring athlete training loads: Consensus statement. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), 161–170. https://doi.org/10.1123/IJSPP.2017-0208

Branquinho, L., Ferraz, R., Travassos, B., & Marques, M. C. (2020). Comparison between continuous and fractionated game format on internal and external load in small-sided games in soccer. *International Journal of Environmental Research and Public Health*, *17*(2). https://doi.org/10.3390/ijerph17020405

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. https://doi.org/10.1080/02640414.2018.1535821

Burgess, D. J. (2017). The research doesn't always apply: Practical solutions to evidence-based training-load monitoring in elite team sports. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), 136–141. https://doi.org/10.1123/ijspp.2016-0608

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. https://doi.org/10.1080/02640414.2010.521168

Casamichana, D., Castellano, J., & Dellal, A. (2013). Influence of different training regimes on physical and physiological demands during small-sided soccer games: Continuous vs. intermittent format. *Journal of Strength and Conditioning Research*, *27*(3), 690–697. https://doi.org/10.1519/JSC.0b013e31825d99dc

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. *Journal of Strength and Conditioning Research*, *27*(5), 1295–1303. https://doi.org/10.1519/JSC.0b013e318267a5d1

Castillo, D., Rodríguez-Fernández, A., Nakamura, F. Y., Sanchez-Sanchez, J., Ramirez-Campillo, R., Yanci, J., Zubillaga, A., & Raya-González, J. (2019). Influence of Different Small-Sided Game Formats on Physical and Physiological Demands and Physical Performance in Young Soccer Players. *Journal of Strength and Conditioning Research*, 1. https://doi.org/10.1519/jsc.0000000000003114

Christopher, J., Beato, M., & Hulton, A. T. (2016). Manipulation of exercise to rest ratio within set duration on physical and technical outcomes during small-sided games in elite youth soccer players. *Human Movement Science*, *48*, 1–6. https://doi.org/10.1016/j.humov.2016.03.013

Clemente, F., Couceiro, M. S., Martins, F. M. L., & Mendes, R. (2012). The usefulness of small-sided games on soccer training. *Journal of Physical Education and Sport*, *12*(1), 93–102.

Clemente, Filipe M., Martins, F. M. L., & Mendes, R. S. (2014). Periodization based on small-sided soccer games: Theoretical considerations. *Strength and Conditioning*

Journal, *36*(5), 34–43. https://doi.org/10.1519/SSC.0000000000000067

Clemente, Filipe Manuel, Mendes, B., Nikolaidis, P. T., Calvete, F., Carriço, S., & Owen, A. L. (2017). Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. *Physiology and Behavior*, *179*, 262–267. https://doi.org/10.1016/j.physbeh.2017.06.021

Clemente, Filipe Manuel, Pracą, G. M., Bredt, S. D. G. T., Linden, C. M. I. V. Der, & Serra-Olivares, J. (2019). External Load Variations between Medium- A nd Large-Sided Soccer Games: Ball Possession Games vs Regular Games with Small Goals. *Journal of Human Kinetics*, *70*(1), 191–198. https://doi.org/10.2478/hukin-2019-0031

Coutts, A. J., Crowcroft, S., & Kempton, T. (2017). Developing athlete monitoring systems: Theoretical basis and practical applications1. In *Sport, Recovery, and Performance: Interdisciplinary Insights* (pp. 19–32). Routledge. https://doi.org/10.4324/9781315268149

Da Silva, C. D., Impellizzeri, F. M., Natali, A. J., De Lima, J. R. P., Bara-Filho, M. G., Silami-Garcxia, E., & Marins, J. C. B. (2011). Exercise intensity and technical demands of small-sided games in young Brazilian soccer players: Effect of number of players, maturation, and reliability. *Journal of Strength and Conditioning Research*, *25*(10), 2746–2751. https://doi.org/10.1519/JSC.0b013e31820da061

Dellal, A., Varliette, C., Owen, A., Chirico, E. N., & Pialoux, V. (2012). Small-sided games versus interval training in amateur soccer players: Effects on the aerobic capacity and the ability to perform intermittent exercises with changes of direction. *Journal of Strength and Conditioning Research*, *26*(10), 2712–2720. https://doi.org/10.1519/JSC.0b013e31824294c4

Edge, J., Bishop, D., & Goodman, C. (2006). The effects of training intensity on muscle buffer capacity in females. *European Journal of Applied Physiology*, *96*(1), 97–105. https://doi.org/10.1007/s00421-005-0068-6

