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Influence of bout duration on exercise demands during small-sided games in elite young football players

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Key Words: global positioning systems; heart rate; performance; monitoring; team sports.

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"Mientras el río corra, los montes hagan sombra y en el cielo haya estrellas, debe durar la memoria del beneficio recibido en la mente del hombre agradecido"

- Virgilio, Roman Poet

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Success means to do the best we can do with the things we have, success is make, not achieve, its try, not triumph. Success is a personal standard, reaching the greatness that lives in ourselves, becoming in all we can be.

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“Invertir en conocimientos produce los mejores beneficios”

- Benjamín Franklin.

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Abstract

Purpose: The aims of this dissertation were twofold: (i) to compare the exercise demands between two intermittent small-sided games (SSGs) and (ii) examine their temporal changes throughout SSGs repetitions, while controlling for exercise duration and relative space per players. **Methods:** Eight young male professional football players (age 16.3 ± 0.5 years) performed a 4v4 plus goalkeepers SSG under two intermittent formats: long bout (LB; 3 reps × 6 min) and short bout (SB; 6 reps × 3 min), separated for 2-min passive recovery. Pitch dimensions were (length 24m × width 17m) with relative space per-player of 51m^2 in both formats. Exercise demands were recorded by using wearable 10-Hz global positioning system (GPS) technology and HR monitors. **Results:** Higher values of total distance, low intensity running (< 12 $km \cdot h^{-1}$), explosive distance (>1.2 $m \cdot s^{-2}$), accelerations frequency >2 $m \cdot s^{-2}$ and player load were observed during LB than SB (ES= 0.94, 0.95, 0.81 and 0.89, respectively; $p<0.05$). Similarly, peak heart rate was moderately higher during LB than SB (ES: 0.50; p= 0.001). Moreover, within-formats analyses revealed moderately higher decreases in peak and mean heart rate when compared the 2nd and 3rd bouts to the last 3 bouts during the SB format (ES=0.72, 0.53, respectively; $p<0.05$). **Conclusions:** LB intermittent SSG format can be prescribed to achieve high physical and physiological demands, while ensuring a workload maintenance across repetitions.

Key Words: global positioning systems; heart rate; physical performance; monitoring; football.

Resumo

Objetivo: A presente dissertação teve como objetivos: (i) comparar as exigências físicas e fisiológicas de dois jogos reduzidos intermitentes (JRI) e (ii) examinar as alterações verificadas ao longo das repetições desses JRI. **Metodologia:** Oito jogadores profissionais sub-17 (idade 16.3 ± 0.5 anos) realizaram jogo de 4v4 com guarda-redes em dois formatos de JRI: longa duração (LD; 3 reps × 6 min; 2-min de recuperação) e curta duração (CD; 6 reps × 3 min; 2-min de recuperação). As dimensões do relvado nos JRI foram mantidas em (24m × 17m) com espaço relativo por jogador de 51m^2. As exigências físicas e fisiológicas do exercício foram registradas mediante a tecnologia GPS (10-Hz) e cardiofrequencímetros, respetivamente. **Resultados:** Valores mais altos de distância total, de corrida em baixa intensidade (< 12 km·h^{-1}), de distância explosiva (>1.2 m·s^{-2}), da frequência de acelerações (>2 m·s^{-2}), e de player load foram observados no DL, quando comparado com o DC (ES= 0.94, 0.95, 0.81, 0.81, 0.89, respeitivamente; p<0.05). Da mesma maneira, valores mais altos de e de frequência cardíaca foram observados no DL, quando comparado com o DC (ES= 0.50, p=0.001) Adicionalmente, a análise intra-formatos mostrou grande diminuição da frequência cardíaca no DC quando se compararam a 2ª e 3ª repetição com as últimas 3 repetições (ES=0.72, 0.53, respeitivamente; p<0.05). **Conclusão:** os JRI em formato de DL podem ser utilizados para colocar alta exigência física e fisiológica no exercício, garantindo consistência da taxa de trabalho ao longo das repetições.

Palavras chave: sistemas de posicionamento global; frequência cardiaca; rendimento físico; monitorização; futebol

Resúmen

Objetivo: Los objetivos de esta tesis fueron: (i) comparar las exigencias físicas y fisiológicas de dos juegos reducidos intermitentes (JRI) y (ii) examinar las alteraciones verificadas a lo largo de las repeticiones de dichos JRI. **Metodología:** Ocho jugadores profesionales sub-17 (edad 16.3 ± 0.5 años) realizaron un 4v4 con porteros en dos formatos de JRI: larga duración (LD; 3 reps × 6 min; 2-min de recuperación) e corta duración (CD; 6 reps × 3 min; 2-min de recuperación). Las dimensiones de la cancha fueron mantenidas en (largo 24m × ancho 17m) con espacio relativo de 51m^2 por jugador. Las exigencias físicas y fisiológicas fueron registradas mediante tecnología GPS (10-Hz) y monitores de frecuencia cardíaca. **Resultados:** Valores más altos de distancia total, carrera en baja intensidad (< 12 km·h^{-1}), distancia explosiva (>1.2 m·s^{-2}), frecuencia de aceleraciones (>2 m·s^{-2}), y de player load fueron observados en el DL, comparado con el DC (ES= 0.94, 0.95, 0.81, 0.81, 0.89, 0.50, respectivamente; $p<0.05$). De la misma manera, valores más altos de frecuencia cardíaca fueron encontrados en DL, comparado con DC (ES= 0.50, $p=0.001$). Adicionalmente, el análisis intra-formatos mostró grandes disminuciones de la frecuencia cardíaca en el DC comparando la 2ª y 3ª repetición con las ultimas 3 repeticiones (ES=0.72, 0.53, respectivamente; $p<0.05$). **Conclusión:** Los JRI en formato DL pueden ser utilizados para colocar alta exigencia física y fisiológica en el ejercicio, garantizando consistencia en la tasa de trabajo a lo largo de las repeticiones.

Palabras clave: sistemas de posicionamiento global; frecuencia cardíaca; rendimiento físico: monitorización: fútbol

List of abbreviations

Acc	Accelerations
Dec	Decelerations
ED	Explosive distance
HR_{ex}	Mean heart rate during exercise
HR_{peak}	Peak heart rate
HSR	High-speed running
LB	Long bout format
LIR	Low intensity running
MIR	Moderate intensity running
SB	Short bout format
SSGs	Small-sided games
TD	Total distance covered

Chapter 1

1. Introduction

1.1. Overview

Football is characterized by prolonged intermittent efforts encompassing brief bouts of high-intensity running interspersed by longer recovery periods (Bangsbo et al., 2006). It is well-known that in match play, each player performs approximately 1000-1400 short activities including jumping, kicking, tackling, turning, sprinting and changing pace with sustaining forceful contractions to maintain their balance under constantly tactical pressure (Mohr et al., 2003; Ryan et al., 2019). Thus, because of the increasing physical demands in endurance and high-intensity actions, players experience acute fatiguing periods among the matches (Pettersen and Brenn., 2019; Rebelo et al., 2014)

Indeed, fatigue has been demonstrated to occurs toward the end of a football match, as well as during the most intense game periods in young football players (Mendez-Villanueva et al., 2013). Moreover, that acute fatigue experienced by the players has suggested to be associated with a high anaerobic energy turnover and extracellular K+ accumulation (Iaia et al., 2010; Mohr et al., 2005).

On the other hand, there is a consensus in the literature that the maximum benefits of training methods are achieved when the training stimuli is similar to that found in competitive demands (Impellizzeri et al., 2006). These data highlight the importance of intermittent endurance performance in young football players, which is a relevant physical fitness component related to the ability to sustain high work rates values throughout training sessions (Rebelo et al., 2014)

Thus, previous research has shown that youth football players benefits from both high-intensity analytic training as well as game-based training (Kunz et al., 2019; Los Arcos et al., 2015; Moran et al., 2019). In this regard, football coaches tend to prioritize these game-based training throughout small-sided games (SSGS). SSGs are modified games played on reduced pitch areas, often using adapted rules involving a smaller number of players than traditional football games (Hill-Haas et al., 2011).

It is acknowledged that in such activities many factors can influence the performance and behavior of the players in accordance to individual, environmental and task constraints (Newell, 1986). However, coaches commonly manipulating key task constrains during SSGs practice (i.e. number of players, pitch dimensions, presence of goalkeepers (GK), coach encouragement, rules modifications and training formats) (Rampinini et al., 2007). In addition, the introduction of wearable technology incorporating global positioning systems (GPS), inertial devices and heart rate (HR) monitors has led to quantify training and match demands on daily basis, providing coaching staff objective information regarding to individual and collective performance of the football players (Dellal et al., 2012; Rago, et al., 2019).

Is recognized that in youth football, the SSGs provide physiological adaptations in the oxygen uptake capacity and football specific endurance (Kunz et al., 2019), in addition to higher levels of enjoyment and mood balance in terms of tension, fatigue and vigor (Los Arcos et al., 2015; Selmi et al., 2018). Moreover, during SSGs players are exposed to a learning environment that can be effectively transferred to competitive performance contexts that can promote the emergence of technical and tactical behaviors (Gabbett et al., 2009).

Therefore, regarding to SSGs in young football players, coaches can adequate the training targets prior to achieve higher aerobic and anaerobic efforts to promote energetic adaptations according to match demands (Rebelo et al., 2014). Thus, intermittent exercise formats has shown to be an effective method to achieve optimal stimulus to elicit those adaptations (i.e. cardiovascular and peripheral) (Billat, 2001). Intermittent formats involves repeated short-to-long bouts of rather high intensity exercise interspersed with passive or active recovery periods (Buchheit and Laursen, 2013).

Prescription of intermittent formats consist in the manipulation of the number and duration of the repetitions, the work: rest ratio schema and the type of recovery (Buchheit and Laursen, 2013b). However, the effect of those manipulations and consequently impact in the exercise demands throughout the SSGs has not been resolve (Arslan et al., 2017; Fanchini et al., 2011).

Additionally, differences in their application between various formats are not yet clear (Hill-Haas et al., 2009). In fact very few studies have investigate the effects of handling the bout duration throughout various intermittent SSGs and their effects on physical and physiological demands (Branquinho et al., 2020; Fanchini et al., 2011b; Köklü et al., 2017).

Thus, a comparison between different bout durations in intermittent SSGs formats with the monitoring of the physical and physiological demands throughout GPS technology and heart rate monitors should help coaches and practitioners to understand the patterns of performance providing meaningful information prior to improve the effectiveness of the training tasks and consequently football specific endurance adaptations in young football players.

1.2. Objectives of the dissertation

The main objectives of this dissertation were twofold:

1. To compare the exercise demands (physical and physiological responses) between two intermittent SSGs formats: long bout (LB: 3 reps× 6 min) and short bout (SB: 6 reps × 3 min) separated for 2-min of passive recovery while controlling for exercise duration and relative space per players in young elite professional football players;

2. To examine the temporal changes in exercise intensity (physical and physiological responses) throughout SSG repetitions in the above mentioned formats (LB and SB) in young elite professional football players

Chapter 2

2. Literature review

Football game is considered as a complex dynamic system composed by several subsystems. Those subsystems are constantly interacting in order to ensure consistent decisions and movement patterns in the players throughout the game (Travassos et al., 2014; Vilar et al., 2014). From this perspective, the players and the game in which they develop their actions constitute to a continuous system that interacts in a mechanically and informational way (Araujo, 2009). Therefore, the results of those interactions derive into changes in the movement patterns constituted by intentional adjustments that are influenced by the constraints of the game because of the development of a particular task (Newell, 1986).

Newell, (1986) developed a model of constraints that is illustrated in **Figure 1**. This model is applied to explain the influence of several constraints (i.e. individual, environmental and task) as the promoters to influence changes overall the performance in the players at game-based activities. For example, the individual constraints (i.e. body structure, behavioral function) over the constitution and state of each player, delimiting certain movement responses and consequently performance. On the other hand, the constraints related to the environmental factors as the weather and context conditions (i.e. surfaces, country and culture) influence the performance as well. Finally, the task constraints refer to the elements of the situations, actions previously designed and associated to a specific purpose results from the players exposed to meet the task constraints.

Thus, because of the interaction and interdependence between individual, environmental and task factors is what determines the emergence of different movement patterns among the game-based activities and limiting certain results or specific responses.

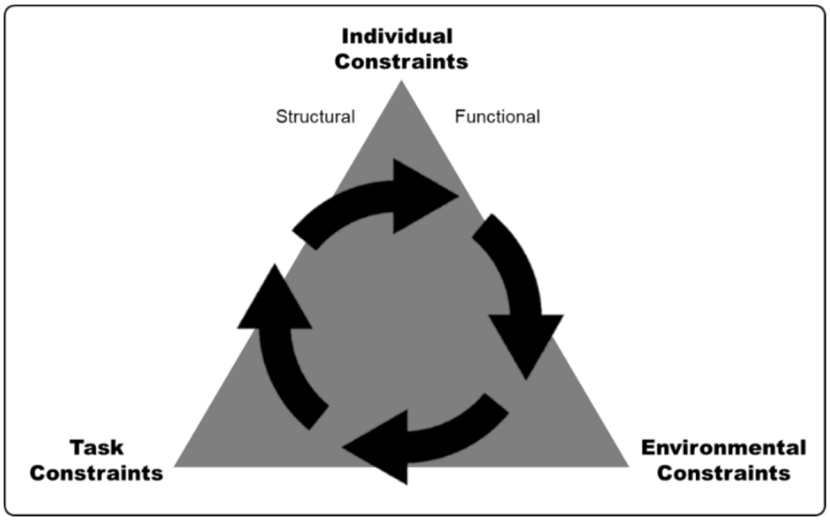

Figure 1. Newell model of constraints (adapted from Serra-Olivares et al., 2016)

2.1. Constraints affecting exercise intensity during small-sided games in young football players

Regarding to the SSGs coaches commonly design the training task throughout manipulating different constraints as the number of players, pitch dimensions, presence of goalkeepers (GK), presence of coaching feedback, rules modifications and training format (Rampinini et al., 2007). Thus, research has been widely investigated the influence of those variables on exercise intensity in young football players (Aguiar et al., 2012; Halouani et al., 2014; Hill-Haas et al., 2011).

Therefore, the increasing studies related to analyze the influence of the variables that induce changes in the exercise intensity in terms of physical and physiological demands during SSGs in youth players derived into a model that is illustrated into the **Figure 2** and complementary described from **Table 1** to **Table 5**.