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. *Journal of Strength and Conditioning Research*, *25*(2), 453–458. https://doi.org/10.1519/JSC.0b013e3181c1f8a2

Faude, O., Schnittker, R., Schulte-Zurhausen, R., Müller, F., & Meyer, T. (2013). High intensity interval training vs. high-volume running training during pre-season conditioning in high-level youth football: A cross-over trial. *Journal of Sports Sciences*, *31*(13), 1441–1450. https://doi.org/10.1080/02640414.2013.792953

Ferraz, R., Gonçalves, B., Coutinho, D., Marinho, D. A., Sampaio, J., & Marques, M. C. (2018). Pacing behaviour of players in team sports: Influence of match status manipulation and task duration knowledge. *PLoS ONE*, *13*(2), e0192399. https://doi.org/10.1371/journal.pone.0192399

Ferraz, R., Gonçalves, B., Van Den Tillaar, R., Jiménez Sáiz, S., Sampaio, J., & Marques, M. C. (2018). Effects of knowing the task duration on players' pacing patterns during soccer small-sided games. *Journal of Sports Sciences*, *36*(1), 116–122. https://doi.org/10.1080/24733938.2017.1283433

Goncalves, B., Esteves, P., Folgado, H., Ric, A., Torrents, C., & Sampaio, J. (2017). Effects of Pitch Area-Restrictions on Tactical Behavior, Physical, and Physiological Performances in Soccer Large-Sided Games. *Journal of Strength and Conditioning Research*, *31*(9), 2398–2408. https://doi.org/10.1519/JSC.0000000000001700

Gonçalves, B., Marcelino, R., Torres-Ronda, L., Torrents, C., & Sampaio, J. (2016). Effects of emphasising opposition and cooperation on collective movement behaviour during football small-sided games. *Journal of Sports Sciences*, *34*(14), 1346–1354. https://doi.org/10.1080/02640414.2016.1143111

Halouani, J., Chtourou, H., Gabbett, T., Chaouachi, A., & Chamari, K. (2014). Small-sided games in team sports training: A brief review. *Journal of Strength and Conditioning Research*, *28*(12), 3594–3618. https://doi.org/10.1519/JSC.0000000000000564

Halson, S. L. (2014). Monitoring Training Load to Understand Fatigue in Athletes. *Sports Medicine*, *44*, 139–147. https://doi.org/10.1007/s40279-014-0253-z

Hammami, A., Gabbett, T. J., Slimani, M., & Bouhlel, E. (2018). Does small-sided games training improve physical ftness and team-sport-specifc skills? a systematic review and meta-analysis. *Journal of Sports Medicine and Physical Fitness*, *58*(10), 1446–1455. https://doi.org/10.23736/S0022-4707.17.07420-5

Helgerud, J., Høydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., Simonsen, T., Helgesen, C., Hjorth, N., Bach, R., & Hoff, J. (2007). Aerobic high-intensity intervals improve VO2max more than moderate training. *Medicine and Science in Sports and Exercise*, *39*(4), 665–671. https://doi.org/10.1249/mss.0b013e3180304570

Hill-Haas, Stephen, Coutts, A., Rowsell, G., & Dawson, B. (2008). Variability of acute physiological responses and performance profiles of youth soccer players in small-sided games. *Journal of Science and Medicine in Sport*, *11*(5), 487–490. https://doi.org/10.1016/j.jsams.2007.07.006

Hill-Haas, S. V., Coutts, A. J., Rowsell, G. J., & Dawson, B. T. (2009). Generic versus small-sided game training in soccer. *International Journal of Sports Medicine*, *30*(9), 636–642. https://doi.org/10.1055/s-0029-1220730

Hill-Haas, Stephen 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. *Journal of Strength and Conditioning Research*, *24*(8), 2149–2156. https://doi.org/10.1519/JSC.0b013e3181af5265

Hill-Haas, Stephen V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football: A systematic review. *Sports Medicine*, *41*(3), 199–220. https://doi.org/10.2165/11539740-000000000-00000

Hill-Haas, Stephen 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. https://doi.org/10.1080/02640410802206857

Hill-Haas, Stephen V., Rowsell, G. J., Dawson, B. T., & Coutts, A. J. (2009). Acute physiological responses and timemotion characteristics of two small-sided training regimes in youth soccer players. *Journal of Strength and Conditioning Research*, *23*(1), 111–115. https://doi.org/10.1519/JSC.0b013e31818efc1a

Ian Lambert, M., & Borresen, J. (2010). Measuring training load in sports. *International Journal of Sports Physiology and Performance*, *5*(3), 406–411. https://doi.org/10.1123/ijspp.5.3.406