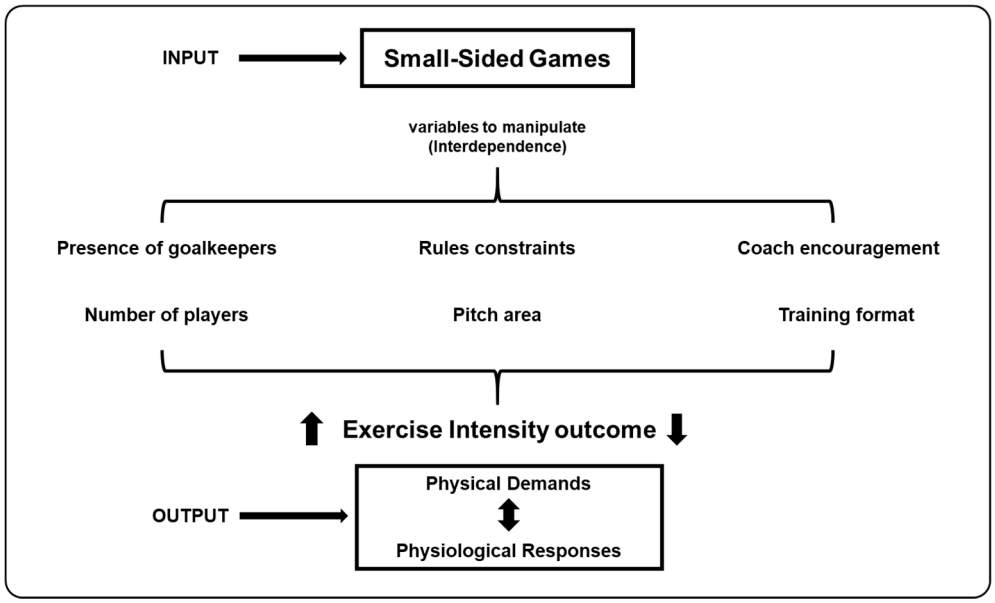

Figure 2. Model of variables that influence exercise intensity during small-sided games

2.1.1. Pitch dimensions

Regarding to **Table 1**, published research showed that by increasing the pitch dimensions (both, length or width) in various formats of SSGs (3v3, 4v4, 5v5 and 8v8) in young football players, elicit higher physical demands (total distance, low intensity running, moderate intensity running and high-speed running), (Casamichana et al., 2018; Casamichana and Castellano, 2010; Coutinho et al., 2019; Lemes et al., 2019; Nunes et al., 2020). While the physiological responses associated to heart rate peak (HR_{peak}), heart rate mean (HR_{ex}) and perceived exertion (RPE) were similarly higher by the increasing of pitch dimensions (Casamichana et al., 2018; Casamichana and Castellano 2010). However, when reducing the pitch dimensions elicit higher number of accelerations and decelerations (Rebelo et al., 2016).

Table 1. Studies analyzing the influence of alterations in the pitch dimensions on exercise intensity during small-sided games in young football players

Authors	Variable of study	SSG format	Participants (n/level)	Exercise intensity outcome
Kelly & Drust, 2009	Pitch dimensions	4v4+GK	(8) Elite U-19	↑ Pitch dimensions = ↔ HR_{peak}, HR_{ex}
Casamichana & Castellano, 2010	Pitch dimensions	5v5+GK	(10) Amateur U-15	↑ Pitch dimensions = ↑ TD, ↑ LIR, ↑ MIR, ↑ HSR, ↑ HR_{peak}, ↑ HR_{ex}
Rebelo et al., 2016	Pitch dimensions	4V4+GK 8V8+GK	(18) Amateur U-20	↓ Pitch dimensions = ↑ Acc, ↑ Dec
Casamichana et al., 2018	Pitch dimensions	5v5	(20) Amateur U-20	↑ Pitch length rather than ↑ Pitch Width = ↑ TD, ↑ Acc, ↑ Dec, ↑ RPE
Coutinho et al., 2019	Pitch dimensions	5v5+GK	(40) Amateur U15	↑ Pitch length, width and orientation = ↑ TD, ↑ HSR
Lemes et al., 2019	Pitch dimensions	3v3	(48) Amateur U-15	↑ Pitch dimensions = ↑ TD, ↑ LIR, ↑ MIR, ↑ HSR
Nunes et al., 2020	Pitch dimensions	4v4	(52) Amateur U-15; U-11	↑ Pitch dimensions = ↑ TD, ↑ Sprint Dist. ↑ LIR (U-11); ↑ TD, ↑ Sprint Num., ↑ RPE (U-15)

SSG: small-sided game; GK: goalkeeper: HR_{peak}: peak heart rate, HR_{ex}: mean heart rate during exercise; TD: total distance covered; LIR: low intensity running; MIR: moderate intensity running; HSR: high-speed running; Acc: accelerations; Dec: decelerations; Sprint Dist.: sprinting distance; Sprint Num.: total number of sprints; RPE: subjective ratio of perceived exertion; ↑: (increased values); ↔: (non-meaningful changes)

2.1.2. Number of players

Studies regarding to **Table 2** showed that when increasing the number of players (2v2, 3v3 vs. 4v4, 5v5) achieved higher physical demands (total distance covered, total number of sprints and player load) (Aguiar et al., 2013). On the other hand, studies showed that when reducing the number of players (2v2 and 3v3) elicited higher physiological responses in terms of HRpeak, HRex, RPE and blood lactate concentrations (Dellal et al., 2011; Köklü and Alemdaroğlu., 2016; López-Fernández et al., 2020)

Table 2. Studies analyzing the influence of alterations in the number of players on exercise intensity during small-sided games in young football players

Authors	Variable of study	SSG format	Participants (n/level)	Exercise intensity outcome
Jones & Drust, 2007	Number of players	4v4+GK 8v8+GK	(8) Elite U-17	↑ Players = ↔ Physical and physiological demands
Dellal et al., 2011	Number of players	2v2 3v3 4v4	(27) Elite U-17	↓ Players = ↑ HR_{peak}, ↑ HR_{ex}
Abrantes et al., 2012	Number of players	3v3 4v4	(16) Pro U-15	↑ Players = ↔ RPE; HR_{peak}; HR_{ex}
Aguiar et al., 2013	Number of players	2v2 3v3 4v4 5v5	(10) Pro U-19	↑ Players = ↑ TD, ↑ Sprint Num., ↑ Player load ↓ Players = ↓ RPE, ↓ HR_{peak}
Köklü & Alemdaroğlu, 2016	Number of players	2v2 3v3 4v4	(16) Elite U-17	3v3: 4v4 vs. 2v2 = ↑ HRpeak, ↑ RPE, ↑ Blood lactate (3v3)
López-Fernández et al., 2020	Number of players	3v3 4v4 5v5 6v6	(63) Sub-Elite U-15 U-17 U-19	↓ Players = ↑ HSR, ↑ HR_{peak}

SSG: small-sided game; GK: goalkeeper: HRpeak: peak heart rate, HRex: mean heart rate during exercise; TD: total distance covered; HSR: high-speed running; Sprint Num.: total number of sprints; RPE: subjective ratio of perceived exertion; ↑: (increased values); ↓ (reduced values); ↔: (non-meaningful changes)

2.1.3. Presence of goalkeepers

Studies related to the presence of GK during SSGs and their effects in exercise outcomes are presented in **Table 3**. Studies compared the presence versus the absence of GK throughout various SSGs formats (2v2, 3v3, 4v4 and with and without GK). SSGs without GK elicited higher physical demands (total distance, low intensity running, moderate intensity running and high-speed running) (Köklü et al., 2015) in addition to higher physiological responses (HR_{peak}, HR_{ex} and blood lactate concentrations) (Hulka et al., 2016; Mallo and Navarro 2008; Sassi et al., 2004).

2.1.4. Coach encouragement

Regarding to **Table 3**, research revealed that by the presence of coach strongly pushed encouragement among the SSGs (2v2, 3v3 and 4v4) induced higher values of RPE in the players, while non-meaningful changes were observed in the other physiological responses (HR_{peak} and HR_{ex}) and physical demands (Brandes and Elvers, 2017; Sampaio and Abrantes, 2007)

Table 3. Studies analyzing the influence of the presence of goalkeepers and coach encouragement on exercise intensity during small-sided games in young football players

Authors	Variable of study	SSG format	Participants (n/level)	Exercise intensity outcome
Sassi et al., 2004	Presence of GK	4v4 vs. 4v4+GK	(9) Elite U-20	SSG without GK = ↑ HR_{peak}, ↑ Blood lactate
Mallo & Navarro, 2008	Presence of GK	3v3 vs. 3v3+GK	(9) Semi-Pro U-19	SSG without GK = ↑ HR_{peak}, ↑ HR_{ex}
Köklü et al., 2015	Presence of GK	2-3-4 vs. 2-3-4+GK	(16) Elite U-17	SSG without GK = ↑ TD, ↑ LIR, ↑ MIR, ↑ HSR, ↑ HR_{peak}, ↑ Blood lactate
Hulka et al., 2016	Presence of GK	5v5 vs. 5v5+GK	(29) Amateur U-19	SSG without GK = ↑ HR_{peak} SSG with GK= ↑ TD
Sampaio & Abrantes, 2007	Coach Encouragement	2v2 3v3	(12) Semi-Pro U-17	Coach encouragement = ↑ RPE, ↔ HR_{peak}; HR_{ex}
Brandes & Elvers, 2017	Coach Encouragement	4v4	U-17 (16) Elite U-17	Coach encouragement = ↑ RPE, ↓ Volume of play, ↔ HR_{peak}; HR_{ex}

SSG: small-sided game; GK: goalkeeper: HRpeak: peak heart rate, HRex: mean heart rate during exercise; TD: total distance covered; LIR: low intensity running; MIR: moderate intensity running; HSR: high-speed running; RPE: subjective ratio of perceived exertion; ↑: (increased values); ↓ (reduced values); ↔: (9non-meaningful changes)

2.1.5. Rules modifications

Table 4 summarizes published studies that have analyzed the effects in the exercise outcome induced by the rules modifications among various SGGs formats (3v3, 4v4, 5v5 and 6v6). For example, when the exercise target was to maintain the ball possession compared to scoring a goal, higher physical demands in terms of sprinting distance were observed, in addition to higher physiological responses associated to RPE were observed during the scoring a goal rule (Hill-Haas et al., 2010).

In addition, the use of small or regular goals among the SSGs also present variations in the exercise intensity. For example, the use of small goals elicited higher physiological responses in terms of HR_{peak} when compared to regular goals (González-Rodenas et al.,2015). In addition the stop ball rule (score in the offensive zone with more than two players) elicited higher physical demands (total distance, sprinting distance, accelerations, decelerations and player load) and higher HR_{ex} when compared to score in small-goals (Halouani et al., 2019).

Finally, the use of jokers among various SSGs formats elicited higher differences when compared to full-time players. The full-time players achieved higher physical demands (total distance covered, moderate intensity running, high-speed running, accelerations, decelerations and player load) and physiological responses (HR_{peak} and HR_{ex}) when compared to jokers (Gollin et al., 2016; Rábano-Muñoz et al., 2019)

Table 4. Studies analyzing the influence of the rules modifications on exercise intensity during small-sided games in young football players

Authors	Variable of study	SSG format	Participants (n/level)	Exercise intensity outcome
Hill-Haas et al., 2010	Rules Modifications	3v3 4v4 5v5 6v6	(16) Elite U-15	Possession vs. Scoring rule = ↑ RPE, ↑ Sprint Dist. (scoring)
Köklü et al., 2012	Rules Modifications	4v4	(32) Semi-Pro U-17	Tactical formation behind $VO2_{Max}$ and Technical level = ↑ HSR, ↑ RPE, ↑ HR_{peak}, ↑ Blood lactate
González-Rodenas et al., 2015	Rules Modifications	4v4 5v5	(20) Elite U-15	Small-goals vs. regular goal = ↑ HR_{peak} (small-goals)
Gollin et al., 2016	Rules Modifications	4v4+ 3 jokers	(22) Elite U-15	Full-time players vs. jokers = ↑ TD, ↑ Acc, ↑ Dec, ↑ player load (full-time players)
Halouani et al., 2019	Rules Modifications	4v4	(16) Elite U-18	Stop-ball rule vs. Small- goals = ↑HR_{ex}, ↑ TD, ↑ Sprint Dist., ↑ Acc, ↑ Dec, ↑ player load (stop-ball rule)
Rábano-Muñoz et al., 2019	Rules Modifications	4v4 + 1 joker	(30) Semi-Pro U-19 U-17	Full-time players vs. jokers = ↑ TD, ↑ MIR, ↑ HSR, ↑ Acc, ↑ Dec, ↑ HR_{peak}, ↑ HR_{ex} (full-time players)

SSG: small-sided game; GK: goalkeeper: HRpeak: peak heart rate, HRex: mean heart rate during exercise; $VO2_{Max}$: maximal oxygen consumption; TD: total distance covered; HSR: high-speed running; Sprint Dist.: sprinting distance; Acc: accelerations; Dec: decelerations, RPE: ratio of perceived exertion; ↑: (increased values); ↓ (reduced values)

2.1.6. Training format

Published studies regarding to the training formats are presented in the **Table 5**, For example, a pre-induced fatigue in a 4v4 SSG elicited higher decreases in the physical demands (sprinting distance, total number of sprint and accelerations) (Pellegrino et al., 2018). In addition, when compared the type of recovery between various SSGs (2v2, 3v3 and 4v4) the active recovery elicited higher physical demands (high-speed running), while the passive recovery achieved higher values in the physiological responses (HR_{peak}, RPE and blood lactate concentrations) (Arslan et al., 2017)

Table 5. Studies analyzing the influence of the training format on exercise intensity during small-sided games in young football players

Authors	Variable of study	SSG format	Participants (n/level)	Exercise intensity outcome
Hill-Haas et al., 2009	Training format	2v2 4v4 6v6	(16) Pro U-17	Continuous vs. intermittent format = ↑ MIR, ↑ HSR, ↑ Sprint Num. (intermittent) ↑ RPE, ↑ HR_{peak} (continuous)
Arslan et al., 2017	Training format	2v2 3v3 4v4	(16) Pro U-17	Passive vs. Active recovery = ↑ RPE, ↑ HR_{peak}, ↑ Blood lactate (passive) , ↑ HSR (active)
Pellegrino et al., 2018	Training format	4v4	(16) Elite U-17	Pre-induced fatigue = ↓ Sprint Dist., ↓ SN, ↓ Acc

SSG: small-sided game; GK: goalkeeper: HRpeak: peak heart rate, HRex: mean heart rate during exercise; MIR: moderate intensity running; HSR: high-speed running; Sprint Dist.: sprinting distance; Sprint Num.: total number of sprints; HRpeak: peak heart rate; RPE: ratio of perceived exertion; ↑: (increased values); ↓ (reduced values)

In sum, this brief review highlighted the effects induced by the manipulation of task constraints during SSGs in accordance with the physical demands and physiological responses. Particularly, the manipulation of one or several variables elicited changes in the overall performance profiles and perceptual workload placed on young professional football players (Aguiar et al., 2012; Halouani et al., 2014)

On the other hand, the structure of the regimen during SSGs are commonly selected between continuous or intermittent formats (Halouani et al., 2014). Continuous format is based into a long bout duration without recovery (i.e. 10 to 30 min); opposite to intermittent formats that are based into consecutive number of bouts interspersed with different types of recovery periods (passive or active) among repetitions. Furthermore, different studies have been published regarding to the benefits between the uses of continuous or intermittent SSGs formats.