Impellizzeri, F. M., Marcora, S. M., Castagna, C., Reilly, T., Sassi, A., Iaia, F. M., & Rampinini, E. (2006). Physiological and performance effects of generic versus specific aerobic training in soccer players. *International Journal of Sports Medicine*, *27*(6), 483–492. https://doi.org/10.1055/s-2005-865839

Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005). Physiological assessment of aerobic training in soccer. *Journal of Sports Sciences*, *23*(6), 583–592.

https://doi.org/10.1080/02640410400021278

Italo, S. (2017). Small-Sided Games in Young Soccer Players: Physical and Technical Variables. *MOJ Sports Medicine*, *1*(1). https://doi.org/10.15406/mojsm.2017.01.00001

Jastrzębski, Z., & Radzimiński, Ł. (2015). Individual vs general time-motion analysis and physiological response in 4 vs 4 and 5 vs 5 small-sided soccer games. *International Journal of Performance Analysis in Sport*, *15*(1), 397–410. https://doi.org/10.1080/24748668.2015.11868801

Jones, S., & Drust, B. (2007). Physiological and technical demands of 4 v 4 and 8 v 8 games in elite youth soccer players. *Kinesiology*, *39*(2), 150–156.

Katis, A., & Kellis, E. (2009). Effects of small-sided games on physical conditioning and performance in young soccer players. *Journal of Sports Science and Medicine*, *8*(3), 374–380.

Kellmann, M., & Kallus, K. W. (2007). Mood, Recovery-Stress State, and Regeneration. In M. Lehmann, C. Foster, U. Gastmann, H. Keizer, & J. M. Steinacker (Eds.), *Overload, Performance Incompetence, and Regeneration in Sport* (pp. 101–117). Springer US. https://doi.org/10.1007/978-0-585-34048-7_8

Kelly, D. M., & Drust, B. (2009). The effect of pitch dimensions on heart rate responses and technical demands of small-sided soccer games in elite players. *Journal of Science and Medicine in Sport*, *12*(4), 475–479. https://doi.org/10.1016/j.jsams.2008.01.010

Kelly, D. M., Strudwick, A. J., Atkinson, G., Drust, B., & Gregson, W. (2020). Quantification of training and match-load distribution across a season in elite English Premier League soccer players. *Science and Medicine in Football*, *4*(1), 59–67. https://doi.org/10.1080/24733938.2019.1651934

Köklü, Y., Alemdaroılu, U., Dellal, A., & Wong, D. P. (2015). Effect of different recovery durations between bouts in 3-a-side games on youth soccer players' physiological responses and technical activities. *Journal of Sports Medicine and Physical Fitness*, *55*(5), 430–438.

Köklü, Yusuf. (2012). A comparison of physiological responses to various intermittent and continuous small-sided games in young soccer players. *Journal of Human Kinetics*, *31*(1), 89–96. https://doi.org/10.2478/v10078-012-0009-5

Köklü, Yusuf, 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. https://doi.org/10.1123/ijspp.2016-0584

Köklü, Yusuf, Sert, Ö., Alemdaroılu, 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. *Journal of Strength and Conditioning Research*, *29*(4), 964–971. https://doi.org/10.1519/JSC.0b013e3182a744a1

Laursen, P. B. (2010). Training for intense exercise performance: High-intensity or high-volume training? *Scandinavian Journal of Medicine and Science in Sports*, *20*(SUPPL. 2), 1–10. https://doi.org/10.1111/j.1600-0838.2010.01184.x

Laursen, Paul B., & Jenkins, D. G. (2002). The scientific basis for high-intensity interval training: Optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Medicine*, *32*(1), 53–73. https://doi.org/10.2165/00007256-200232010-00003

Little, T. (2009). Optimizing the use of soccer drills for physiological development. *Strength and Conditioning Journal*, *31*(3), 67–74. https://doi.org/10.1519/SSC.0b013e3181a5910d

Little, T., & Williams, A. G. (2006). Suitability of soccer training drills for endurance training. *Journal of Strength and Conditioning Research*, *20*(2), 316–319. https://doi.org/10.1519/R-17094.1

Los Arcos, A., Vázquez, J. S., Martín, J., Lerga, J., Sánchez, F., Villagra, F., & Zulueta, J. J. (2015). Effects of Small-Sided Games vs. Interval Training in Aerobic Fitness and Physical Enjoyment in Young Elite Soccer Players. *PloS One*, *10*(9), e0137224–e0137224. https://doi.org/10.1371/journal.pone.0137224

Manuel Clemente, F., Theodoros Nikolaidis, P., Rosemann, T., & Knechtle, B. (2019). Variations of internal and external load variables between intermittent small-sided soccer game training regimens. *International Journal of Environmental Research and Public Health*, *16*(16), 2923. https://doi.org/10.3390/ijerph16162923

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.

Platt, D., Maxwell, A., Horn, R., Williams, M., & Reilly, T. (2001). Physiological and technical analysis of 3 v 3 and 5 v 5 youth football matches. *Insight*, *4*(4), 23–24.

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. https://doi.org/10.1080/02640410600811858

Reilly, T. (2005). Training Specificity for Soccer. *International Journal of Applied Sports Sciences*, *17*(2), 17–25. http://ezproxy.lib.utexas.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=19653609&site=ehost-live

Sampaio, J., Garcia, G., Maçãs, V., Ibáñez, S. J., Abrantes, C., & Caixinha, P. (2007). Heart rate and perceptual responses to 2x2 and 3x3 small-sided youth soccer games. *Journal of Sports Science and Medicine*, *6*(10), 121–122.

Seiler, S., & Tønnessen, E. (2009). Intervals , Thresholds , and Long Slow Distance : the Role of Intensity and Duration in Endurance Training. *Training*, *13*(13), 32–53. http://sportsci.org/2009/ss.htm

Silva, P., Duarte, R., Sampaio, J., Aguiar, P., Davids, K., Araújo, D., & Garganta, J. (2014). Field dimension and skill level constrain team tactical behaviours in small-sided and conditioned games in football. *Journal of Sports Sciences*, *32*(20), 1888–1896. https://doi.org/10.1080/02640414.2014.961950

Spencer, M., Bishop, D., Dawson, B., & Goodman, C. (2005). Physiological and metabolic responses of repeated-sprint activities: Specific to field-based team sports. *Sports Medicine*, *35*(12), 1025–1044. https://doi.org/10.2165/00007256-200535120-00003

Strudwick, A., & Reilly, T. (1999). The physiological load imposed on elite young professional soccer players during intense training and competitive match-play. *Journal of Sports Sciences*, *17*, 925.

Yücesoy, M., Erkmen, N., Aktas, S., Güven, F., & Durmaz, M. (2019). Interval Versus Continuous Small-Sided Soccer Games With Same Pitch Size and Number of Players. *Facta Universitatis, Series: Physical Education and Sport*, 631. https://doi.org/10.22190/fupes181009057y

Chapter 5 – General Discussion

Alghannam, A. F. (2012). Metabolic limitations of performance and fatigue in football. *Asian Journal of Sports Medicine*, *3*(2), 65–73. https://doi.org/10.5812/asjsm.34699

Aziz, A. R., Mukherjee, S., Chia, M. Y. H., & Teh, K. C. (2007). Relationship between measured maximal oxygen uptake and aerobic endurance performance with running repeated sprint ability in young elite soccer players. *Journal of Sports Medicine and Physical Fitness*, *47*(4), 401–407.

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Nutrition and Football: The FIFA/FMARC Consensus on Sports Nutrition*, *24*(07), 1–18. https://doi.org/10.4324/9780203967430

Billat, L. V. (2001). Interval training for performance: A scientific and empirical practice. Special recommendations for middle- and long-distance running. Part I: Aerobic interval training. *Sports Medicine*, *31*(1), 13–31. https://doi.org/10.2165/00007256-200131010-00002

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. *Cognitive Brain Research*, *25*(1), 107–116. https://doi.org/10.1016/j.cogbrainres.2005.04.011

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2006). Mental fatigue, motivation and action monitoring. *Biological Psychology*, *72*(2), 123–132. https://doi.org/10.1016/j.biopsycho.2005.08.007

Brehm, B. A., & Gutin, B. (1986). Recovery energy expenditure for steady state exercise in runners and nonexercisers. *Medicine and Science in Sports and Exercise*, *18*(2), 205–210. https://doi.org/10.1249/00005768-198604000-00010

Brehm, J. W., & Self, E. A. (1989). The Intensity of Motivation. *Annual Review of Psychology*, *40*(1), 109–131. https://doi.org/10.1146/annurev.ps.40.020189.000545

Christopher, J., Beato, M., & Hulton, A. T. (2016). Manipulation of exercise to rest ratio within set duration on physical and technical outcomes during small-sided games in elite youth soccer players. *Human Movement Science*, *48*, 1–6. https://doi.org/10.1016/j.humov.2016.03.013