For example, in an study conducted by Hill-Haas et al., (2009), compared the use of a continuous (1 rep × 24 min) versus an intermittent format (6 reps × 4 min) during a 2v2 4v4 and 6v6 without GK. The authors reported that intermittent format elicited higher physical demands in terms of high intensity actions (i.e. moderate intensity running, high-speed running and total number of sprints) when compared to the continuous format in all the SSGs.

Similarly, Köklü, (2012) investigate the physiological demands when compared a continuous (1 rep × 9 min) versus an intermittent format (3 reps × 3 min) during a 3v3 without GK. The authors revealed that intermittent format reached the higher values in terms of HR_{peak} and blood lactate concentrations when compared to the continuous format.

In addition, a recent study by Branquinho et al., (2020) compared a continuous (1 × 24 min) versus two intermittent formats (6 reps × 4 min; 4 reps × 6 min) during a 5v5 without GK. The authors reported that the intermittent format

achieved higher values in the physical demands (i.e. high-speed running, total distance covered) when compared to the continuous format.

Thus, the intermittent format seems to present the higher benefits related to promote higher physical demands and consequently physiological responses. However, when programing intermittent formats many variables can be manipulated. Such variables as: (a) the work intensity and duration; (b) recovery type (passive/active) and duration; and (c) total work duration (work interval number × work duration) can affect the physical demands and acute physiological responses (Buchheit and Laursen, 2013)

However, very few studies have analyze the influence of the number and duration of the bouts and their influence in the physical and physiological responses throughout intermittent SSGs in young professional football players. Those studies are widely described in the next topic.

2.2. Influence of constraint the bout duration in intermittent small-sided games

The manipulation of the bout duration throughout intermittent formats has been highlighted as a factor that change the load imposed to the players and consequently modify the physiological responses (Billat, 2001), However, regarding to SSGs, very few studies have analyze the variations in physical demands and physiological responses induced by the use of different bout duration in intermittent formats.

For example, Fanchini et al., (2011) investigated the influence of three types of bout durations (2 vs. 4 vs. 6 min) on physiological responses and technical actions during 3v3 plus GK. The authors observed that the 4-min bout elicited higher physiological responses in terms of HR_{peak} and HR_{ex} when compared to the 6-min bout. In addition, the 2-min bout showed the lower physiological responses in HR_{peak} and HR_{ex} when compared to the other bouts, while non-meaningful differences were reported in RPE and technical actions.

In addition, Rebelo et al., (2016) analyzed the within variations emerging during practice of an intermittent 4v4 plus GK SSG (3 reps × 6 min). They verified a tendency for players to decrease their total distances covered in low intensity running, as well as the total number of accelerations and decelerations throughout repetitions.

On the other hand, Köklü et al., (2017) examined differences in physical and physiological responses when manipulating different bout durations: short (6 reps × 2 min), medium (3 reps × 4 min) and long (2 reps × 6 min) during 2v2, 3v3 and 4v4 SSGs without GK. The authors observed higher physical demands (total distance covered and moderate intensity running), while higher physiological responses (HR_{peak}, RPE and blood lactate concentrations) were observed during the long bout format.

Similarly, a recent study by Clemente et al., (2019) examined the physical and physiological variations between and within two intermittent SSGs formats: short bouts (6 reps × 3 min) versus long bouts (3 reps × 6 min) during 5v5 without GK. Results showed higher physical demands (moderate intensity running, accelerations and decelerations) in short bouts when compared to long bouts. The same study revealed that the RPE values increased in the last repetition of both formats, while physical demands values were relatively constant across repetitions.

Chapter 3

3. Materials and methods

3.1. Experimental approach

A cross-sectional design was conducted to compare the physical demands (total distance covered (TD); low intensity running (LIR); moderate intensity running (MIR); high-speed running (HSR); explosive distance (ED); total of accelerations; total of decelerations; player load) and physiological responses (HR_{peak}; HR_{ex}) during practice in two 4v4+GK intermittent SSGs formats. To remove the effect of training volume, total SSGs duration was maintained in 18-min in both formats. The experiment was conducted immediately after the last match of the season and consisted in two sessions interspersed for 72-hours between each other. Each session was monitored individually with wearable GPS devices and heart rate monitors.

3.2. Participants

Eight male professional young football players (age: 16.3 ± 0.5 years; experience: 5.5 ± 0.5 years; height: 171.2 ± 6.9 cm; weight: 57.9 ± 3.8 kg) participated in this experiment. These players belonged to the same team that compete at the Mexican National U-17 league, also with one international FIFA tournament the year before. In addition, players trained five times per week with one match every weekend.

All players were frequently exposed to the game formats used in the present experiment. The experimental procedures and data were collected without interferences on the normal context training as established in previous ethical approval requirements (Winter & Maughan, 2009).

3.3. Procedures

The experiment was organized into two sessions over one week; the schedule was maintained over the same hour in the morning in both sessions. Before the experiment, the group was divided into two randomized teams composed by four players plus two GK. Before each session, players wore GPS devices and heart rate monitors, in addition, each player performed a 15-min

warm up consisting of a 5-min jogging followed by mobility exercises plus 10-min of technical skills drills.

After the warm-up, a 4v4+GK were performed in both intermittent formats, the procedures of both sessions were the same, also are summarize in **Figure 3.** Two sessions were implemented with 72 hours interspersed. The first session (temperature: 11°C – humidity: 73%) consisted in three bouts of 6-min (3 × 6 min; long bout-LB), while the second session (temperature: 10°C – humidity: 76%) included six bouts of 3-min (6 × 3 min; short bout-SB). A 2-min passive recovery was established for both formats.

The SSGs layout is illustrated in **Figure 4**. The 4v4+GK was performed in a pitch sized 24 × 17 m with an area-player ratio of 51m^2 in concomitance to previous studies (Aguiar et al., 2012). In addition, two medium goals (5 × 2 m) were placed into the pitch game area. The teams were tactically organized according to one GK, two defenders, one midfielder and one forward. The presence of GK was employed to maintain the relationship with the match scenario and allowed to increase players motivations, as mentioned in previous studies (Dellal et al., 2008; Halouani et al., 2014).

Coach encouragement was provided across all regimens to keep players in high attention and exertion level, while non-specific verbal instructions were established with the purpose to non-disrupt the progression of the game. Ten balls were placed beside the pitch to ensure constantly effective game time. A free-touches rule was established before each game with the mainly instruction to score the higher number goals as possible.

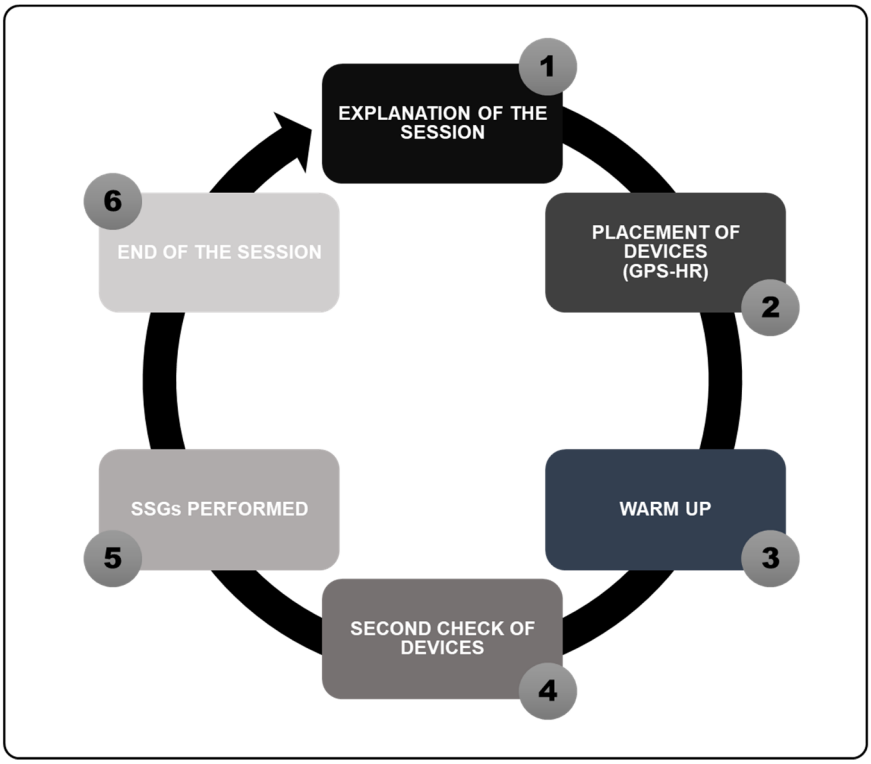

Figure 3. Protocol of intermittent small-sided games sessions

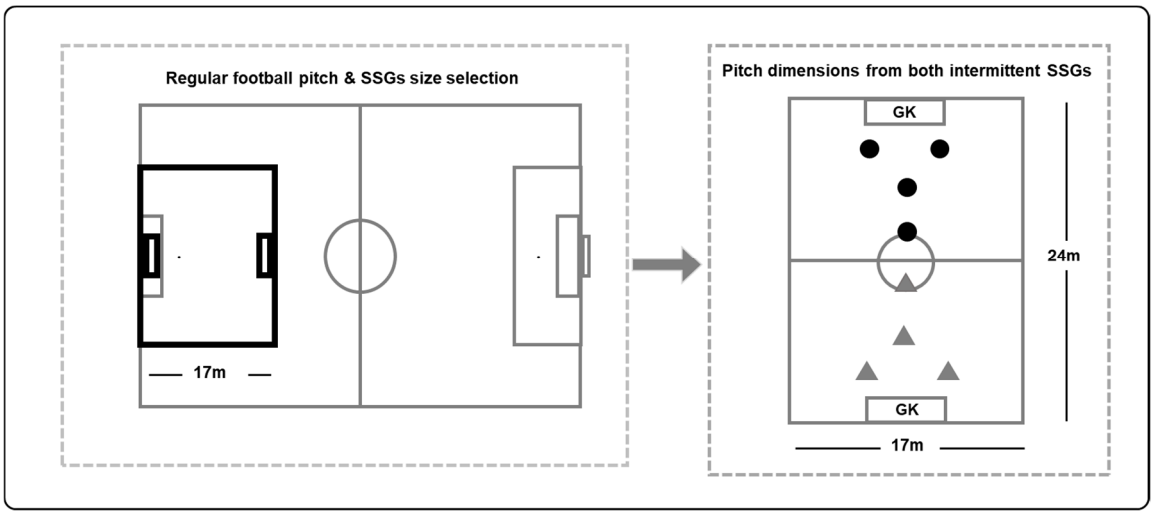

Figure 4. Pitch dimensions from both intermittent small-sided games formats.

3.4. Physical demands

Physical demands were recorded using an inertial device (GPS) WIMU Pro™ (Real Track Systems, Almeria, Spain). Each player wore one device that was placed on the upper back inside a specific vest to achieve the best signal reception. The accuracy and reliability of the GPS, gyroscope and accelerometer in the inertial device have been previously evaluated with satisfactory results (CV<1.00%). In addition to inter-unit reliability (ICC=0.75-0.96) (Bastida-Castillo et al., 2019; Gómez-Carmona et al., 2019).

The device harnessed different sensors to record the data: (a) four triaxial accelerometers, (b) three triaxial gyroscopes, (c) three dimensional (3) magnetometers and (d) a 10-Hz GPS chip. Before collecting the data, different criteria were considered in each session, as the appropriate players wear into tight-fitting vest to hold the device and minimize unwanted movement, plus a 15-min double check was allowed to ensure accurate satellite connection, in addition, players used the same device to ensure inter-unity errors. After each sessions, data from each device was processed by SPRO™ software and consequently exported to excel files.

The following variables from the GPS were considered: (a) total distance covered (TD); low intensity running (LIR: <12 $km \cdot h^{-1}$); (c) moderate intensity running (MIR: 13.0 – 17.9 $km \cdot h^{-1}$); (d) high-speed running (HSR: > 18 $km \cdot h^{-1}$); (e) explosive distance (ED: > 1.2 $m \cdot s^{-2}$); (f) number of accelerations (Acc: >2 $m \cdot s^{-2}$); (g) number of decelerations (Acc: > - 2 $m \cdot s^{-2}$) and (g) player load. (measure derived from the sum of the acceleration of body in vertical, antero-posterior and medio-lateral vectorial axes expressed in total g (Teles et al., 2020)).

3.5. Heart rate measures

Physiological responses were measured by recording heart rate (HR) with a chest strap sensor GARMIN™ HR premium band (Garmin Ltd, Olathe, KS, USA), used in previous studies to measure HR during football and game-based activities (Ceberino et al., 2020; Molina-Carmona et al., 2018; Rago, Krustrup, et al., 2019). The GARMIN™ HR has validity and reliability to measure HR compared to a Polar Team 2, in football players (r2=.958, p<.001). The HR band was placed in each player 15-min before the sessions to ensure data was recorded. Peak heart rate (HR_{peak}) and heart rate mean (HR_{ex}) variables were recorded during exercise and consequently analyzed by the SPRO™ software (Real Track Systems, Almeria, Spain).

3.6. Statistical analyses

Exploratory analyses revealed that both physical and physiological variables were normally distributed within each bout. After the assumption of normality, between and within training formats inferences were performed with the one-way repeated measures of variance (ANOVA) the bout number was established as independent variable, while physical and physiological demands were considered as dependent variables. When a significant difference was found, a Bonferroni post-hoc test was performed to examine pairwise comparisons between bouts. The magnitude of the differences was interpreted according to Cohen's d test as small (< 0.49), moderate (0.50 – 0.79) and large (> 0.8) (Cohen, 1998). Significance value was set at $p<0.05$. Data analyses were performed with the Statistical Package for Social Science software (IBM SPSS Statistics for Windows, version 26.0. Armonk, NY).

Chapter 4

4. Results

4.1. Differences between formats

Differences between intermittent SSGs formats can be found in **Table 6**. One-way ANOVA test showed significant differences between formats in physical demands and physiological responses.