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. *Journal of Strength and Conditioning Research*, *25*(2), 453–458. https://doi.org/10.1519/JSC.0b013e3181c1f8a2

Ferrari Bravo, D., Impellizzeri, F. M., Rampinini, E., Castagna, C., Bishop, D., & Wisloff, U. (2008). Sprint vs. interval training in football. *International Journal of Sports Medicine*, *29*(8), 668–674. https://doi.org/10.1055/s-2007-989371

Gaitanos, G. C., Williams, C., Boobis, L. H., & Brooks, S. (1993). Human muscle metabolism during intermittent maximal exercise. *Journal of Applied Physiology*, *75*(2), 712–719. https://doi.org/10.1152/jappl.1993.75.2.712

Glaister, M., Howatson, G., Jpattison, O. R., & Mcinnes, G. (2008). The Reliability and validity of fatigue measures during multiple-sprint work: Andd issue revisited. *Journal of Strength and Conditioning Research*, *22*(5), 1597–1601. https://doi.org/10.1519/JSC.0b013e318181ab80

Harris, G. R., Stone, M. H., O'Bryant, H. S., Proulx, C. M., & Johnson, R. L. (2000). Short-Term Performance Effects of High Power, High Force, or Combined Weight-Training Methods. *Journal of Strength and Conditioning Research*, *14*(1), 14–20. https://doi.org/10.1519/00124278-200002000-00003

Hill-Haas, S. V., Rowsell, G. J., Dawson, B. T., & Coutts, A. J. (2009). Acute physiological responses and timemotion characteristics of two small-sided training regimes in youth soccer players. *Journal of Strength and Conditioning Research*, *23*(1), 111–115. https://doi.org/10.1519/JSC.0b013e31818efc1a

Köklü, Y., Alemdaroılu, U., Dellal, A., & Wong, D. P. (2015). Effect of different recovery durations between bouts in 3-a-side games on youth soccer players' physiological responses and technical activities. *Journal of Sports Medicine and Physical Fitness*, *55*(5), 430–438.

Köklü, Yusuf, Alemdaroğlu, U., Cihan, H., Wong, D. P., Köklö, 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. https://doi.org/10.1123/ijspp.2016-0584

Laursen, P. B. (2010). Training for intense exercise performance: High-intensity or high-volume training? *Scandinavian Journal of Medicine and Science in Sports*, *20*(SUPPL. 2), 1–10. https://doi.org/10.1111/j.1600-0838.2010.01184.x

Manuel Clemente, F., Theodoros Nikolaidis, P., Rosemann, T., & Knechtle, B. (2019). Variations of internal and external load variables between intermittent small-sided soccer game training regimens. *International Journal of Environmental Research and Public Health*, *16*(16), 2923. https://doi.org/10.3390/ijerph16162923

Midgley, A. W., & Mc Naughton, L. R. (2006). Time at or near VO2max during continuous and intermittent running: A review with special reference to considerations for the optimisation of training protocols to elicit the longest time at or near VO 2max. *Journal of Sports Medicine and Physical Fitness*, *46*(1), 1–14.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, *21*(7), 519–528. https://doi.org/10.1080/0264041031000071182

Müller, E. A. (1953). the Physiological Basis of Rest Pauses in Heavy Work. *Quarterly Journal of Experimental Physiology and Cognate Medical Sciences*, *38*(4), 205–215. https://doi.org/10.1113/expphysiol.1953.sp001031

Sampson, J. A., Fullagar, H. H. K., & Gabbett, T. (2015). Knowledge of bout duration influences pacing strategies during small-sided games. *Journal of Sports Sciences*, *33*(1), 85–98. https://doi.org/10.1080/02640414.2014.925571

Seiler, S., & Tønnessen, E. (2009). Intervals , Thresholds , and Long Slow Distance : the Role of Intensity and Duration in Endurance Training. *Training*, *13*(13), 32–53. http://sportsci.org/2009/ss.htm

Spencer, M., Bishop, D., Dawson, B., & Goodman, C. (2005). Physiological and metabolic responses of repeated-sprint activities: Specific to field-based team sports. *Sports Medicine*, *35*(12), 1025–1044. https://doi.org/10.2165/00007256-200535120-00003

Tomlin, D. L., & Wenger, H. A. (2001). The relationship between aerobic fitness and recovery from high intensity intermittent exercise. *Sports Medicine*, *31*(1), 1–11. https://doi.org/10.2165/00007256-200131010-00001