Table 6. Between- formats differences in physical demands and physiological responses in terms of means, standard deviations and effect sizes during intermittent small-sided football games

Variables	Long bout (3 × 6 min)	Short bout (6 × 3 min)	Differences between SSG formats		
	Mean SD	Mean SD	P	ES (n^2)	Interpretation
HR_{peak} (bpm)	179.2 (8.3)[a]	172.0 (8.2)	0.01	0.50	Moderate
HR_{ex} (bpm)	162.7 (9.6) [a]	155.9 (8.4)	0.01	0.37	Small
TD (m)	500.5 (39.6)[a]	258.0 (26.5)	0.01	0.94	Large
LIR (m)	443.8 (36.1) [a]	227.1 (19.8)	0.01	0.95	Large
MIR (m)	53.9 (17.5)	29.4 (12.2)	0.02	0.41	Moderate
HSR (m)	2.7 (3.7)	1.4 (1.7)	0.04	0.10	Small
ED (m)	87.3 (13.5) [a]	48.2 (8.1)	0.01	0.81	Large
Acc (n) >2 $m \cdot s^{-2}$	22.0 (3.2) [a]	11.6 (1.7)	0.01	0.81	Large
Dec (n) > -2 $m \cdot s^{-2}$	19.5 (4.8)	10.9 (2.3)	0.01	0.68	Moderate
Player load (g)	7.0 (0.8) [a]	3.8 (0.4)	0.01	0.89	Large

SSG: small-sided game; SD: standard deviation; HRpeak: peak heart rate; HRex: mean heart rate during exercise; TD: total distance; LIR: low intensity running; MIR: moderate intensity running; HSR: high-speed running; ED: explosive distance; Acc: accelerations; Dec: decelerations; bpm: beats per minute; m: total meters; n: total number; P: statistical significance established at $p<0.05$; ES (n2): a = large difference founded in long bout than short bout; Cohen's d effect size interpreted as: <0.49 (small), 0.50-0.79 (moderate) and >0.8 (large)

4.1.1 Physical demands

Significant differences were observed for TD (p= 0.001); LIR (p= 0.01); MIR (p= 0.01); ED (p= 0.01); Acc >2 $m \cdot s^{-2}$ (p= 0.01); Dec < -2 $m \cdot s^{-2}$ (p= 0.01) and player load (p= 0.01). Post-hoc pairwise comparisons showed that LB reached higher values in all bouts when compared to SB regimen. Values of the effect sizes revealed a large effect associated to TD, LIR, ED, Acc >2 $m \cdot s^{-2}$ and player load (ES= 0.94; 0.95; 0.81; 0.81; 0.89 respectively) while a moderate effect was found for MIR and Dec < -2 $m \cdot s^{-2}$ (ES= 0.41; 0.68 respectively).

4.1.2 Physiological responses

Significant differences were found for HR_{peak} (p= 0.01) and HR_{ex} (p= 0.01). Post-hoc pairwise comparisons showed that LB elicited higher values in all bouts compared to SB regimen. In addition, Cohen's d test (ES: n^2) was applied to display the effect sizes of the differences. The effect size revealed a moderate effect for HR_{peak} (ES= 0.50) and a small effect for HR_{ex} (ES= 0.37).

The between analyses revealed that LB format was more demanding in total workload associated to physical demands and consequently physiological responses when compared to the SB format.

4.2. Exercise demands during bouts

Physical demands and physiological responses variables associated with LB and SB formats are presented in **Table 7** and **Table 8**. One-way repeated ANOVA test showed statistical significant differences throughout the bouts in few variables for both formats

Table 7. Exercise demands in terms of physical and physiological responses throughout long-bout small-sided football games

Long bout format	HR_{peak} (bpm)	HR_{ex} (bpm)	TD (m)	LIR (m)	MIR (m)	HSR (m)	ED (m)	Acc (n) >2 $m \cdot s^{-2}$	Dec (n) -2 $m \cdot s^{-2}$	Player load (g)
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
1st (6 min)	174.3 (4.4)	158.0 (7.9)	519.8 (43.9)	464.3 (41.4)	53.6 (21.6)	1.8 (3.1)	95.2 (13.0)	23.0 (4.2)	22.3 (4.1)*a	7.6 (0.9)*a
2nd (6 min)	183.5 (5.3)	166.1 (7.6)	483.0 (30.3)	452.2 (30.0)	54.4 (14.2)	3.9 (5.0)	87.2 (15.2)	22.0 (3.2)	20.2 (4.3)	7.1 (0.6)
3rd (6 min)	179.9 (12.6)	163.9 (11.9)	498.0 (39.3)	441.9 (28.2)	53.7 (18.4)	2.4 (2.9)	79.4 (7.6)	21.2 (1.9)	16.0 (4.2)	6.4 (0.6)

HRpeak: peak heart rate; HRex: mean heart rate during exercise; TD: total distance covered; LIR: low intensity running; MIR: moderate intensity running; HSR: high-speed running; ED: explosive distance; Acc: accelerations; Dec: Decelerations; bpm: beats per minute; m: total meters; n: total number; * = statistical significance at $p<0.05$; Cohen's d Effect size: a=small effect between the 1st than 3rd bout (0.31;0.30 respectively)

Table 8. Exercise demands in terms of physical and physiological responses throughout short-bout small-sided football games

Short bout format	HR_{peak} (bpm)	HR_{ex} (bpm)	TD (m)	LIR (m)	MIR (m)	HSR (m)	ED (m)	Acc (n) >2 $m \cdot s^{-2}$	Dec (n) >-2 $m \cdot s^{-2}$	Player load (g)
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
1st (3 min)	164.4 (7.4)	149.1 (7.7)	271.8 (35.7)	245.9 (19.9)*	25.4 (16.1)	0.4 (1.1)	49.3 (14.2)	11.7 (2.0)	10.6 (2.8)	4.0 (0.4)
2nd (3 min)	187.7 (7.1)*b	167.6 (12.9)*b	277.4 (11.6)	238.9 (16.1)	35.7 (6.4)	2.7 (3.5)	52.6 (8.1)	12.1 (1.8)	11.8 (3.0)	4.0 (0.4)
3rd (3 min)	182.1 (3.0)*b	166.9 (3.8)*b	253.1 (25.2)	223.3 (19.2)	28.8 (12.9)	0.9 (1.7)	50.7 (10.4)	12.7 (2.7)	10.3 (2.7)	3.8 (0.4)
4th (3 min)	172.1 (3.6)	155.8 (7.4)	248.8 (31.8)	223.4 (18.6)	24.6 (16.6)	0.7 (1.7)	43.1 (8.1)	10.5 (2.2)	10.7 (3.6)	3.7 (0.5)
5th (3 min)	163.9 (6.3)	150.6 (7.5)	249.8 (27.6)	216.1 (26.1)	32.8 (10.9)	0.8 (1.3)	48.5 (5.6)	11.6 (2.6)	11.2 (3.0)	3.7 (0.5)
6th (3 min)	161.6 (9.1)	145.5 (9.1)	256.9 (37.6)	214.9 (14.8)	29.1 (23.0)	2.8 (4.4)	45.3 (12.2)	11.3 (3.2)	10.5 (2.8)	3.6 (0.7)

HRpeak: peak heart rate; HRex: mean heart rate during exercise; TD: total distance covered; LIR: low intensity running; MIR: moderate intensity running; HSR: high-speed running; ED: explosive distance; Acc: accelerations; Dec: Decelerations; bpm: beats per minute; m: total meters; n: total number; SD: standard deviation; * = statistical significance at $p<0.05$; Cohen's d Effect size: b= moderate effect between 2nd and 3rd bout than 4th, 5th and 6th bout (0.72; 0.53 respectively)

Within LB:

Significant differences were found for Dec < -2 $m \cdot s^{-2}$ ($p = 0.021$) and player load ($p = 0.023$). Post-hoc pairwise comparisons revealed that the differences were observed between the first and the last bout (1st vs. 3rd) in both variables. In addition, a Cohen's d test (ES n^2) showed a small effect in both variables (ES= 0.31, ES= 0.30). Moreover, no differences were observed for physiological responses variables.

Within SB:

Significant differences were observed for HR_{peak} (, $p = 0.01$) HR_{ex} ($p = 0.01$) and LIR ($p = 0.013$). Post-hoc pairwise comparisons showed that: a) the second and third bout elicited higher HR_{peak} and HR_{ex} values when compared to other bouts (2nd and 3rd bout vs. 4th, 5th 6th), and: b) the first bout displayed higher values of LIR when compared to the last bout (1st vs. 6th). In addition, effect size of the results revealed a moderate effect for the HR_{peak} and HR_{ex} (ES= 0.72, ES= 0.53), while LIR presented a small effect (ES= 0.28).

The within analyses throughout both intermittent formats showed only significant decreases in physiological responses across repetitions in the SB. Therefore, the lack of differences in the majority of the variables in physical demands in both formats revealed a highly consistency in performance throughout the bouts.

Chapter 5

5. Discussion

The present dissertation analyzed the differences in physical and physiological responses during exercise between two intermittent SSGs (3 × 6 min vs. 6 × 3 min), as well as to examine how these variables change throughout SSGs repetitions. The results revealed that LB elicited higher values of HR_{peak}, TD, LIR, ED, Acc >2 $m \cdot s^{-2}$ and player load when compared to SB format. Moreover, analyses of within-formats showed that SB exhibited a moderate decrease in physiological responses in terms of HR_{peak} and HR_{ex} across repetitions, while values of physical demands variables were consistent throughout repetitions in both formats.

The comparison between training formats revealed different data from other studies. For example, a recent study conducted by (Clemente et al., 2019) compared two intermittent formats (6 reps × 3 min vs. 3 reps × 6 min) found that short bouts elicited higher values in physical demands ([moderate running distance (14 - 20 $km \cdot h^{-1}$)], accelerations and decelerations) compared to long bout formats. Our results showed the opposite, i.e. higher values were achieved in physical responses in LB (TD, LIR, ED, Acc, Dec and player load). These contrasting results can be explained by skill level differences, as our study focused on professional young football players, while the study performed by (Clemente et al., 2019) employed the same tasks in young amateur players. It is well known that professional football players are able to perform more intense physical activities across SSGs when compared to amateur players (Dellal et al., 2011).

Moreover, regarding to the physiological responses between formats, higher values in HR_{peak} and HR_{ex} were found in LB compared to SB format. These results are corroborated by the findings of Köklü et al., (2017), as the authors observed large differences in HR_{peak} when the length of the bout increased in various intermittent formats of SSGs.

Interestingly, the between analysis showed a minimum values achieved regarding to the high-speed running (HSR= velocity >18 $km \cdot h^{-1}$) variable in both formats (LB= 2.7 ± 3.7 m; SB: 1.4 ± 1.7 m) those results suggest that velocities

above 18 km·h^{-1} were rarely reached during both intermittent SSGs. This can be explained by the constrained effect of the pitch size (24 × 17 m), hindering the possibility to elicit higher speed velocities. Indeed, previous studies highlighted that increasing the pitch sizes led to higher values in high-speed running (Casamichana et al., 2018)

On the other hand, regarding to the within analysis of the physical demands, a study conducted by Rebelo et al., (2016) analyzed the within variations in the physical performance during a 4v4+GK with long bout format (3 reps × 6 min), the authors reported a tendency of decrease in physical demands associated to low intensity running (< 13.0 km·h^{-1}), accelerations (> 3 m·s^{-2}) and decelerations (> -3 m·s^{-2}) throughout repetitions. Our results showed the opposite, i.e. non-variations in physical demands throughout repetitions were observed in both formats (LB and SB).

In our study we did not find significant variations of physical performance across repetitions. However, this may suggest that the resting period of 2-min between repetitions was enough to maintain the performance and intensity levels prior to maximize the energy resources (Billaut et al., 2011b). Nonetheless, the maintenance of physical demands values across repetitions during our study are in line to other authors. For example, Clemente et al., (2019c) showed non-meaningful changes between repetitions in the physical performance associated to sprinting distances > 20 km·h^{-1}, accelerations (> 2 m·s^{-2}) and decelerations (> -2 m·s^{-2}) during 5v5 in two intermittent SSGs.

In addition, it can be speculated that the previous knowledge about the duration of the bout and format structure may have induced pacing strategies of the players during the games. In fact, a recent study by Ferraz et al., (2018) investigated the effects of knowing the task duration in football players behind three conditions (previously know, partially known and unknown) during a 5v5 SSG without GK. The authors showed that partially and previously knowledge of the task duration elicited a consistency of the physical performance in terms of total distance and high-speed running.

On the other hand, regarding to the within analysis of the physiological responses, our results of showed large decreases in HR_{peak} when compared the second and third repetition with the last three repetitions during the SB format. In other words, an increase in the number of repetitions led to a decrease in the internal load. These results can be explained by temporal acute fatigue experienced by players in shorter intermittent sets (Edwards & Noakes, 2009; Gibson et al., 2006). In fact, a recent study from Branquinho et al., (2020), analyzed the physiological responses in various intermittent SSG formats (4 reps × 6 min; 6 reps × 4 min) during a 5v5 without GK. The authors found that by increasing the number of repetitions elicited decreases in HR_{peak} and HR_{ex}.

Finally, we would like to underline some limitations of this dissertation: (i) the reduced number of participants might hamper the generalization of our results. Nonetheless, it is worth mentioning that participants comprised elite youth football players; (ii) we analyzed just two SSGs involving intermittent regimens. Future studies need analyze higher variety of SSGs involving continuous and intermittent regimens to better understand the physiological, tactical and technical demands of practicing under these two condition in order to obtain a more comprehensive picture; (iii) data was not controlled for players intra-individual differences. In fact, due to high variability within-subjects, future studies need to individualize heart rate thresholds in regards to subjective perceived exertion in order to provide accurate data on the physiological effort imposed to the players; (iv) future research needs to include more SSGs with different pitch dimensions and consider the increasing of the lengths bouts durations in addition to changes in the work: rest ratio schema; (v) since this experiment was conducted in a specific period of the season: it would be interesting in future studies to conduct identical experiment in different periods of the competitive season to gain a better understanding regarding to player performance throughout the season.

Chapter 6

6. Conclusion

Conclusion

Long and short-bout of SSGs differed in terms of physical demands and associated physiological responses, but were similar in terms of physical performance maintenance across repetitions. Specifically, long bout SSG (3 reps × 6 min) elicited largely higher physical (TD, ED, Acc > 2m·s^{-2} and player load) and physiological (HR_{peak}, HR_{ex}) demands compared to short bout SSG format (6 reps × 3 min). Additionally, both SSGs formats showed non-significant decreases throughout repetitions in terms of physical demands, although increasing the number of sets while reducing bout duration elicited moderately large declines in HR_{peak} and HR_{ex}.

Overall, our results possible suggests that LB intermittent SSGs format can be prescribed to achieve higher physical and physiological demands, while ensuring the maintenance of workload values across repetitions.

Coaches and practitioners should be aware of the importance of handling SSG bout duration and understanding it repercussion in physical and physiological demands. This is necessary to design training sessions to ensure adequate stimuli to improve physical fitness of young football players.

Chapter 7

7. References

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